December 5, 1963

THE EDUCATION OF THE WOMAN SCIENTIST TO BE

For a Conference on

The Expanding Need for Women in Science

My title this afternoon "The Education Of The Woman Scientist-To-Be" leaves me a broad area in which to roam, and it seems that a good place to begin might be with the placing of a few limitations on the subject. I shall not attempt to join the throngs of writers and speakers who are gaining an attentive and frequently receptive ear these days by expounding on what is wrong with education. Although there may well be things wrong with the way in which we are educating women for achievement in the sciences, I am not going to talk about that. I am not even going to talk about what we should do in education. I'm going to spend my time instead talking about what we are doing by presenting a factual description of those attributes of today's woman student which would seem to bear directly on her potential for scientific contribution. I shall leave it to this conference to consider what steps should be taken if we are to educate women for a more effective participation in the scientific achievement of the nation.

It seems to me that the most helpful background for our discussion might be presented in terms of three characteristics of the potential scientist. Presumably the major contributions in science will come from those who have high scientific ability or aptitude plus the interest and opportunity to achieve the necessary knowledge and skills in the field. Thus, I shall give particular attention to what we know about the scientific aptitude of women, their interest in studying scientific subjects, and their school achievement in mathematics and science.

A massive amount of data has been gathered in the study of the intellectual abilities and we can now put together a picture which is rather comprehensively

descriptive--if not very adequately explanatory. Let me begin by describing what we know about the aptitudes of women for scientific endeavors.

We do know that differences in the verbal and mathematical ability of boys and girls--men and women--have been reported with remarkable consistency over the years. There remains no controversy about the relative performance of males and females on tests of mathematical and verbal ability. There is perhaps some controversy as to why this difference exists and, in any discussion of differential abilities between men and women, we should keep in mind a number of things.

In the first place these reported differences are as they are measured in this existing culture. When the concept of the I.Q. became widespread and entered the vocabulary of the man on the street, there grew up the myth that the I.Q. or aptitude test measured "innate capacity" for learning. This suggested that one was born with a certain mental capacity, represented by a single number and ~~which was~~ unchanged through cultural experiences--that a deprived environment or inadequate schools, or poverty, or any of a number of other disadvantages, etc. would not handicap the child in his performance on an I.Q. test.

Unfortunately, no one has found a way to measure "culture-free" capacity for learning. Furthermore for whatever reason we might want to know the "innate capacity" of an individual, it is probably not directly relevant to his or her ability to produce in scientific fields. For unless the innate capacity has been developed, unless the student has acquired the knowledge and skills of science, he is unable to reach the academic level required for scientific contribution no matter how great his undeveloped innate capacity may have been.

There is another commonly accepted idea that has grown up with the spread of half-understandings about the I.Q. and that is that intelligence

is represented by a single factor which would enable one to learn all types of information more readily—that the higher I.Q. would be more capable in reading, computational work, logic, or any other learning activity. Actually, repeated research has indicated the presence of not a single mental ability but of two relatively independent primary abilities which are most basic to future learning—verbal ability and mathematical ability. Most of the tests of aptitude today report both a verbal and a mathematics score rather than a single "intelligence quotient."

Today's aptitude tests have proved themselves of considerable value in the measurement of intellectual characteristics. Although they do not claim to be free of cultural influences, they do attempt to avoid direct measurement of the results of school learning. Research has shown repeatedly that the major aptitude tests, such as the Scholastic Aptitude Test of the College Entrance Examination Board, are quite resistant to the cram sessions and special coaching that have become undeservedly popular with students intent on gaining admission to the prestige colleges. The aptitude tests are widely used by college admissions officers because they ~~especially~~ especially provide successful measures of the two factors which have emerged as most basic to future learning—verbal ability and mathematical ability.

Another caution that I want to state before presenting research evidence about the differential test performance of men and women is that statistics speak in terms of groups. Despite the fact that there may be significant differences in the mean or average scores of men and women, we must not lose sight of the fact the degree of variation within a group of males or females is almost always greater than the difference between average scores of men and women i.e., in intellectual abilities individual women differ much more from each other than the average woman does from the average man.

With these cautions in mind regarding the interpretation of research data let me proceed now to the evidence about the measured aptitude of women.

Generally speaking, females are superior in verbal and linguistic functions and males are superior in mathematics and scientific abilities. The patterns of development of the verbal and mathematical abilities show interesting differences. The female superiority in language is pronounced among young children and seems to taper off among older students. On the average, girls begin to talk earlier than boys; at pre-school age they have a larger vocabulary than boys; they use sentences earlier; they make more rapid progress in reading; and there is a much lower number of reading disabilities, stuttering, stammering, and other speech disorders among girls than among boys. (1, p. 473) When the verbal abilities are separated into two factors of word fluency and verbal comprehension, however, it is found that girls are significantly better in word fluency but that there are no significant sex differences in verbal comprehension.

Measurements taken during the senior year of high school, show that the girls are only slightly ahead of the boys on the verbal section of the SAT. At the end of four years of college, there is virtually no difference between the score distributions of verbal ability for men and women on the Graduate Record Examinations.

The history of mathematical abilities, however, follows a somewhat different course of development from that seen in the verbal abilities. Studies at the primary grades and earlier show no significant sex differences in numerical aptitude. Computational tests show little sex difference at any level, but males excel quite consistently on arithmetic problems and other tests of numerical reasoning. (11) Male superiority on quantitative measures

does not appear until children are well into elementary school period and it seems to pick up speed through the various levels of education. High school boys do considerably better than girls on the mathematical section of the Scholastic Aptitude Test and there is likewise a marked difference in favor of men in the quantitative section of the Graduate Record Examinations at the college level.

Thus, throughout the years of greatest potential for the education of the scientist-to-be, we find the average boy superior to the average girl in quantitative abilities. Furthermore, this difference is consistent at all levels of ability. Among the National Merit Scholars, some of the brightest young people in the country, 35% of the boys made a score above 750 on mathematics section whereas only 13% of the girls scored this high.

In the face of these rather dramatic and consistent differences in favor of the men in mathematical abilities we should perhaps remind ourselves that these are data for groups. In this last example for instance, 13% of the female Merit Scholars <u>are</u> as good at mathematical concepts as this highly-selected group of men who show perhaps the greatest potential for scientific achievement of any young people in the country.

To sum up the picture then on aptitude measures, we can say that the average male consistently out-performs the average female on the quantitative aptitude tests. These tests, of course, show a high relationship to future learning in the sciences. Realistic planning for the future role of women in science then should take into consideration the existence of this differential. Obviously the critical question now becomes why should we so consistently find men out-performing women in tests of mathematical aptitude. This is a rich field for further inquiry, but not part of my task today.

To continue my job of presenting a descriptive picture of the potential women scientist let me turn now to test measures of the achievement of women. Unlike the aptitude tests, achievement tests are specifically designed to sample the student's understanding of the essential knowledge in a field and this, of course, is usually a test of school learning. A well designed achievement test does not attempt to measure isolated informational details or facts, nor does it emphasize rote responses to stereotyped questions. Rather it emphasizes the ability to make use of the knowledge one has; it demands an understanding of relationships; and it requires the selection of a relevant course of action from a broad background of information.

Last spring, in connection with the launching of the new Comprehensive College Testing Program, ETS conducted a study of the American college sophomores' achievement in five basic areas of liberal arts education. These achievement tests are designed to measure at the college levels the student's command of essential knowledge in English, humanities, mathematics, social sciences and natural sciences.

The sample of students used for this study was unusually carefully selected to be representative of the students in this country who are completing their second year of study at two- or four-year colleges or universities. The 2,600 full-time students participating in the testing came from 180 institutions of higher education well distributed throughout the country.

The results were these: Men scored higher than women on mathematics, natural sciences, and social sciences; and women scored higher than men on English and humanities. These results are quite consistent with those of Graduate Record Examinations taken by college seniors. The Graduate Record Examinations Area Tests sample knowledge in three areas; social sciences,

humanities, and natural sciences. On these tests men do consistently better on natural sciences, and somewhat better on the social sciences. Women score higher than men on the humanities test.

Since it is a well known fact that girls tend to take courses in literature and the humanities whereas boys specialize in the sciences, it is informative to look at the performance of the minority of women who do specialize in mathematics and the sciences. One might hypothesize that girls who resist the cultural pressures and study in what is primarily a man's field ought to be unusually good at it.

This is not the case, however, and once again we find that men specializing in scientific subjects make higher achievement test scores than women specializing in the same areas. At the college sophomore level, the Comprehensive College Tests showed that the mean scores of men planning to major in mathematics, natural sciences or social sciences were higher than the mean scores of women planning to major in these areas. Men are markedly better in mathematics achievement, better in the natural sciences, and slightly better in social sciences. On the other hand, men are in the same boat when it comes to English and the humanities. Men specializing in these areas do not do as well on the achievement tests as their female classmates. Once again these results are consistent with the Graduate Record Examinations which show that after four years of college education in a major field, men majoring in the natural sciences score better than women majoring in science. Men in the social sciences out-score women social science majors and woman humanities majors out-perform the male humanities majors.

Lest this sound too dismal, let me hasten to say that women majoring in the sciences do have a greater knowledge of mathematics and science than

men majoring in the humanities. Of course, we should be quite surprised and discouraged about the potentiality of women scientists if this were not the case.

There are, of course, many hypotheses for male superiority in science—most of which have to do with cultural influences. Anastasi (1) reports on two studies in the cognitive area which may shed a little light on the matter.

Sweeney (11) found that college men were significantly superior to women on problems that called for "restructing" i.e., organizing facts in new ways. Along the same line Kostic (5) found that high school senior boys were superior to girls in their ability to transfer knowledge and skills to new situations. These differential abilities of men and women were apparent even when groups were equated for intelligence, verbal and mathematical aptitudes, previous knowledge, and other relevant variables. More research on the extent to which problem solving attitudes may be amenable to training would prove most helpful.

All of us have witnessed in our own experience the complex interweaving of abilities and interests and the circle which is generated. We like to do those things at which we excel and, as we expose ourselves to new interests, we are likely to increase our skills and knowledge in the area.

It seems reasonable to hypothesize that the differential development of mathematical and verbal abilities in men and women may be attributable in large measure to this very human trait of doing what we like to do insofar as possible. Part of the problem may very well be that it is possible (and perhaps culturally encouraged) for the high school and college girls to avoid mathematics, whereas it is not very possible for the high school and college boys to avoid English. The constant exposure not only in school but outside to verbal experiences for both boys and girls may help to

decrease the early lead of girls in the verbal abilities.

This exposure does not exist for the mathematical skills, however. Math is rarely required in senior high school or in college, and we do not run into it in the course of our daily conversation, the reading of newspapers, magazines, and other leisure time activities. The exposure to mathematics and science courses is likely to be through choice, and the pattern of choice follows that of the test results. Girls choose English and humanities; boys choose mathematics and science.

The ETS study on the college sophomore to which I referred earlier indicated that at the high school level there is a minimum of variation in the amount of English students take. Eighty-five per cent of the men and 91% of the women had taken four years of high school English. Mathematics was a different question, however, and we found that 50% of the men had taken four years of high school mathematics whereas only 23% of the women had had this much. At the college level, 41% of the women had taken no courses in mathematics, whereas only 21% of the men lacked college math. It is encouraging to note, however, that these figures show that over half of the women had had some college mathematics and this is more than we might have expected some years ago.

Another extremely bright trend is illustrated by the startling increase in the amount of high school mathematics preparation presented to some of the highly selective colleges by entering freshmen. Mount Holyoke found that 62% of their entering freshmen this year had taken four years or more of high school mathematics compared with only 38% in 1959.

The college sophomores participated in this study at the time in their educational careers when they make the decision about a major field of study. Thirty-six per cent of the men and 14% of the women said they planned to

major in some phase of the sciences. Over half of the women, 51%, planned to take majors in education or the humanities; two fields that accounted for the interest of only 18% of the men. Once more then, we find a sex differential in the descriptive statistics of men and women as it pertains to the expressed interest in studying in scientific fields.

In summary up to this point, all evidence points to a greater interest in science on the part of men as contrasted with women, higher scores in achievement tests in the sciences, and better performance on the quantitative aspects of the aptitude tests.

If we accept the proposal that we should encourage women to plan careers in science, then we might well ask where we are beginning to lose the women who have the greatest potential for scientific achievement.

In all probability the greatest loss of potential women scientists occurs very early--perhaps as early as eight years of age. A recent study based on reports from 2,433 finalists of National Science Fairs shows that the age of first interest is given as twelve years of age with age ten now becoming nearly as productive of possible scientists (6). It is of special interest to us to note how this interest in science first becomes sparked. Those finding their first scientific interest at the age of eight gave most of the credit to their parents and relatively little to schools and teachers. On the other hand those who found scientific interests beginning at the age of ten claimed that they were predominantly self-motivated. The twelve year olds reported that school opportunities and course plus the influence of individual teachers were most important to them. As a group, however, these young scientists are increasingly reporting discovering scientific interests as a result of their own curiosity. The impact of school on the stimulation of scientific interests dropped from 35% in 1962 to 24% this year.

The trends in this study showing a decrease in the age of first interest in science, and some indication of less dependence on school for stimulating an interest in science, may indicate that science is rapidly becoming a more integral part of our cultural interests. The great interest in space flights found young children as well as adults glued to the TV programs which gave attention to a great range of scientific problems--from astronomical to gastronomical. All of us found principles of science creeping into our daily conversations. The New York Times reported last Sunday that general science was the most popular course on educational TV.(9) It will be interesting to observe whether these trends have an impact when young people select their high school and college courses.

For this is perhaps the next point at which we lose potential women scientists. Indices of educational levels show that until the college level is reached more women than men stay in school. In 1962, the median number of years of school completed was 12 for women as against 11.6 for men. But once the college level is reached the women fall behind. Last year women constituted 42% of the entering class in colleges and from that point on they lose ground steadily. Women earn about one in three of the B.A.'s and M.A.'s, and only one in ten of the Ph.D.'s. The fact that these ratios are lower than they were in the 1930's has been a well-publicized fact. Although today we find a much greater number of women taking advanced course work, proportionally speaking not as many are going on to advanced degrees as did in the 1930's when women earned 40% of the Bachelor's and Master's degrees and about 14% of the Ph.D.'s.

Let me return now for a moment to see if we can throw any light on what happens to women even before they reach the point of choice as to whether to go on for advanced degrees. And here I should like to give particular

attention to women of high ability citing primarily studies that are concerned with women ranking among the top 50% in ability.

Havinghurst (3) quoted figures in 1960 showing that 27% of the females and 16% of the males possessing ability among the upper half of the population were not in college. That 27% of high ability women undoubtedly represents a rich and untapped reservoir of women scientists.

A 1956 study by ETS (10) attempted to answer some questions concerning the interest or lack of interest in college attendance expressed by "high ability"* public high school seniors.

Very briefly, the results of that study can be summarized as follows:

(1) Those of high ability are more likely to be interested in college. Among girls making top scores in the aptitude test 80% said they were interested in going to college. Whereas, at the 70th percentile of ability--still a high level of ability and definitely college material--only 61% expressed such interest.

(2) Those who have done well in terms of high school grades expressed greater interest in college. Eighty per cent of the girls in the top quarter of their high school classes said they would like to attend college, whereas, only 50% of those in the lower half of their high school class reported such interest.

(3) Neither the size of the high school attended nor the geographic region had any consistent relationship to the student's interest in college.

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*Defined as those scoring in the top 30% on a brief academic aptitude test.

(4) Parental occupation is a significant factor in college interest. Among the children of parents in professional occupations, 95% of the boys and 90% of the girls said they would like to attend college.

From this study done for the National Science Foundation, Stice, et al concluded that "among students headed toward college there is considerable orientation of their entire lives toward this goal. Their friends expect to go to college; they discuss college plans with their families and teachers as a matter of course, and they have more information about financial assistance for going to college." (10, p. 66)

In addition to simply finding out what factors showed relationships to interest in attending college, Stice et al added an interesting question to see how many high ability students could be motivated to modify their college plans by a hypothetical proposal for financial assistance. This information was obtained by asking the students this question, "Suppose that you would get a scholarship to go to college if you agreed to study a particular subject. The scholarship would be large enough to make it possible for you to attend a good college and you would have no need to worry about earning any part of your expenses. But to get the scholarship you would have to agree to major in (or emphasize) some particular subject."

The student was then asked to indicate on a five point scale whether he "would certainly," "would probably," "might," "would probably not," or "would certainly not" accept the scholarship in each of ten areas, should any one of them be offered to him under the conditions described.

Sixty-one per cent of the boys would "probably" or "certainly" accept a scholarship to study engineering, whereas only 5% of the girls would do so. Mathematics appeared somewhat more acceptable to the women, with 24% of the

women saying they would "probably" or "certainly" accept the scholarship to study mathematics, and 21% of the girls would "probably" or "certainly" accept the scholarship to study physical science. When compared, however, with fields such as liberal arts (48% would "probably" or "certainly" accept) or education (where 52% would "probably" or "certainly" accept) the sciences did not fare too well even when proposed to the girls as "free" college education.

There is some very heartening recent evidence, however, which gives us some important data, not on what people say but on what they do. Dolan (2) presents a chart showing the change in the percentage of women receiving degrees in various fields from 1958-61. A rather dramatic increase is evident in the number of women receiving higher degrees in scientific subjects.

In the years from 1958 to 1961, there has been an 116% increase in the number of women receiving bachelor's degrees in mathematical subjects compared with a 31% increase over all fields. Mathematics shows the largest percentage increase in any subject area. Other fields with large increases are foreign languages and literature with a 95% increase in Bachelor's degrees granted, English and journalism with a 55% increase, and biological sciences with a 52% increase.

Master's degrees to women went up 22% over all fields, but showed a 109% increase in mathematical subjects (exceeded only by a 233% in library science). The sciences did quite well on the master's level, too, showing a 64% increase in biological sciences, and a 42% increase in physical sciences.

The number of doctoral degrees granted to women increased by 29% over all fields, with the greatest increases being in the following areas: 81% increase in English; 77% increase in psychology; 47% in social sciences;

and a 32% increase in the physical sciences.

An article in the New York Times (6) indicated that this past year's graduating classes continued the trend of a "growing interest on the part of women in the world of science...." and stated that the U. S. Office of Education reported that the number of mathematics majors again this year was "most impressive."

Obviously, we are seeing a great growth of interest in science. Much has already been done, but the discrepancy between what is and what must be if women are to play an important role in the scientific achievements of the nation leaves much to be done.

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