A STUDY OF SOME ACHIEVEMENTS OF PUPILS IN THE
SPECIAL SCIENCES - GENERAL SCIENCE VERSUS
NON-GENERAL SCIENCE GROUPS - IN THE HIGH SCHOOLS
OF KANSAS CITY, MISSOURI.

by

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Chapter I.

Introduction.

In this study attention has been directed to the teaching of General Science as a preparation for later science courses. In general we have asked the question "Does achievement in General Science predict a like achievement in the special sciences that are ordinarily taught in the high school?" We shall attempt to find out if General Science can be justified in the high school curriculum with special emphasis on the carry-over, if any, from it to the other high school sciences.

One of the outstanding studies on the aims of General Science teaching¹ gives the following as the most important ones. They are given in the order of their importance as determined by the number of times they occur in the literature.

1. Watkins, Ralph K. "The Technique and Value of Project Teaching in General Science." General Science Quarterly, Vol. 7, No. 4, pp. 251-256.

1. Better understanding and control of environment.
2. Information about nature and science.
3. Preparation for later science courses.
4. Training in scientific method.
5. Development of power of interpretation and appreciation.
6. Development of interest in science.
7. Culture.

These aims are practically the same as were found in at least five other extensive studies.²

So far as the writer has been able to examine the literature on the subject there has been no serious effort on the part of anyone to find out whether General Science is really accomplishing these aims, with one possible exception. Mr. Dvorak of the University of Washington has just completed a study of this kind, but at the present writing only a part of it has been published.³

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2. Worun, A.A. "General Science in Michigan." General Science Quarterly, Vol. 2, pp. 267-284.
 - Roecker, W.F. "An Elementary Course in General Science." School Science and Mathematics, Vol. 14, pp. 755-758.
 - Howe, C.M. "Can and Should General Science be Standardized?" School Science and Mathematics, Vol. 19, pp. 248-255.
 - Miller, C.F. "Survey of the General Science Situation in Illinois." School Science and Mathematics, Vol. 19, pp. 398-406.
 - Leker, W.R. "The Articulation of General Science with the special sciences." General Science Quarterly, Vol. 2, pp. 158-173.
 3. Dvorak, August "A Study of Achievement and Subject matter in General Science" General Science Quarterly, Vol X, Nov. 1925, pp. 289-310.

There is still much discussion about the value of General Science in the high school curriculum. A great deal has been said in its favor and almost as much against it. But nearly all that has been said on either side has been a matter of opinion and has not been based on an objective study of the subject. Teachers of the special sciences often offer the criticism that General Science causes their pupils to lose interest because the novelty of the subject has been taken away by the previous study.⁴

This is in direct contrast to aim number six above. In fact, aims number two, three, four, five and six, if really accomplished, should all contribute directly to a greater success in the special sciences that follow the course in General Science. Twiss,⁵ while sympathetic toward the work of those who are carefully studying the General Science proposition from various standpoints, frankly questions the wisdom of widespread introduction of such courses in schools where adequate equipment and well trained teachers for the purpose are lacking.

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4. Andrews, W.E. "Correlation in High School Science Courses." School Review, Vol. 27, pp.1-12.
 5. Twiss, G.R. "A Textbook in the Principles of Science Teaching." The Macmillan Co. N.Y. 1917, pp. 411-433.

Andrews⁶ offers the criticism that General Science fails to accomplish what is claimed for it because it is shallow and superficial and disobeys the idea of individual differences in that all pupils are required to study the same things. On the other hand, in spite of the newness of General Science and the generalized nature of its content it has aroused a "volume of popular interest sufficient, not only to warrant its place among secondary school subjects, but also to place it among the required subjects in numbers of secondary schools."⁷

In view of these contrasting opinions, an inquiry into the effect of the teaching of General Science upon some of the well established special sciences in the high school seems distinctly worthwhile.

6. See reference four above.

7. See reference three above.

Chapter II.

The Present Status of the Problem.

(a) Historical Sketch.

The first science to be taught in the United States was Chemistry in 1767 in Columbia College. It made its appearance in the high schools first in 1819 at Massam Private Academy, North Carolina.⁸ Since then nine other science courses have been introduced into the secondary school curricula. These sciences, in the main tended toward such high specialization that about the beginning of the twentieth century there was felt a need for a kind of science teaching which did not have as its goal specialization in science, but which did fill an immediate and even a local need.

Such a "reform" course was offered in England as early as 1869 by Thomas H. Huxley.⁹ He gave a series of illustrated lectures to London children at the Royal Institution, and later published the course in a book entitled "Physiography", which means literally a description of nature. In this course Huxley dealt with the immediate vicinity of London and the Thames.

8. Powers, S.R. "A History of the Teaching of Chemistry in the Secondary schools of the United States Previous to 1850." Research Publications of the University of Minnesota. No. 13, p. 16.

His subject matter embodied the physiography and Geology of the Thames basin and the activities of the London people. The course was informational and scarcely suited to other communities, but it did fill a desired end and, strange to say, its organization was much like the most recent General Science texts - in that it used the inductive method.

It is interesting to note that Huxley gave as his aims of the course much the same objectives as are outlined today for General Science.

1. "To furnish in the first year of high school the information and the training in thinking that are fundamental to the special sciences and are necessary to the successful pursuit of these sciences later on in high school or college."
2. "To impart information from a scientific standpoint about the useful and interesting things that are all about us, especially for the benefit of those who will not go to college and may not go farther in high school, and who, therefore, would otherwise remain ignorant of scientific facts and of the scientific way of dealing with the materials and forces that are every where available for our use."
3. "To give to the first year pupils an attractive view of the content of all the sciences, so that they may find out where their tastes and capabilities lie, and thus choose more wisely among the studies

that are offered them in later courses, or that they may find the field in which they prefer to read, work and study after leaving school to stimulate and foster such amature interest in science."

4. "The teacher of a General Science course,..... is free to disregard the logical fences that specialists have for convenience erected between their subjects. He may, therefore, pick and choose for his lessons those facts which lie nearest the interests of his pupils and are best adapted to their intellectual, economic and social needs. He is free to organize these materials with reference to these interests and these needs and to make voluntary problem-solving and pupposeful information-getting the proximate aim of the pupils. He may thus hope to train the pupils in methodically gathering information and applying systematic thought to the things in the environment that they desire to comprehend and manage."

5. It is thought by some that a General Science course may serve to show something of the relations of the sciences to one another, of the order and unity that exist in nature, and of the essential unity of the scientific method, and thus that it may appeal to imagination, contribute to a state of

mental poise or balance, and perhaps develop power of interpretation that could not so well be gained by separate courses in the special sciences."

The real beginning of General Science in the United States was about 1905. It seems to have begun in the eastern and northeastern part of the United States. In 1908 Massachusetts led in the number of classes taught which was a very few.¹⁰ Today it is the most taught science in the freshman year of high school, the state of New York being the only laggard in its adoption. The reason for this is because the state system of education imposes regent's examinations in Biology the first year of the public high school course. The rapid growth of General Science is shown in the following table which was compiled by three different studies. The first two of 1906-1911 and 1915-1918 were made by Doctor Stout of Northwestern University and were followed up by one made by Mr. Leker of the Milwaukee University School in 1924.¹¹ Dr. Stout's investigation included replies from forty high schools in South Dakota, Ohio, Michigan, Missouri, Illinois, Nebraska, Kansas, and Iowa. Mr. Leker received replies from thirty-four of the same schools.

10. Hunter, Geo. W. "The Position of General Science in the Secondary Schools of Today." G.S. Qr. Vol. 9, p. 9.
11. Leker, W. R. "The Articulation of General Science with the Special Sciences." G.S. Qr. Vol. 9, pp. 158-173.

Subject	The percent of schools offering the different sciences during		
	<u>1906 - 1911</u>	<u>1915 - 1918</u>	<u>1924</u>
General Science	2.5%	47.5%	88.2%
Physios	100.0	100.0	100.0
Chemistry	92.5	92.5	97.0
Biology	17.5	45.0	73.5
Zoology	55.0	40.0	17.6
Botany	85.0	67.5	38.2
Physiology	65.0	52.5	47.0
Physical Geography	82.5	52.5	35.2
Astronomy	12.5	2.5	0.
Geology	10.0	7.5	0.

In the first stage General Science was little more than a mere collection of parts of the special sciences. This, coupled with the fact that the course was usually taught by a special science teacher, led to the result that the course often became largely a special science course - the particular science depending upon the special interest of the teacher. Thus the early courses were not planned for the interest and need of the pupil but for the convenience and accommodation of the teacher. The general result was one of superficiality, lack of organization, and one sidedness. Today the situation is quite reversed. Particularly in Kansas City, Missouri, the General Science course is planned to suit the need of the pupil and is taught by teachers who can adapt the content and procedure to the elementary mind.

(b) Related Literature and Opinion.

During the last fifteen years much has been written on the value of General Science. At first there was

much skepticism but this is disappearing more and more as the subject gains in popularity. A great deal that has been written is mere opinion. We have seen fit to include here a few typical articles which deal with the relation between General Science and the special sciences taught in the high school.

George Mounce¹² in an article in "School Science and Mathematics" in October, 1920, seems to have some well defined ideas as to what General Science will do will do for pupils who later elect Chemistry and Physics, but so far as the writer can learn these ideas are not based on an objective study. He says that General Science helps students to elect later sciences intelligently and that "Those students who have had General Science rank best in Physics and Chemistry. They have acquired a working vocabulary of scientific words. Many of them have acquired that scientific attitude of mind which enables them to attack and solve problems with but little help from the teacher."

The opinion that General Science should stimulate a permanent interest in science and thus contribute to success in the special sciences is further expressed by Arthur Deamer in a paper before the National Education Association in 1917. "A course in General Science, after all, must depend, not only upon the

12. Mounce, Geo. "Some Tangible Results from a Course in General Science." School Science and Mathematics. Vol. 20 pp. 632-636.

information given, but also upon the permanent interest stimulated and interest aroused."¹³ Again, Hines, in speaking of the things that led to the development of such a course, says, "First for Junior high school pupils or for beginning pupils in the Senior high school, an introductory course is needed that, not only will explain the natural phenomena but will lay the foundation for later scientific study."¹⁴

Hunter,¹⁵ of Knox College, made quite an extensive study of the scientific situation in the high school in 1923 by means of a questionnaire. It was sent to about 800 schools. At the time of reporting the study, 357 replies, in which a large majority of the states of the union were represented, had been received. We are interested in three facts which were evident from the study. First, "General Science has found a place for itself in the ninth grade." Second, "In response to the question 'Do Chemistry and Physics gain anything from the earlier science courses?' there was a very decided answer in the affirmative - 78.2%

13. Deamer, Arthur "General or Elementary Science in the Junior High School." National Education Association Journal, 1917. pp. 706-709.

14. Hines, H.C. "Junior High School Curricula." The Macmillan Co., N.Y. 1924, p. 109.

15. Hunter, G.W. "Is there a Sequence in Secondary School Science?" School and Society. Vol. 20, pp. 762-766.

of those answering said 'yes'. 10% were uncertain and 11.8% gave a negative reply. Third, "In response to the general question 'Are the science courses more closely related to each other and to other courses in the secondary school than they were fifteen years ago?' 71% answered in the affirmative." In a later report of the same study we have the conclusion, "In schools where General Science is being given there appears to be a real belief on the part of the teachers that this work when properly correlated with the subsequent work of Biology, Chemistry, and Physics, gives the pupil a preliminary introduction to science that, not only enables him to choose his subsequent courses intelligently but gives the science teachers a foundation on which to build."

Mr. Leker, of Milwaukee University School, after making a study¹⁷ of the articulation of General Science with the special sciences makes the recommendation that "General Science should be required of every pupil going through the ninth grade of the high school." One of his conclusions is interesting in the light of our study. "The trouble with the science course in the high school today is simple. In most cases the sequence of subjects is worked out but the teachers do not know exactly what has been taught the pupils before they come to the special science classes. Each teacher begins therefore, with the preliminary things,

17. See reference 11.

generally to accommodate a few who did not have General Science where those things were taught. According to the articulation of subject matter, the majority of the class, who took General Science, will shirk on the job for they have already had 34.5% of the Biology, 25% of the Chemistry, and 41.4% of the Physics that is being offered by the teacher. That is enough to make many of our best students lazy and careless and it is because of this lack of articulation that spoils the interest of many students. This explains why many General Science students do poorer work in the special sciences than those never taking General Science. The subject is taught for the interest of the non-General Science pupil."

(c) Related Practice in Similar Problems.

So far as the writer can ascertain there has been no other study in the field of General Science comparable in practice to this study. Two studies which are related in method and purpose but which are in the field of the languages are of significance here. We are indebted to them for some valuable suggestions as to procedure. Both studies were made as a part of the general investigation of the teaching of Latin in the secondary schools by the American Classical League. The particular question involved was "In what measure, if any, is success

in Romance languages directly attributable to a previous study of Latin?"

The first of these studies to be reported was made by Thomas J. Kirby¹⁸ of the State University of Iowa. He studied the effect of Latin as commonly taught in high schools, upon the mastery of first and second semester French in the State University of Iowa during the year 1921-22. The procedure was to find three correlations by the Pearson Product Moment Formula. (1) The correlation between the number of years that Latin was studied in the high school and the University grades made in French. (2) The correlation between intelligence (Thorndike College Entrance Examination scores) and the University grades made in French. (3) The correlation between intelligence and the number of years Latin was studied in the high school. Each of these correlations was found for the first and second-semester French grades separately. Then by application of a partial correlation formula the factor of intelligence was rendered constant and the resulting correlation between the number of years Latin was studied in the high school and the University grades in French was found.

18. Kirby, Thomas J. "Latin as a Preparation for French." School and Society. Vol. 18, pp. 563-569.

Kirby found that (1) "There is a positive correspondence between the number of years students have pursued Latin in the high school and in the marks they made in first and second-semester French in the University. (2) This correlation is so low ($r = .22 \pm .04$ for each semester) as to indicate that the study of Latin by the methods used in the high schools from which these students came has only a slight relationship to the probable future success in first and second-semester French in the University." The second study was by L.E. Cole¹⁹ of Oberlin College. He attempted to find out in what measure, if any, success in French and Spanish was attributable to a previous study of Latin. His procedure was the same for each language so we have included here only the study of French. From the freshmen classes entering Oberlin College in 1919, 1920 and 1921 those pupils were chosen who took up the study of French for the first time.

The procedure was as follows:

(1) To secure correlation between performance in first semester French and intelligence score.*

(2) To secure the correlation between performance in first semester French and the amount of Latin studied in the high school.

19.

Cole, L.E. "Latin as a preparation for French and Spanish." School and Society, Vol. 19, pp. 618-22.

* Army Alpha.

(3) To secure the correlation between intelligence score and the amount of Latin studied in the high school.

(4) To render the factor of intelligence constant by application of a partial correlation formula where-ever the difference in intelligence levels of the groups is an appreciable one.

(5) To render the factor of intelligence constant by the method of pairing, and, having done this, to discover the remaining superiority, if any, in the Latin group.

(6) To render the factor of intelligence constant as in (5), and to determine whether or not a general superiority (as against a specific performance in French) persists in favor of the Latin group."

Cole found that there was a positive relationship between the amount of Latin studied in the high school and performance in first year French and Spanish and that there was some evidence of a specific Latin-French and a Latin-Spanish transfer.

Chapter III.

The Study Analyzed

The idea of a carry-over or transfer from General Science to any one special science assumes in the first place, that there are certain identical elements common to both sciences.²⁰ That there are identical elements common to General Science and the special high school sciences has been shown conclusively by several studies that have been made.* In the second place, in order to show a transfer of training, it would be necessary to show that those identical elements had been acquired in a General Science class previous to the time they were studied in the special science. Not only must we show that the pupil at the close of a course in General Science actually has more information of the kind that is included in the special sciences, but, we must show that he has more than he would have had had he not taken the General Science course.

But this alone will not solve our problem. We must go farther and show that there is a positive correspondence between success in General Science and success in the special sciences.

20. Gates, A.I. "Psychology for Students of Education." Macmillan, 1925, Ch. XV.

* See the study by Mr. Leker, reference #11 above.

That is, we must find out if achievement in General Science tends to be followed by a similar achievement in the special sciences. Furthermore, if we find that intelligence is a factor in achievement in the special sciences we must seek a method of ruling it out or holding it constant.

But since many other factors than intelligence and a previous course in General Science may contribute to success in the special sciences we need to ask a further question. Do the pupils who have had a course in General Science rank higher in scholarship in the special sciences than similar pupils who have not had such a course? In what measurable degree, if any, is the accomplishment of the General Science group superior to that of the group who have not preceded their special science course by a course in General Science?

Lastly, if we find that higher scholarship is attained in the special sciences by those who have previously had General Science, is this higher scholarship attained in all the special sciences without exception? Is there a lack of transfer in some and an apparent transfer in others, or is there an evident transfer in each? In which, if any, of the special sciences is the transfer most pronounced?

To summarize we believe we may be able to find the correct solution to our thesis in the answers to the following questions:

(1) Do students who have had General Science have any more scientific information than those who have not had it?

(2) Does achievement in General Science tend to be followed by a similar achievement in the advanced sciences?

(3) In what measure, if any, is success in the special sciences directly attributable to a previous study of General Science?

(4) Is the transfer from General Science to the special sciences consistent?

Chapter IV.

(a) The Groups Studied.

This study was made in the high schools of Kansas City, Missouri. All data were collected from the Freshman, Sophomore, Junior and Senior classes of the school year 1924-25. All reference to high school classes will mean the classes of this school year unless otherwise stated. It includes students of the second year* class in the Central Junior High School, the Sophomore, Junior and Senior classes in the Central (Senior) High School and a few of the same last three-mentioned classes of Northeast High School.

It is evident from the summary at the close of Chapter III that data will be required for two entirely distinct groups of students. We shall name them group I and group II. Group I will be taken from the freshman class of Central Junior high school. It will include first, those freshmen who completed a whole year of General Science during the school year 1924-25. We shall name this sub-group Ia. Second, those freshmen who had not previously taken

* Second year Junior high school in Kansas City, Mo., corresponds to the Freshman year in the four year high school. In the following pages we shall use the term 'freshmen' to designate the pupils from this class since this term is the more common one.

or did not take General Science during the year 1924-25 will be called sub-group Ib. They will be a control group for Ia. These pupils shall be used to answer question number 1, in the summary at the close of Chapter III.

Group II will be made up of pupils of the sophomore, junior and senior classes who took a special science during the year 1924-25 or had taken a special science before the year 1924-25. The special sciences included are Botany, Human Physiology, Zoology, Physics and Chemistry. Biology is the only other special science taught at Central high school and we have not included it because it is made up of one semester each of Botany and Zoology. Group II will contain two sub-groups of pupils. First, sub-group IIa will be composed of pupils who had preceded the study of the special science by one year of General Science. Second, sub-group IIb will be a control group for IIa and will be made up of pupils who did not precede the study of the special science by any other science. It is important to note that a pupil can be eligible to group II only once although he may have studied three or even four different special sciences. He is eligible only when he is taking his first special science. This precludes the possibility of a transfer from one special science to another.

(b) Collection of Data.

Group I. As has been indicated in the preceding division of this chapter, data for group I were collected from the freshman class of Central Junior high school, 1924-25. There were about 1100 enrolled in classes open to freshmen. The following data were required for each pupil: (1) Student's name; (2) Intelligence test score; (3) General Science test score, form A; (4) General Science test score, form B; (5) Item four minus item three. It was decided to give the Ruch-Popinoe General Science test* to all of these in the fall and again near the close of school. On Tuesday of the third week of school form A was given in the English classes (all freshmen are required to take English). On Thursday of the last week of school, form B was given by the same teachers. We had expected to give form B a week or two earlier but the tests were late in arriving. The intelligence test score was obtained from the office records. It is given every year to the freshman class sometime during the last semester. It was used as a basis for pairing sub-groups Ia and Ib.

Group II. Data for this group were collected from the office records of Central and Northeast

* See complete test in appendix.

high schools. It was the original intention to confine the study to Central high school but so few cases were obtainable there in Physics and Chemistry that it was thought best to consult the records of Northeast. About the same type of work is given at the two schools and the classification of pupils is exactly the same, being in charge of the same person at both schools. The following data were collected for each pupil of sub-group IIa (1) pupil's name; (2) Terman group intelligence test score; (3) date Terman test was taken; (4) General Science grade; (5) special science grade; (6) year and semester special science was taken; (7) all other grades made during the semester the special science was taken; (8) date of entering school. In item seven the grades in the non-solids, (subjects that count for half credit only) were underlined so that they would count only half in averaging. Data for sub-group IIb were the same except there was no General Science grade to record; item (4) above. Data sheets for group IIa and group IIb were kept separately. For example, the data sheets for group IIa in Botany were headed "Group IIa, Botany preceded by General Science but no other science," and the corresponding sheets for group IIb were headed, "Group IIb, Botany not preceded by General Science or any other science."

The Terman test scores made during the freshman year are kept on file in the office and were the source of item (2). Data for all other items on the data sheets were found on the permanent individual record cards. Cards were investigated for all pupils entering in September, 1921 or later, even though they had withdrawn from school.

(c) Pairing.

All pupils attending Central and Northeast are given the Terman Group Test of Mental Ability in the spring of their freshman year. These test scores are later used as a basis of classifying them into A, B, and C sections for class work. Therefore, it seemed entirely appropriate for us to use these same scores as a basis for pairing. Furthermore, the Terman group test is recognized as one of the best group tests for predicting achievement in school work.*

In the case of Group I above, the raw scores were used for pairing without change, because the test taken during the year when General Science was being studied and between the initial and final tests on

* Dr. Paul Witty of the University of Kansas in his class in "Mental Measurements" during the summer session, 1925, made a statement to the effect that, while the Terman group test of mental ability probably does not measure general intelligence, it is a good test to use for the classification of students because it predicts well the kind of school work a student can do.

General Science information. A maximum of only four points of the score was allowed in pairing. However, pairing in group II presents a different problem. To illustrate, let us assume a group of seniors of 1924-25 who are eligible to group II according to the conditions stated above and who took Botany as their special science. All of them would have taken the Terman test in the spring of 1922. Most of them probably would have taken Botany during the Sophomore year but a part of them would have taken it in their Junior year, and still others during their Senior year. It would be unfair to pair a pupil who had made a score of say, 100, and who had taken Botany during his Sophomore year with another pupil who had made a score of 100 and had taken Botany during his senior year, for the latter pupil would have the advantage of two full years of mental growth not recorded in his intelligence score. Therefore, before any pairing could be done in Group II, all the intelligence test scores had to be made comparable at the time the special science was taken. This was accomplished by means of Table I, page 9, of the Manual of directions of Terman's Group Test. In this table percentile scores are given for each grade from seven to twelve inclusive. In our study the scores made were most nearly like those given for the tenth grade of Terman's table. Therefore,

See other side

Graph I. Showing the number of points to be added to the Terman scores in Case the special science was taken during the junior year (graph A), or the senior year (graph B)

x-distance = Raw test scores

y-distance = points to be added to raw test scores

Numbers between dots are the percent who equal or exceed that raw score

if a pupil took his special science during his sophomore year the test score was taken as a basis for pairing without change. But if he took his special science in his junior year or his senior year, it was necessary to estimate what his score would be at that time, before pairing could be done. For this purpose graph I, page 26, was made from Table I, (Terman) mentioned above. To illustrate how it is read let us suppose a pupil made a Terman score of 101 when he took the test at the close of the freshman year. If he took the special science during his junior year we read from the graph that fifteen points should be added making a total of 116 as his score for pairing purposes. If he took the special science during his senior year then twenty-five points should be added, making a total of 126 as his score for pairing purposes. This merely means that for a large group of pupils the mean gain on the Terman test from the tenth grade to the eleventh grade is fifteen points and from the tenth year to the twelfth year it is twenty-five points.

In pairing the pupils of Group II, a maximum difference of only five points between the Terman scores was allowed in Botany, Human Physiology, and Zoology, and in most cases, in Physics and Chemistry. However, because the number of cases was so small, it was thought best to allow a wider difference in

a few cases. In no case was this difference more than eleven points which, according to Terman's table of mental ages on page 10 of the manual of directions, is about six months of mental age. So far as the writer has been able to find out no P.E. has been published for the Terman Group Test of Mental Ability.

(d) Procedure.

All of the General Science tests given to the freshman class at the beginning and close of the year were graded by my wife, Ethel S. Cramer, and myself. Of the 1100 who took it about 400 were enrolled in General Science classes for one half year. Then there were quite a few mid-year freshmen who were in the General Science classes so that they could not be included in the study. When these irregulars were taken out there remained about 650. Of these some were absent when one of the tests was given and a few had mental scores which could not be paired. When pairing was complete there were 310 in each of the equivalent groups, or a total of 620. (See table I for a distribution of the mental scores).

In order to arrive at the answer to question 1, of Chapter III, let D be the difference between the final test and the initial test of the General Science pupils, sub-group Ia, and let d be the difference between the final test and the initial test of the

control pupils, sub-group Ib. Then the actual gain, if any, in scientific information will be D minus d .

To answer question 2, Chapter III, we shall find the following correlations and partial correlations for each special science and for sub-group I Ib as a whole:

- (1) Correlation between the grades made in General Science and the grades made in the special science.
- (2) Correlation between General Science grades and intelligence test scores.
- (3) Correlation between special science grades and intelligence test scores.
- (4) By partial correlation hold intelligence constant and find the correlation between General Science grades and special science grades. In outline form for Botany this may be stated as follows:

Let 1 General Science grades made by the pupils who later took Botany.

2 Botany grades.

3 Intelligence test scores (same as used in pairing)

Then find r_{12} , r_{13} , r_{23} , and $r_{12:3}$.

Use the following formulae $r = \frac{\sum x'y' - 4c_y}{\sigma_x \sigma_y}$ and

$$r_{12:3} = \frac{r_{12} - r_{13} \cdot r_{23}}{\sqrt{1-r_{13}^2} \sqrt{1-r_{23}^2}}$$

The grades given in the high schools of Kansas City during the time this study was made were F, P, M, G, E, in order from low to high. F was failing.

To answer question 3, Chapter III, four steps will be taken. We shall describe them using Botany as the special science, since the procedure was the same for each of the five special sciences studied.

(1) Pair each pupil who preceded his study of Botany by a course in General Science (sub-group IIa) with a pupil who did not precede his study of Botany with a course in General Science (sub-group IIb). This will hold intelligence constant. (For distribution of mental scores see table II).

(2) Using the grades made in Botany as a measure of achievement* the mean was found for each sub-group. In doing this the following values were

* We realize that teachers' marks are not considered a very reliable measure of achievement but in our study they were the only measure that could be had. There were no standardized tests in Botany, Zoology or Human Physiology and the tests that were available in Chemistry and Physics were so poorly standardized that they would probably not be any more reliable than the teachers' marks. Furthermore, we could get many more cases by going to the records and taking teachers' marks than would be possible by giving the tests, since in this way we could get at the achievement, not only of the pupils enrolled in the special sciences at the time our data were collected, but also those who had previously taken them. According to a recent investigation by Prin. E.F. Orr of Hobart, Indiana, they are quite reliable. (See Orr, E.F., "A Principal's Observations on Intelligence Testing," American School Board Journal, May, 1925, Vol. 70.)

assigned to the grades: $F=0$, $P=2$, $M=4$, $G=6$, $E=8$. If we let M_a equal the mean of all Botany grades made by pupils of sub-group IIA and M_b equal the mean of all Botany grades made by pupils of sub-group IIB, then, M_a-M_b may be thought of as the amount of achievement in Botany by which the General Science group excelled the control group. But we know that many factors enter into scholarship, other than the factor of intelligence, and that a general superiority is likely to exist in either sub-group IIA or IIB. Let us suppose a general superiority really does exist in sub-group IIA then to find the actual amount of achievement by which IIA exceeds IIB, we must subtract this general superiority from the difference M_a-M_b .

In step (3) we attempted to find any general superiority that might exist in either sub-group in the following way. The average grade, made during the semester Botany was taken, was found for each pupil. The mean of these averages was found for each sub-group. Then the difference between these means was taken as the general superiority of the one group over the other. In finding the average grade for each pupil the same numerical values were assigned the grades as those mentioned in step (2) above in the solid subjects. For the non-solids, or those subjects which were supposed to require no preparation outside of the class period

and for which only half credit is allowed, we assigned the following values to the grades: $F=0$, $P=1$, $M=2$, $C=3$, $E=4$. These are just half the values assigned to the grades of the solid subjects.

(4) After correcting the quantity M_a-M_b for any general superiority that might exist in either group the resulting measure is taken as the actual amount by which achievement in Botany is directly attributable to a previous study of General Science. In this step the results of all the special sciences are thrown together in order to get the average measure of achievement.

Question four of Chapter III can now be answered without any further computations, by merely comparing the results in each of the special sciences.

Chapter V.

Presentation and Interpretation of Results.

All data collected in this study have been arranged in tabular form in this chapter.

(a) Freshman Group, General Science Information Test.

Table I, page 34, is a frequency distribution of the mental test scores of the group studying General Science and of the control group that did not study General Science together with the lower quartile (Q_1), the median (Med.) and the upper quartile (Q_3). The table shows that the two groups are, for practical purposes, equivalent in intelligence.

Table II, page 36, presents the difference between the initial test and the final test score made on the Ruch-Popinoe General Science test for each group. It will be noticed that the median difference, or median gain for the General Science group is 12.4 points and for the control group it is 1.3 points. The General Science group gained nine and one half times as much as the control group. That is, the pupils who study General Science do get more scientific information than do those who do not study it.

Graph I, page 35, presents the facts of table II in graphical form.

Table I. Frequency distribution of mental test scores showing a comparison of the General Science group of freshmen and the control group.

Terman Group (Intel. Test) Score	Gen. Sci. Group	Control Group
181-190	5	5
171-180	7	7
161-170	22	20
151-160	17	19
141-150	20	20
131-140	30	29
121-130	40	44
111-120	37	35
101-110	41	39
91-100	33	35
81- 90	28	26
71- 80	18	18
61- 70	9	9
51- 60	1	2
41- 50	2	2
	N = 310	N = 310
	$Q_1 = 96.9$	$Q_1 = 96.9$
	Med. = 117.2	Med. = 117.9
	$Q_3 = 138.8$	$Q_3 = 138.8$

Graph II.

Comparing the achievement of the General Science Group of freshmen with the achievement of the control group. Numbers at the bottom represent the dif-

ference, FT - IT of the General Science Information test. (A total of 90 points are possible)

A General Science Group.

B Control Group.

Table 2. Results of the General Science information test in terms of the difference, FT - IT, for each group.

Differences	Gen. Sci. Group	Control Group
29-30.9	2	
27-28.9	3	
25-26.9	5	
23-24.9	5	
21-22.9	6	
19-20.9	17	
17-18.9	27	
15-16.9	33	
13-14.9	44	3
11-12.9	43	1
9-10.9	39	2
7- 8.9	36	21
5- 6.9	28	34
3- 4.9	11	51
1- 2.9	8	50
-1- .9	2	55
-3--1.1	0	50
-5--3.1	1	27
-7--5.1		12
-9--7.1		4

N = 310, $Q_1 = 8.5$
Med. = 12.4, $Q_3 = 16.2$

N = 310 $Q_1 = -1.6$
Med = 1.3, $Q_3 = 4.4$

(b) Correlations. Groups from the Special Sciences.

Tables 3, 4, and 5, pages 39 to 41, give the correlations in the study of achievement in Botany. The pupils involved—those who preceded their study of Botany by a course in General Science and who took no other intervening course in science. The correlation between the General Science grades and the mental test scores is shown in table 3, between the Botany grades and the mental test scores in table 4, and between the General Science grades and Botany grades in table 5. The value of r is given at the close of each table. In addition to r at the close of table 5 (Correlation between grades) is given the value of $r_{12.3}$ that is, the correlation between the General Science grades and the Botany grades with the factor, intelligence, held constant by partial correlation.

Tables 6, 7, and 8, pages 42 to 44, give similar information for Chemistry. In this case the pupils involved are those who preceded the study of Chemistry by a course in General Science and who took no other intervening course in science.

Tables 9, 10, and 11, pages 45 to 47, give the information for Physics.

Tables 12, 13, and 14, pages 48 to 50, give the information for Human Physiology.

Tables 15, 16, and 17, pages 51 to 53, give the information for Zoology.

Tables 18, 19, and 20, pages 54 to 56, give the information for all the special sciences combined.

Table 21, page 57, is a summary of the results given in tables 3 to 20 inclusive.

Probably the most significant fact about these correlations, so far as our study is concerned, is that the correlations between the General Science grades and the special science grades are, without exception, positive.

Table 3.

CORRELATION BETWEEN GENERAL SCIENCE GRADES AND INTELLIGENCE TEST SCORES OF BOTANY PUPILS.

X distance is General Science grades.

Y distance is intelligence test scores.

	F	P	M	G	E	f
190-199				1		1
180-189						0
170-179			1	1	1	3
160-169				1		1
150-159			3	6		9
140-149		1	5	2	1	9
130-139		1	4	6	1	12
120-129			7	6		13
110-119		5	5	6	1	17
100-109			6	6		12
90- 99		2	3	2		7
80- 89		3	3	2		8
70- 79		1	4	1		6
60- 69						0
50- 59			2			2

f 0 13 43 40 4 100

$$r_s = .31 \pm .06$$

Table 4.

CORRELATION BETWEEN BOTANY GRADES AND
INTELLIGENCE TEST SCORES.

X-distance is Botany grades.

Y-distance is intelligence test scores.

	F	P	M	G	E	f
190-199			1			1
180-189						0
170-179			1	2		3
160-169		1				1
150-159			2	6	1	9
140-149		1	4	4		9
130-139		2	4	5	1	12
120-129		1	7	5		13
110-119		2	8	7		17
100-109		1	9	2		12
90- 99		2	5			7
80 - 89		3	4	1		8
70- 79	1	1	4			6
60- 69						0
50- 59	1	1				2
f	2	15	49	32	2	100

$$r_{xy} = .40 \pm .06$$

Table 5.

CORRELATION BETWEEN GENERAL SCIENCE GRADES
AND BOTANY GRADES.

X-distance is Botany grades.

Y-distance is General Science grades.

	F	P	M	G	E	f
E		1		3		4
G		2	16	21	1	40
M	2	9	24	7	1	43
P		3	9	1		13
F						0
f	2	15	49	32	2	100

$$r_{12} = .36 \pm .06$$

$$r_{1,3} = .27$$

Table 6.

CORRELATION BETWEEN GENERAL SCIENCE GRADES AND INTELLIGENCE TEST SCORES OF CHEMISTRY PUPILS.

X-distance is General Science grades.

Y-distance is intelligence test scores.

	F	P	M	G	E	f
190-199				1	1	2
180-189				6	3	9
170-179				1	1	2
160-169				3	1	4
150-159			2	1		3
140-149		1		1		2
130-139						0
120-129						0
110-119						0
100-109						0
90- 99			1	1		2
80- 89				1		1
f	0	1	3	15	6	25

$$r_{13} = .43 \pm .11$$

Table 7.

CORRELATION BETWEEN CHEMISTRY GRADES AND
INTELLIGENCE TEST SCORES.

X-distance is Chemistry grades.

Y-distance is intelligence test scores

	F	P	M	G	E	f
190-199				1	1	2
180-189			1	6	2	9
170-179				1	1	2
160-169			2	2		4
150-159	1		1	1		3
140-149			1	1		2
130-139						0
120-129						0
110-119						0
100-109						0
90- 99		1	1			2
80- 89		1				1
f	1	2	6	12	4	25

$$r_{23} = .65 \pm .08$$

Table 8.

CORRELATION BETWEEN GENERAL SCIENCE GRADES
AND CHEMISTRY GRADES.

X-distance is Chemistry grades.

Y-distance is General Science grades.

	F	P	M	G	E	f
E				4	2	6
G		1	4	8	2	15
M	1	1	1			3
P			1			1
F						0
f	1	2	6	12	4	25

$$r_{12} = .59 \pm .09$$

$$r_{12.3} = .66$$

Table 9.

CORRELATION BETWEEN GENERAL SCIENCE GRADES AND INTELLIGENCE TEST SCORES OF PHYSICS PUPILS.

X-distance is General Science grades.

Y-distance is intelligence test scores.

	F	P	M	G	E	f
200-209				1		1
190-199				1		1
180-189					2	2
170-179			1	6	2	9
160-169			2	4	3	9
150-159			2	3	2	7
140-149			3	1	1	5
130-139			1	2		3
120-129			3	2		5
110-119		1	2			3
100-109			1	1		2
90- 99			1	2		3
f	0	1	16	23	10	50

$$r_{13} = .44 \pm .08$$

Table 10.

CORRELATION BETWEEN PHYSICS GRADES AND INTELLIGENCE TEST SCORES.

X-distance is Physics grades.

Y-distance is intelligence test scores.

	F	P	M	G	E	f
200-209	1					1
190-199			1			1
180-189				1	1	2
170-179			3	4	2	9
160-169	1	2	3	2	1	9
150-159		2	3	1	1	7
140-149	2		2	1		5
130-139			3			3
120-129	1	1	3			5
110-119		2	1			3
100-109				2		2
90- 99			3			3
f	5	7	22	11	5	50

$$r_{23} = .19 \pm .09$$

Table 11.

CORRELATION BETWEEN PHYSICS GRADES AND
GENERAL SCIENCE GRADES.

X-distance is Physics grades.

Y-distance is General Science grades.

	F	P	M	G	E	f
E			2	4	4	10
G	1	2	13	6	1	23
M	4	4	7	1		16
P		1				1
F						0
f	5	7	22	11	5	50

$$r_{12} = .63 \pm .06$$

$$r_{12.3} = .70$$

Table 12.

CORRELATION BETWEEN GENERAL SCIENCE GRADES AND INTELLIGENCE TEST SCORES OF HUMAN PHYSIOLOGY PUPILS.

X-distance is General Science grades.

Y-distance is intelligence test scores.

	F	P	M	G	E	f
180-189				2	1	3
170-179				2	2	4
160-169		1	1	2	1	5
150-159			1	3	1	5
140-149		1	4	6		11
130-139		4	5	4		13
120-129	1	2	11	2		16
110-119		4	9	3	2	18
100-109		2	4	1		7
90- 99	1	2	3	2		8
80- 89		2	4			6
70- 79		1				1
60- 69			2	1		3
f	2	19	44	28	7	100

$$r_{13} = .40 \pm .06$$

Table 13.

CORRELATION BETWEEN HUMAN PHYSIOLOGY GRADES AND
INTELLIGENCE TEST SCORES.

X-distance is Human Physiology grades.

Y-distance is intelligence test scores.

	F	P	M	G	E	f
180-189			2	1		3
170-179				3	1	4
160-169			2	2	1	5
150-159			3	1	1	5
140-149			8	1	2	11
130-139		4	3	6		13
120-129		4	7	4	1	16
110-119		5	8	4	1	18
100-109		1	5	1		7
90-99	1		4	3		8
80- 89		3	1	1	1	6
70-79			1			1
60- 69		1		2		3
f	1	18	44	29	8	100

$$r_{13} = .23 \pm .06$$

Table 14.

CORRELATION BETWEEN HUMAN PHYSIOLOGY GRADES
AND GENERAL SCIENCE GRADES.

X-distance is Human Physiology grades.

Y-distance is General Science grades.

	F	P	M	G	E	f
E				5	2	7
G		3	13	8	4	28
M	1	9	20	12	2	44
P		6	9	4		19
F			2			2
f	1	18	44	29	8	100

$$r_{12} = .39 \pm .06$$

$$r_{12.3} = .37$$

Table 15.

CORRELATION BETWEEN GENERAL SCIENCE GRADES AND INTELLIGENCE TEST SCORES OF ZOOLOGY PUPILS.

X-distance is General Science grades.

Y-distance is intelligence test scores.

	F	P	M	G	E	f
200-209					1	1
190-199						0
180-189				1	1	2
170-179			1	3	1	5
160-169			3	3		6
150-159			3	3	1	7
140-149		1	2	6	1	10
130-139			4	10		14
120-129			10	6		16
110-119		1	8	5		14
100-109		2	5			7
90- 99		1	3	1		5
80- 89		1	5	2		8
70- 79			3			3
60- 69			1	1		2
f	0	6	48	41	5	100

$$r_{13} = .46 \pm .05$$

Table 16.

CORRELATION BETWEEN ZOOLOGY GRADES AND INTELLIGENCE TEST SCORES.

X-distance is Zoology grades.

Y-distance is intelligence test scores.

	F	P	M	G	E	f
200-209					1	1
190-199						0
180-189			1		1	2
170-179			2	1	2	5
160-169			4	2		6
150-159			4	2	1	7
140-149		1	7	1	1	10
130-139		2	6	4	2	14
120-129	1	3	9	3		16
110-119		3	6	5		14
100-109	1	3	2	1		7
90- 99		3	2			5
80- 89	1	2	4	1		8
70- 79	1		1	1		3
60- 69	1	1				2
f	5	18	48	21	8	100

$$r_{23} = .46 \pm .05$$

Table 17.

CORRELATION BETWEEN ZOOLOGY GRADES AND
GENERAL SCIENCE GRADES.

X-distance is Zoology grades.

Y-distance is General Science grades.

	F	P	M	G	E	f
E				1	4	5
G	1	5	23	9	3	41
M	4	12	20	11	1	48
P		1	5			6
F						0
f	5	18	48	21	8	100

$$r_{12} = .35 \pm .06$$

$$r_{23} = .18$$

Table 18.

CORRELATION BETWEEN GENERAL SCIENCE GRADES AND INTELLIGENCE TEST SCORES OF ALL SPECIAL SCIENCE PUPILS.

X-distance is General Science grades.

Y-distance is intelligence test scores.

	F	P	M	G	E	f
200-209				1	1	2
190-199				3	1	4
180-189				9	7	16
170-179			3	13	7	23
160-169		1	6	13	5	25
150-159			11	16	4	31
140-149		4	14	16	3	37
130-139		5	14	22	1	42
120-129	1	2	31	16		50
110-119		11	24	14	3	52
100-109		4	16	8		28
90- 99	1	5	11	8		25
80-89		6	12	5		23
70- 79		2	7	1		10
60- 69			3	2		5
50- 59			2			2
f	2	40	154	147	32	375

$$r_{13} = .46 \pm .03$$

Table 19.

CORRELATION BETWEEN ALL SPECIAL SCIENCE GRADES AND
INTELLIGENCE TEST SCORES.

X-distance is special science grades.

Y-distance is intelligence test scores.

	F	P	M	G	E	f
200-209	1				1	2
190-199			2	1	1	4
180-189			4	8	4	16
170-179			6	11	6	23
160-169	1	3v	11	8	2	25
150-159	1	2	13	11	4	31
140-149	2	2	22	8	3	37
130-139		8	16	15	3	42
120-129	2	9	26	12	1	50
110-119		12	23	16	1	52
100-109	1	5	16	6		28
90- 99	1	6	15	3		25
80- 89	1	9	9	3	1	23
70- 79	2	1	6	1		10
60- 69	1	2		2		5
50- 59	1	1				2
f	14	60	169	105	27	375

$$r_{23} = .36 \pm .03$$

Table 20.

CORRELATION BETWEEN ALL SPECIAL SCIENCE GRADES AND
GENERAL SCIENCE GRADES.

X-distance is all special science grades.

Y-distance is General Science grades.

	F	P	M	G	E	f
E		1	2	17	12	32
G	2	13	69	52	11	147
M	12	35	72	31	4	154
P		11	24	5		40
F			2			2
f	14	60	169	105	27	375

$$r_{12} = .40 \pm .03$$

$$r_{12.3} = .29$$

Table 21.

SUMMARY OF CORRELATIONS.

	Botany Group		Chemistry Group		Physics Group	
	2Bot.	3Intel.	2Chem.	3Intel.	2Phys.	3Intel.
1Gen. Sci.	.36±.06	.31±.06	.59±.09	.43±.11	.63±.06	.44±.08
3Intel. Scores	.40±.06		.65±.08		.19±.09	
	$r_{12.3} = .27$		$r_{12.3} = .66$		$r_{12.3} = .70$	

	H. Physiol. Group		Zoology Group		Total Special Sciences	
	2Physiol.	3Intel.	2Zool.	3Intel.	2Spec. Sci.	3Intel.
1 Gen. Sci.	.39±.06	.40±.06	.35±.06	.46±.05	.40±.03	.46±.03
3 Intel. Scores	.23±.06		.46±.05		.36±.03	
	$r_{12.3} = .37$		$r_{12.3} = .18$		$r_{12.3} = .29$	

Interpretation of the table for the subject, Botany, is as follows: For all those pupils who preceded their botany by General Science the correlation between their General Science grades and their Botany grades is $.36 \pm .06$, the correlation between their General Science grades and their intelligence scores is $.31 \pm .06$ and the correlation between their Botany grades and their intelligence scores is $.40 \pm .06$. The correlation between their General Science grades and their Botany grades, when the factor of intelligence has been rendered constant by partial correlation, is .27.

(c) Study of Achievement in the Special Sciences.

Tables 22 and 23, pages 50 and 51, give the data gathered in a comparative study of the success achieved in the special sciences. There were two groups from each science equated on the basis of intelligence. In one group were included those pupils who preceded the study of the special science by a course in General Science. In the other group, called the control group, were those who did not precede the special science by a course in General Science. Table 22 is a distribution of the mental scores in each group of each of the sciences. It is evident from a study of these that the equated groups are practically equal. In Physics the control group seems a little higher in intelligence. This is borne out by table 23 where it will be seen that the general superiority of the control group is somewhat higher. Table 23 sums up the achievement made by each group in each of the special sciences. It will be noticed that the General Science group excels in every one of the special sciences. The greatest transfer seems to be in Chemistry where it is 27.5% and the lowest in Zoology where it is 6.1% with an average of 10.6% for all. It must be recalled here that there were only twenty-five pairs in Chemistry and that, therefore, the data are not

so reliable in this subject. To the writer the most significant fact is that the apparant carry-over is consistent in all sciences. It is not large for each science but we would not expect it to be since the percentage of identical elements in General Science and any one special science is not large.*

* See Reference 11, page 7.

Table 22.

Showing the distribution of Intelligence Scores for each special science. In the First Column (G.S) are the Scores of the Pupils who had General Science. In the Second (C) are the scores of the control group. - those who did not have General Science.

Intel- Scores	Botany		Chemistry		Physics		H. Physiol.		Zoology		Total	
	G.S.	C	G.S.	C	G.S.	C	G.S.	C	G.S.	C	GS.	C
200-209					1	0			1	1	2	2
190-199	1		2	6	1	2			0	0	4	8
180-189	0	11	9	3	2	2	3	3	2	2	16	11
170-179	3	3	2	4	9	12	4	2	5	3	23	24
160-169	1	2	4	4	9	8	5	7	6	8	25	29
150-159	9	8	3	2	7	3	5	3	7	7	31	22
140-149	9	8	2	3	5	8	11	15	10	9	37	43
130-139	12	13	0	0	3	4	13	12	14	14	42	43
120-129	13	10	0	0	5	3	16	14	16	14	50	41
110-119	17	21	0	0	3	3	18	13	14	18	52	55
100-109	12	10	0	0	2	2	7	13	7	6	28	31
90- 99	7	8	2	3	3	3	8	7	5	4	25	25
80- 89	8	9	1	0			6	7	8	8	23	24
70- 79	6	5					1	1	3	3	10	9
60- 69	0	1					3	3	2	3	5	7
50- 59	2	1									2	1
N	100	100	25	25	50	50	100	100	100	100	375	375
Q ₃	138.3	137.7	185.3	189.2	170.6	172.9	142.7	143.3	146.0	145.0	152.3	151.0
Med.	118.8	117.6	172.5	171.3	152.7	156.7	124.4	124.3	126.9	125.7	128.4	128.7
Q ₁	111.7	111.0	154.2	151.3	129.0	133.8	110.0	105.4	110.0	110.6	110.3	109.0

Table 23.

Comparison of achievement in the Special Sciences as made by the General Science Group (GS) and the Control Group. (C).

	<u>Botany</u>		<u>Chemistry</u>		<u>Physics</u>		<u>Physiol.</u>		<u>Zoology</u>		<u>Total</u>	
	GS	C	GS	C	GS	C	GS	C	GS	C	GS	C
I	4.34	4.26	5.28	4.56	4.16	4.44	4.50	4.00	4.18	4.12	4.38	4.20
II	4.03	4.27	4.91	5.33	3.93	4.58	4.02	4.09	3.97	4.15	4.06	4.30
III		.24		.42		.65		.07		.18		.24
IV	4.34	4.02	5.28	4.14	4.16	3.79	4.50	3.93	4.18	3.94	4.33	3.96
V	.32		1.14		.37		.57		.24		.42	
VI	8%		27.5%		9.8%		14.5%		6.1%		10.6%	

I is the average grade in Special Science.

II is average grade in all subjects during the semester special science was taken.

III is the superiority in scholarship of one group over the other.

IV is the average grade in special science after correction for superiority.

V is the actual superior achievement in special science attributable to General Science.

VI is the percent by which the General Science Group excels the Control Group.

In averaging grades F=0, P=2, M=4, G=6, E=8.

Chapter VI.

Conclusions.

The analysis in Chapter III called for the answers to four special questions. We are now ready to answer these on the basis of the data presented. Under the conditions out of which our data grew and in the field of our study we believe the correct answers to be

1. Students who have had a course in General Science have more scientific information than do similar students who have not had such a course. According to table 2 and graph 2 the evidence points unquestionably to this answer.

2. There is a positive correspondence between achievement in General Science and in the special sciences. While the correlation is not high it is consistent even when the factor, intelligence, has been removed. These positive correlations mean simply that success in General Science tends to be followed by a like success in the special sciences. It may be true but it does not necessarily mean, that the success in the subsequent science is caused by success in General Science. However, in our study, the first, third and fourth answers would imply this.

3. According to table 23 there is a measurable

success in the special sciences that is apparently due to a previous study of General Science. The mean grade made by the General Science group in Botany is 8% higher than the mean grade of the control group; in Chemistry it is 27.5% higher; in Physics 9.8% higher; in Human Physiology 14.5%; in Zoology 6.1%; and for all the special sciences thrown together 10.6%.

4. The transfer or carry-over from General Science to the special sciences is consistent in that it is positive for each science studied. It is not the same for each science. We would not expect it to be the same since the identical elements in each case would not be the same. The significant point for our study is the fact that there is a superior achievement in each one of the special sciences that is apparently attributable to a previous study of General Science.

In general then we may say that, in the field studied, General Science does seem to prepare students for a study of the special sciences. There is apparently a transfer of training from General Science to the special sciences studied.

Chapter VII.

Summary

In this study we have attempted to find out if General Science served as a preparation for a study of the special sciences taught in the high school. The special sciences studied were Botany, Chemistry, Physics, Human Physiology, and Zoology and the place of the study was in the high schools of Kansas City, Missouri.

Briefly our procedure has been as follows:

1. By means of a General Science information test, to find out if pupils who study General Science get any more scientific information during the school year than do similar pupils of equivalent intelligence.
2. To secure the correlation between performance in General Science and in each special science.
3. To secure the correlation between General Science and the intelligence score.
4. To secure the correlation between intelligence score and performance in each special science.
5. To secure the correlation between General Science and each special science when the factor of intelligence had been rendered constant by partial correlation.
6. To render the factor of intelligence constant by the equivalent groups method, and, having

done this, to discover any superiority that might exist in the General Science group.

7. To render the factor of intelligence constant, as in 6, and to determine whether or not a general superiority (as against a specific performance in the special sciences) persists in favor of either group.

8. In case a general superiority was found, to take it into consideration in the final comparison in achievement of the equivalent groups.

Our general conclusion is that there seems to be a carry-over from General Science to the special sciences and that, therefore, General Science does apparently serve as a preparation for a study of the special sciences.

RUCH-POPENOE GENERAL SCIENCE TEST

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MANUAL OF DIRECTIONS

INTRODUCTION

Description and purpose of the test. This test is designed primarily to measure the accomplishment of pupils in general and elementary science courses in either the 8th or the 9th grade. It is not based upon any single textbook in general science, nor is it intended to apply to any particular type of a course of study in this subject.

Part I is composed of fifty items of general information concerning familiar elementary scientific facts, principles, concepts, terms, definitions, and applications. These fifty items sample a wide range of relatively simple knowledge in the fields of physics, chemistry, astronomy, agriculture, botany, zoölogy, and physiology.

Part II measures the ability of the pupil to identify apparatus, organisms, structures, and principles, and to apply principles of science to the solution of simple problems. For this purpose twenty diagrams and drawings have been prepared, together with completion exercises based upon these illustrations. It is believed that the use of drawings enlists the interest and effort of the pupils to a greater extent than purely linguistic tests. It is also likely that the pictorial tests involve abilities not found in the information test of Part I, and that these abilities are prominently involved in the laboratory method of instruction.

The Ruch-Popenoe General Science Test is published in two forms, designated as Form A and Form B. These are identical in construction and are of equal difficulty. Either form can be used alone, or both forms can be given and the results averaged. The use of both forms increases the reliability of the scores very considerably. One form can easily be given in a class period of forty-five minutes. The time limits have purposely been made generous enough to make the tests almost entirely power tests, and the slow

pupil will not be penalized to any considerable extent. Increasing the time allowance has not been found to increase the scores significantly.

This test should prove of value to teachers of general science in several ways:

1. In the assignment of school marks, by furnishing a more objective and reliable basis than that afforded by the judgment of the teacher alone.
2. In the determination of promotions and failures.
3. In the classification of pupils into sections for the purpose of differentiating rates of progress or for enriching the curriculum of the abler students. In this connection it is advisable that some standard group test of intelligence like those of Otis and Terman¹ be given as well and both sets of test scores be utilized in dividing classes into sections.
4. In comparison of the results obtained by the teacher of one class with the accomplishment of similar classes in the same school or in other localities.

Construction and validation of the test. The selection of the items in the Ruch-Popenoe General Science Test has been based largely upon an analysis of the contents of existing textbooks in general science. Although there are more desirable criteria for the validation of test materials for most school subjects than the one here used, it is nevertheless true that, during the formative period of any new subject, teaching practice follows very closely the organization of the available textbooks. This very practical consideration is held to be sufficient justification for the construction of a test which embodies the best of the materials actually occurring in the books which must be used in general science classes.

¹ Otis Self-Administering Tests of Mental Ability and Terman Group Test of Mental Ability, published by World Book Company, Yonkers-on-Hudson, New York.

The present form of the test is a revision and extension of the Range of Information Test in General Science published in 1919 by one of the authors.¹ The original test consisted of three forms of fifty scientific terms each, which had been selected from a list of more than five hundred of such terms obtained by analysis of twenty-three texts and manuals in general science. Of these five hundred items, about 180 were common to half or more of the texts and for this reason were considered to be valid for test purposes. Some further eliminations necessitated by reasons stated in the articles cited below reduced the final number to 150. These were roughly equated and standardized as three forms of fifty items each.

In the present test, two of these forms have been standardized in more objective form. The ease of scoring has been greatly increased, and greater objectivity of scoring has been made possible.

The selection of the diagrams of Part II was carried out in a manner similar to the information item of Part I, except that the ratings of a number of experienced teachers were secured as an additional guarantee of the desirability and validity of these materials. Some further eliminations were made in order to prevent undue overlapping of the fields covered by Parts I and II.

The tests were carried through two try-outs. The preliminary try-out involved about 250 pupils in ten classes representing five different states. From the results of this try-out the relative difficulties of the separate items were determined and two forms of the test were made and roughly equated. The second try-out was held in order to gather additional data for norms and reliability coefficients. For this purpose four classes in four different states (California, Michigan, Oregon, and Pennsylvania) were used.

Table 1 shows the analysis of the content of the test in terms of percentages for the various fields of science.

TABLE 1

SUBJECT-MATTER ANALYSIS OF THE RUCH-POFENOE GENERAL SCIENCE TEST IN PERCENTAGES

Biological science (botany, physiology, and zoölogy)	30%
Chemistry	12%
Physics and mechanical applications	38%
Earth science (agriculture, astronomy, geology, and physiology)	20%

¹ Ruch, G. M., "A Range of Information Test in General Science," *General Science Quarterly*, 1919, 4, 257-262; and *ibid.*, 1920, 5, 15-19.

Reliability of the test. The reliability coefficients of the test have been computed for several classes by correlating the scores in Form A with those in Form B. Table 2 gives these coefficients.

TABLE 2

RELIABILITY COEFFICIENTS OF THE TEST, FORM A WITH FORM B

School	State	N	Entire test	Part I only	Part II only
1 Westinghouse	Penn.	48	.81	.69	..
2 University High	Oreg.	23	.87	.76	.74
3 Grand Rapids	Mich.	42	.80	.64	..
4 Palo Alto	Calif.	22	.85	.78	.69
Averages			.833	.718	.72

The probable error of a score found from average of these coefficients (.833) by the formula

$P.E.(\text{score}) = .6745 \sqrt{1 - r(\text{reliability})} \sigma(\text{dist. of scores})$
is 4 points in score. This means that the chances are even that the score of any individual will be correct within 4 points; that is, that it will not deviate more than 4 points from the hypothetical average of an infinite number of scores of that individual.

DIRECTIONS FOR ADMINISTERING

The directions for giving Form A and Form B are exactly the same. Each test consists of two parts, designated as Part I and Part II.

The examination booklets should be distributed to the pupils, with instructions not to turn over the pages until the command is given. Ask the pupils to fill in the blanks provided for name, grade, and other information. See that each pupil has a sharpened lead pencil before beginning the test. A number of extra pencils should be provided by the teacher in case a pupil should break a pencil point during the examination. The pupils should be instructed to raise their hands as a signal that a pencil point has been broken during the test.

After the blanks have been filled in properly, say to the class:

"Here is a test of a number of facts of science. You will probably not know all the answers, but do as many as you can. If you do not know the answer to a question, do not waste too much time but go on to the next.

"Now, turn over to Part I." After the page has been turned, say: "Look at the directions

at the top of the page while I read them: 'Draw a line under the one word or phrase that makes the truest answer to the question, as shown in the sample. Sample: An example of a liquid is iron glass air water lead zinc oxygen.' The only one of these seven things that is a liquid is water. Therefore the word 'water' has been underlined. That is the way you are to answer the questions. Do not write anything. Just draw a line under the right answer. Begin with No. 1 and answer as many as you can before time is called. You will be given 15 minutes to answer the 50 questions. Ready—Go."

After 15 minutes (time to exact second), say: "Stop! Turn over to Part II." After the pupils have turned to Part II, say: "Look at the directions at the top of the page while I read them: 'On this page and the following pages there are 20 diagrams and several statements about each diagram. Part of each statement is left blank. You are to fill each blank so as to make a true statement. Make the statements as complete and definite as possible. In most cases you will need to write but ONE WORD in each blank. You will be given 25 minutes to do this part of the test.' Ready—Go."

After 25 minutes (time to exact second), say: "Stop! Close your booklets." The examination booklets should then be collected at once.

DIRECTIONS FOR SCORING

Part I contains 50 items. Each item correctly answered counts one point.

Part II contains 80 blanks to be filled. Each blank properly filled constitutes one correct response. The score in Part II is the number of correct responses divided by 2. (Maximum scores: Part I, 50; Part II, 40; Total, 90.)

A Key containing the correct answers to each question is included in each package of examinations. To score the examination, place the Key over the examination so that the answers on the Key are adjacent to the responses given on the examination. Place a check mark opposite the number or letter of each question at the right-hand side of page, or a cross opposite each wrong or omitted answer, or both checks and crosses.

In scoring Part I, it will save considerable time if a celluloid stencil is used. Such a stencil is quickly made by superimposing a piece of sheet

celluloid over the page of the test booklet and then marking a dot with indelible ink over the correct response to each question. In using such a stencil the scorer need only look to see whether the lines and dots coincide. However, the scoring can be done very efficiently without such a stencil by the use of the Keys provided.

To some of the blanks in Part II there are a number of correct responses possible. Where this is true, several correct answers are suggested on the Key as samples of what should be accepted for credit. As a rule, no credit should be given for a response not given on the Key unless there is absolutely no doubt that the pupil's answer is equivalent in merit to those listed as acceptable on the Key. Do not give any partial credits. A response is either given full credit or marked entirely wrong.

Enter the scores of each part in the space provided on the last page of the part. These scores should then be copied into appropriate spaces on the first page of the examination booklet and added to find the total score in the examination.

RECORDING SCORES

There is included in each package of examinations a Class Record on which the scores of 50 pupils may be entered for convenience in filing. This is to be kept by the examiner or school principal. When filling in the data, a carbon copy should be made on the attached Report to Author (see page 4).

INTERPRETATION AND UTILIZATION OF RESULTS

Tentative norms. Table 3 gives tentative percentile norms based on the scores of 363 pupils in general science classes. Twelve schools and six different states are represented. The tests were given after the pupils had studied general science for eight or nine months, except in one school where the tests were given at the end of the first semester of the course.

TABLE 3

TENTATIVE PERCENTILE NORMS

10% of the pupils reach or exceed	53.4	
25% of the pupils reach or exceed	44.6	
50% of the pupils reach or exceed	34.7	(Median)
75% of the pupils reach or exceed	24.9	
90% of the pupils reach or exceed	18.8	

Report to Author. The establishment of reliable norms awaits the receipt of data from examiners. A sheet called the Report to Author is provided in each package of examinations for reporting scores to the authors. This is to be a carbon copy of the Class Record. Cooperation of examiners in aiding in the establishment of comprehensive norms by sending reports will be appreciated both by the authors and the users of the test. Address Dr. G. M. Ruch, care of World Book Company, Yonkers-on-Hudson, New York.

Use of results. For most purposes of the teacher of general science the scores can be used without reference to age or grade norms. In order to illustrate some of the possible interpretations and uses of the results, a few scores have been selected from an actual class.

PUPIL	SCORE
A	18
J	34
P	57

In the case of Pupil A, it will be seen by reference to Table 3 that a score of 18 places the pupil in the lowest 10 per cent of the distribution of 363 unselected pupils. Such a score should be taken as evidence of very poor accomplishment on the part of this pupil and the question of his promotion should be seriously considered. It would be advisable to give the second form of the test as well. It would probably be a safe rule to give both forms of the tests to all pupils earning a score of 25 or less (i.e., the lowest quarter of the distribution) on a single form. Pupil B with a score of 34 can be rated as approximately average, since the median score is 33. Pupil C, who earned a score of 57, can be rated as doing very superior work, surpassing the attainments of more than ninety pupils in a hundred.

Although it is not advised that the results of the tests alone be used for determining promotions or for the assignment of grades, nevertheless, the greater objectivity and reliability of the test scores should cause the test results to be weighed heavily in deciding these questions.

In schools where general science serves as a required introductory subject to the science curriculum, the tests may serve an important function in deciding which pupils should be encouraged to

elect the more advanced and specialized science courses.

The test can also be used, as was previously suggested, to differentiate pupils into "fast," "average," and "slow-moving" groups in order that the more capable pupils be given the opportunities of an enriched curriculum. Intelligence tests are almost a necessity in this connection in order that a pupil's accomplishment in science can be compared with his native capacity to acquire knowledge. Considerable evidence is now at hand which indicates that general intelligence is probably the most important single factor conditioning the rate of learning. For this reason a pupil in the 9th grade with a mental age of 13 years who earns a score of 30 in this test is probably more nearly achieving his maximum results than a pupil who earns a score of 40 with a mental age of 17 or 18 years. The same principle should be applied in comparing the results of different teachers, since equal attainments can be justly expected only where the range of talent is similar in the classes to be compared. Too much stress can hardly be laid on this frequently overlooked point in educational measurement.

THE PERCENTILE GRAPH

In order to compare the score of any pupil with the scores of the class as a whole, or to compare two or more classes, the most effective way is to draw a percentile curve for each grade or class on the Percentile Graph, a copy of which is included in each package of examinations.

Definition of a percentile curve. A percentile curve is a smooth line having a horizontal length representing 100 per cent of the scores of any group of individuals and so drawn that any point on the curve has a height representing the amount of a given score and a horizontal position on the graph representing the per cent of the scores of the group that is exceeded by the given score. The method of drawing a percentile curve is given in full below. One not familiar with percentile curves will appreciate their significance after studying the directions for drawing them.

A percentile curve shows at a glance not only the median score of a class but also the range and variability of the scores. It shows at a glance just what per cent of the scores of the class is

FIGURE 1

exceeded by the score of any given individual and just what per cent of the class attains or exceeds any given score. Two or more curves on the same graph show very vividly the amount of overlapping of the scores of different classes.

It is not at all necessary to use the Percentile Graph in connection with the Ruch-Popenoe General Science Test. The Percentile Graph, however, is a convenience and an aid to the full appreciation of the results of the test.

The accompanying Percentile Graph and Scale Charts were devised by Dr. Arthur S. Otis for use with any test. They may be used, therefore, with tests other than the Ruch-Popenoe General Science Test, if desired.

DIRECTIONS FOR DRAWING A PERCENTILE CURVE

General procedure. The steps taken in drawing the percentile curve are: (1) distributing the scores, (2) finding the subtotals—number of cases to and including those in each class interval, (3) reducing these subtotals to per cents of the number of cases in the group, (4) locating points in the graph representing these per cents, (5) drawing a smooth curve through these points.

Provision is made for distributing the scores of two groups of individuals on one Percentile Graph sheet, and from these distributions two percentile curves may be drawn. This does not mean, however, that only two curves may be drawn on one graph. The scores of additional groups may be distributed on other Percentile Graph sheets or any sheet of paper and as many curves drawn on one graph as may be conveniently distinguished.

The blank spaces at the top of the sheet should be filled as shown in the sample Percentile Graph (Figure 1, on page 5). The space after "Examination" is provided for writing the name of any other test with which the Percentile Graph may be used. When used with the Ruch-Popenoe General Science Test, it is not necessary to write the name in this space.

Distributing the scores. First enter in the column at the left, headed "Score," the intervals of score, 0-4, 5-9, 10-14, etc., as shown in the sample (Fig. 1). Next, in one of the columns headed "Tallying," distribute the scores of a grade by putting a short mark for the score of each individual opposite the interval of score within which the score falls. The sample percentile graph shows that in the 8th grade one

pupil made a score between 55 and 59, one made a score between 50 and 54, four made scores between 45 and 49, etc. The number of tallies which tells the number of scores falling within any given interval of score is called a "frequency." The frequency of scores of 8th-grade pupils in the interval 45 and 49 is 4.

Finding the subtotals. Begin at the bottom of the column of frequencies and place in the square to the right of each frequency the sum of the frequencies up to and including that frequency. In the subtotal column under 8th grade there are 2 scores in the first interval, a subtotal of 7 to and including the second interval, a subtotal of 15 to and including the third interval, etc., and 50 to and including the last interval. This last "subtotal" (50) should equal the number of pupils in the class, as entered at the top of the column.

Reducing subtotals to per cents. In the column headed "Per cents" write opposite each subtotal the per cent that subtotal is of the whole number of pupils in the class. In the sample, under Grade 8, 2 is 4 per cent of 50, 7 is 14 per cent of 50, 15 is 30 per cent of 50, etc., and 50 is 100 per cent of 50.

It is not necessary to reduce subtotals to per cents when use is made of the Scale Chart A printed on the back of the Percentile Graph. The method of using the Scale Charts is given below.

Locating the points in the graph. First, place a dot at the left edge of the graph on the horizontal line representing the lower limit of the lowest class interval containing a score. Next, place on the next line above, a dot having a distance to the right of the left margin of the graph equal to the lowest number in the "Per cents" column, according to the scale at the top or bottom of a graph. (In the sample the second dot in the percentile curve for the 8th grade is placed in 4 units from the edge of the graph.) Next, place on the next line above, a dot having a distance to the right of the margin representing the next per cent, etc. (The third dot represents 14 per cent, etc., and the last dot represents 100 per cent.)

Use of the scale chart. Scale Chart A on the back of each Percentile Graph is provided to simplify the process of plotting the points in the graph. It is used as follows: Let us take the case of the 8th grade, there being 50 pupils in the grade. Find Scale 50 on Scale Chart A, according to the numbers at the right. This line is

divided into exactly 50 equal parts by the slanting lines in the chart. Each space, therefore, represents $\frac{1}{50}$ or 2 per cent the width of the graph. The second dot in the 8th-grade percentile curve is to be placed just $\frac{2}{50}$ of the distance to the right of the margin. This is just 2 spaces on Scale 50. The third dot is to be placed just 7 spaces to the right of the margin, the fourth point just 15 spaces to the right of the margin, etc., according to Scale 50. By the use of Scale 72 the points have been plotted in the same way for the 9th grade. (Each 2 spaces on Scale 72 = $\frac{1}{50}$ of the width of the graph.)

By folding the chart on the proper scale and applying it to the percentile graph¹ the width of the graph may be divided into any number of equal parts from 40 to 100. By letting 2 or 4 graduations represent 1 unit or letting 1 graduation represent 2 units, the width of the graph may be divided into any number of equal parts from 10 to 200.

Drawing the curve. Draw a smooth curve through the dots plotted as described above. This is the percentile curve.

Graduating the vertical scale. Inasmuch as the Percentile Graph is arranged to be used with different tests having different ranges of scores, it is not possible to provide a scale on the 50-percentile line which will fit all cases. Scale Charts B to G are provided, therefore, on the back of each Percentile Graph for graduating the spaces between horizontal lines to scales corresponding to groupings of 1, 2, 3, 4, 5, and 10 units to the interval. By applying the appropriate one of these scales (or a copy of it) to the percentile graph, the score represented by the point at which a percentile curve cuts the 50-percentile line, or any other percentile line, can be read to the nearest unit. To graduate the vertical scale of the percentile graph for interpreting percentile curves representing scores in the Ruch-Popenoe General Science Test, as shown in the sample, use Scale Chart F.

Finding the median score of a class. The point where the percentile curve cuts the 50-per-

centile line represents the median score of the group.¹ In the sample percentile graph the median scores of the 8th and 9th grades are respectively 34 and 40.

Finding the variability of the scores of a class. The points at which the curve cuts the 25- and 75-percentile lines represent the lower and upper quartile scores of a distribution. The interval between these is the interquartile range—a very convenient measure of the scatter of the distributions. In the sample percentile graph the interquartile ranges for the 8th and 9th grades respectively are 11.3 points (from 28.2 to 39.5) and 14.3 (from 32.7 to 47). This shows the variability of the 9th grade to be greater than that of the 8th grade.

Overlapping of classes. It will be seen by a glance at the percentile curves that the 9th grade is appreciably better than the 8th, but that the distributions of scores of the two grades overlap considerably. A convenient way to express this overlapping is to say that 29 per cent of the 9th grade fall below the median of the 8th, or that 24 per cent of the 8th grade exceed the median of the 9th.

Percentile rank in class. If an individual makes a score exceeding 25 per cent of the scores of his class, he is said to have a percentile rank of 25 in his class; and the same for other percentages. The percentile rank of any individual among the members of his class may be found from the percentile curve representing the scores of his class as follows: Suppose an individual in the 8th grade has made a score of 37. Find the point 37 on the vertical scale in the Percentile Graph and move the pencil horizontally to the point at the same height on the percentile curve for the 8th grade. This point represents on the horizontal scale a percentile rank of 64. The percentile rank of the individual among the members of his class is, therefore, 64, which means that his score exceeds the scores of 64 per cent of his class. A score of 37 represents a percentile rank of only 39 among the members of Grade 9.

¹ The value so found may not be exactly the same as the median found in the usual way by counting to the middle paper in order of score, but if not, the median score found by means of the curve is considered to represent the distribution better and to be in that sense more accurate.

¹ If only one percentile graph is at hand, the proper distances may be transferred from the scale chart on the back by means of a strip of paper.

RUCH-POPENOE GENERAL SCIENCE TEST

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EXAMINATION: FORM A

Primarily for Grades 8 and 9

Do not open this paper, or turn it over, until you are told to do so. Fill these blanks, giving your name, age, birthday, etc. Write plainly.

Name
(First name, initial, and last name)

Age last birthday years. Birthday
(Month and day)

Grade Teacher

School City

Date of examination

PART	SCORE
I	
II	
TOTAL	

PART I

DIRECTIONS. Draw a line under the one word or phrase that makes the truest answer to the question, as shown in the sample.

SAMPLE. An example of a liquid is iron glass air water lead zinc oxygen

Begin here.

- 1 Pneumonia is a disease of the heart liver lungs brain stomach muscles kidneys 1
- 2 Volcanoes are most likely to be found in
deserts valleys coastal plains mountains deltas interiors islands..... 2
- 3 Distance above sea level is called
longitude rotation altitude latitude declination revolution inclination..... 3
- 4 The earth rotates on its axis once in
12 hours 24 hours 7 days 31 days 3 months 365½ days 4 years..... 4
- 5 An example of a rock which weathers rapidly is
granite marble slate schist augite obsidian limestone..... 5
- 6 Radium was discovered by
Edison Marconi Burbank Davy Curie Metchnikoff Einstein..... 6
- 7 An example of oxidation is the
rusting of iron electrolysis of water melting of ice dissolving of salt
action of acid on marble heating potassium chlorate boiling of water..... 7
- 8 "Shooting stars" are properly called
planets suns nebulae asteroids moons comets meteors..... 8
- 9 The capacity to do work is termed
energy inertia momentum efficiency mechanical advantage mass velocity.. 9
- 10 When a liquid contains all the dissolved substance possible, the condition is termed
osmosis permeability fusion neutralization reduction transpiration saturation 10
- 11 The handle of a skillet becomes hot as the result of
convection resistance conduction expansion friction radiation latent heat.. 11
- 12 The best "all-round" fertilizer is probably
lime bone meal dried blood Chile saltpeter manure ammonium nitrate
calcium phosphate..... 12
- 13 Poisonous products secreted by bacteria are called
enzymes anti-bodies toxins vaccines ferments hormones legumes..... 13
- 14 The law of gravitation was discovered by
Archimedes Galileo Priestley Copernicus Aristotle Newton Marconi..... 14
- 15 An organism which reproduces by means of spores is the
maple amœba bread mold sponge earthworm minnow cedar..... 15
- 16 Sunlight can be broken up into the spectrum by means of a
telescope mirror burning glass lens prism microscope color-mixer..... 16
- 17 The act of transfer of pollen from anther to stigma is called
pollination reproduction fertilization transpiration mitosis adaptation filtration 17
- 18 Images are formed by the passage of light through a
prism helix ampere lens diaphragm mirage spectrum..... 18
- 19 The propelling mechanism of a machine is termed the
chassis piston motor differential carburetor governor fly-wheel..... 19
- 20 The separation of liquids and solids by evaporation and condensation is called
solution distillation diffusion fusion transpiration reduction pasteurization 20
- 21 A mirage is a kind of
swamp rainbow body of water optical illusion vision desert warfare..... 21
- 22 Decaying vegetable matter in the soil is termed
fungus nitrates mineral phosphates lichens potash humus..... 22
- 23 The smallest of the planets is Mercury Venus Mars Jupiter Saturn Uranus Neptune 23

24	The length of a meter in inches is about	12 19 24 2 39 47 144.....	24
25	A general term for any living thing is a	plant cell larva animal organism mammal nucleus.....	25
26	A violent circular windstorm of small area is a	cyclone tornado monsoon trade wind norther blizzard equinox.....	26
27	A collection of similar cells is called an	organism tissue organ gland muscle sense-organ function.....	27
28	The watt is the unit of measurement of	resistance current velocity power potential inductance friction.....	28
29	The unborn young of an animal is termed the	larva embryo pupa adult chrysalis ovum sperm.....	29
30	An example of a chemical element is	water glass mercury carbon dioxide ammonia nitric acid sugar.....	30
31	All space is believed to be filled with	air oxygen nitrogen ether hydrogen heat moisture.....	31
32	Electrolysis of water liberates hydrogen and	chlorine nitrogen carbon dioxide ammonia acetylene oxygen bromine.....	32
33	Pollen is produced in the	ovary calyx corolla stamen receptacle stigma pistil....	33
34	Pasteurization of milk is produced by	boiling evaporation chemical agents moderate heating freezing cooling.....	34
35	The mercurial barometer reads at sea level about	10 inches 18 inches 30 centimeters 30 inches 100 inches 980 inches 1 meter	35
36	Heat can pass through a vacuum only by means of	fusion convection conduction capillarity radiation gravitation combustion..	36
37	The process of food manufacture in green plants is called	respiration transpiration digestion mitosis pollination photosynthesis pasteurization	37
38	The greatest vertical height to which water can be siphoned is about	30 inches 10 feet 30 feet 40 feet 100 yards 1 mile 5½ miles.....	38
39	The anther is a part of the	calyx corolla receptacle ovary pistil stamen petiole	39
40	A small calorie is the amount of heat necessary to raise the temperature of one gram of water	1°C. 2.4°C. 32°F. 100°C. 212°F. 212°C. 1000°F.	40
41	An example of a leguminous plant is the	willow clover toadstool pansy lilac moss maple	41
42	An example of an alkali is	aluminum lead oxide sodium hydroxide table salt mercury potassium chlorate glucose.....	42
43	The distinguishing feature of the mammals is the possession of	backbones hair two pairs of legs warm blood milk glands nervous systems teeth	43
44	The one of these substances having the highest specific heat is	water iron glass lead copper soil rubber.....	44
45	"Hypo" is used in photography as a	developer fixing bath intensifier reducing agent bleaching agent sepia-toner hardening bath.....	45
46	Glucose is found in large quantities in	eggs grapes olive oil beefsteak onions rice tapioca.....	46
47	The calyx is made up of the	petals stamens petioles leaves pistils sepals stipules	47
48	Fusion means the same as	evaporation melting boiling freezing dissolving distilling burning.....	48
49	A metal which can be drawn into fine threads is said to be	elastic ductile flexible malleable amorphous magnetic viscous.....	49
50	The attraction between molecules of a body is called	capillarity adhesion magnetism inertia buoyancy cohesion convection.....	50

PART II

DIRECTIONS. On this page and the following pages there are 20 diagrams and several statements about each diagram. Part of each statement is left blank. You are to fill each blank so as to make a true statement. Make the statements as complete and definite as possible. In most cases you will need to write but **ONE WORD** in each blank. You will be given 25 minutes to do this part of the test

Begin here.

FIGURE 1

- a* The water does not rise to fill the tumbler completely because of the of the air in the tumbler. *a*
- b* The fact that the water has risen a short distance into the tumbler as shown at C shows that air is slightly under *b* pressure.

FIGURE 2

In this diagram of a typical flower:

- a* The petals (the corolla) are marked by the letter *a*
- b* The stamens are marked by the letter *b*
- c* The sepals (the calyx) are marked by the letter *c*
- d* The pistil is marked by the letter *d*

FIGURE 3

- a* The North Star (Polaris) is marked by the letter *a*
- b* The Big Dipper is marked by the letter *b*

FIGURE 4

- a* In this lever the power or force is applied at *a*
- b* The fulcrum is placed at the point marked *b*
- c* The mechanical advantage of a lever of this class is always than 1. *c*

FIGURE 5

- a This diagram illustrates the facts of the of light. a
- b The amount of apparent bending of the stick depends upon the of the liquid. b

FIGURE 6

- a In the bar magnet suspended by the strings, the north pole is the one marked a
- b The law of magnets states that poles each other and that poles each other. b

FIGURE 7

- a This diagram illustrates the facts of a
- b The rise of liquids in small tubes is proportional to the of the tubes. b

FIGURE 8

In this diagram of the digestive tract :

- a The small intestine is lettered a
- b The œsophagus is lettered b
- c The liver is lettered c
- d The stomach is lettered d
- e The pancreas is lettered e

FIGURE 9

- a This is a drawing of a cross section of a a
- b The palisade layer is marked by the letter b
- c A vein is marked by the letter c
- d The mesophyll layer is marked by the letter d
- e A stoma is marked by the letter e

FIGURE 10

- a The mechanical advantage of this pulley system is..... a
- b The rule for the mechanical advantage of any pulley system is that the mechanical advantage is equal to the number of times the cord passes to and from the..... pulley. b
- c Disregarding friction, the force needed to lift the 100-pound weight shown is.....pounds. c

FIGURE 11

- a In the northern hemisphere the season is..... when the earth is in the position marked A, and it is..... when the earth is in the position marked B. a
- b In the northern hemisphere the season is..... when the sun's rays fall directly upon the Tropic of Cancer. b
- c The season is.....when the sun's rays fall directly upon the equator. c
- d The season is.....when the sun's rays fall directly upon the Tropic of Capricorn. d
- e The earth's axis is inclined at an angle of about..... degrees to the plane of its orbit. e

FIGURE 12

The thistle tube shown in the drawing has been filled with a colored solution of sugar. A piece of parchment membrane was then tied over the mouth of the thistle tube and the tube was then inverted in a jar of water.

- a This apparatus illustrates the facts of..... a
- b The final level of the liquid in the tube will be nearest the point marked..... b
- c A similar principle is involved in the exchange of..... and..... in the lungs of animals. c

FIGURE 13

- a In the barometric map shown at the left, the region shown is termed a..... a
- b The more or less circular curved lines are called..... b
- c A wind blowing from the south, as shown by the arrow, in the northern hemisphere will be turned to the....., due to the..... of the earth. c
- d It is most likely to rain in the.....half of this area. d

FIGURE 14

In this diagram of the main parts of a flame:

- a The burning zone is marked by the letter a
- b The region of unburned gas is marked b
- c The region made up of the products of combustion is marked c
- d The chief products of combustion (burning) besides heat are:
1.
2. d

FIGURE 15

- a This is a drawing of a a
- b The piston is lettered b
- c The valve which opens on the upstroke is lettered c
- d The greatest distance that valve C can be placed above the level of the water at D, if the instrument is to work successfully, is about feet. d

FIGURE 16

In this diagram the earth is the planet marked C.

- a Mars is the planet marked a
- b Jupiter is the planet marked b
- c Mercury is the planet marked c
- d Saturn is the planet marked d
- e Uranus is the planet marked e

FIGURE 17

In this drawing of an artificial ice plant:

- a The freezing vats are located at a
- b The condensing pump is located at b
- c The principle involved in the manufacture of artificial ice by is that the liquid turns into a when the pressure is removed and, in so doing, it takes up from the brine, which in turn the temperature of the in the freezing vats. c

FIGURE 18

- a In the apparatus shown, some hydrochloric acid has just been poured into the thistle tube so as to act on the bits of marble (limestone) in the flask. The gas which is being collected at A is a
- b If this gas is passed into , a will be formed. b

FIGURE 19

In this loaf of bread the food materials which are contained in bread are shown in rough proportions by the parts A, B, C, and D.

- a The fat content is the section marked by the letter a
- b The carbohydrate content is the section marked b
- c The water content is the section marked c

FIGURE 20

This diagram represents a hydraulic press.

- a If the small piston B has an area of 100 square inches, and the large piston A has an area of 1000 square inches, a force of pounds must be applied at B to lift the 65-pound weight. a
- b Complete this statement: "A force applied at one point in a liquid is transmitted..... in all....." b

Number of blanks correctly filled _____ ÷ 2 = Score in Part II

RUCH-POPENOE GENERAL SCIENCE TEST

By GILES M. RUCH, PH.D.

Assistant Professor of Psychology, University of Iowa

and HERBERT F. POPENOE, A.B.

Stanford University

EXAMINATION: FORM B

Primarily for Grades 8 and 9

Do not open this paper, or turn it over, until you are told to do so. Fill these blanks, giving your name, age, birthday, etc. Write plainly.

Name
(First name, initial, and last name)

Age last birthday years. Birthday
(month and day)

Grade Teacher

School City

Date of examination

Part	Score
I	
II	
Total	

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PART I

DIRECTIONS. Draw a line under the one word or phrase that makes the truest answer to the question, as shown in the sample.

SAMPLE. An example of a liquid is iron glass air water lead zinc oxygen

Begin here.

- 1 Wind-deposited piles of sand are called
moraines loess deltas drumlins dunes meanders monadnocks..... 1
- 2 The path of a heavenly body is called its
circumference orbit inclination radius equator latitude declination..... 2
- 3 Soft coal is also known as anthracite asphalt lignite bituminous basalt creosote peat 3
- 4 Galileo invented the
printing press cotton gin microscope telescope dynamo camera steamboat 4
- 5 Boiling point of water on the Centigrade thermometer is 0° 32° 100° 120° 180° 212° 273° 5
- 6 A vacuum is characterized by the absence of
moisture heat atmosphere objects gravity light motion..... 6
- 7 The process by which plants and animals change their food materials into soluble form is
known as absorption putrefaction digestion photosynthesis osmosis
peristalsis respiration..... 7
- 8 The passage of the moon between the sun and the earth is called an eclipse of the sun
full moon third quarter eclipse of the moon eclipse of the earth winter solstice
equinox 8
- 9 An organism which derives its food from a living host is a
saprophyte larva spore toxin parasite legume chrysalis..... 9
- 10 Distance east and west around the earth is called
longitude altitude declination rotation revolution inclination latitude.... 10
- 11 Formaldehyde is often used as a
dye vaccine developing agent disinfectant cleaning agent fertilizer stimulant 11
- 12 The vertebræ are parts of the heart brain muscles nerves backbone teeth toes 12
- 13 Hot-air furnaces heat rooms chiefly by
radiation convection evaporation gravitation fusion induction conduction.. 13
- 14 A kind of serum is often used in the treatment of
diphtheria smallpox rheumatism heart trouble malaria goiter Bright's disease 14
- 15 The largest of the planets is Venus Saturn Mars Jupiter Uranus Neptune Earth 15
- 16 A metal much used for electric-light filaments is
copper manganese iron iridium bronze tungsten aluminum..... 16
- 17 An example of a lever of the first class is found in the nutcracker scissors wheelbarrow
spring balances inclined plane screw biceps muscle..... 17
- 18 An illustration of the action of capillarity is found in the
ink blotter thermometer barometer force pump action of the lungs excretion of urea
absorption of the products of digestion..... 18
- 19 Combustion is another name for
freezing drying boiling expanding shrinking burning melting..... 19
- 20 Rocks formed by the action of heat are called
bituminous metamorphic sedimentary igneous stratified anthracite conglomerate 20
- 21 The term "induction" is used most in connection with
levers pumps pulleys falling bodies solutions pendulums electric currents 21
- 22 Voltaic cells are studied in
geology botany bacteriology photography zoölogy electricity psychology... 22
- 23 The resistance a body offers to being set in motion is called
momentum friction cohesion erosion voltage inertia fusion..... 23

24	The aneroid barometer depends upon the action of alcohol mercury metal membrane electric current buoyancy friction light	24
25	Escaping illuminating gas mixes with the air of the room by capillarity diffusion cohesion valence radiation gravitation chemical affinity	25
26	The smallest of these things is the molecule bacterium yeast plant paramecium dust particle red blood corpuscle atom	26
27	The unit of weight in the metric system is the liter ounce meter pound ton gram cubic centimeter.....	27
28	The ovum or egg cell is produced in the stamen kidney embryo seed ovary gamete receptacle.....	28
29	The ampere is a measure of air pressure humidity resistance gravitation current potential temperature	29
30	White dome-shaped clouds in the late afternoons of hot days are usually cirrus stratus altus cirro-stratus tornadoes cumulus fog.....	30
31	The processes which tend to level down the earth's surface are collectively termed vulcanism sedimentation erosion metamorphism stratification adhesion reduction	31
32	Refraction is studied in connection with sound gravity heat falling bodies buoyancy light electricity.....	32
33	Isobars are used in diagraming magnetism rainfall temperature air pressure humidity winds gravitation..	33
34	An example of a fungus plant is the mistletoe orchid clover pond scum bread mold Indian pipe mother of vinegar	34
35	Gases enter and leave the leaves of plants through organs called stipules tracheids root hairs stomata micropyles cotyledons chloroplasts..	35
36	Another term for an anti-cyclone is a high-pressure area typhoon trade wind horse latitudes.....	36
37	Potential energy is energy possessed by an object by virtue of its weight combustibility motion position density temperature structure.....	37
38	A food rich in carbohydrates is beefsteak olive oil butter cucumbers watermelon salt honey.....	38
39	The main purpose of respiration is energy release elimination of carbon dioxide purification of the blood manufacture of food elimination of wastes secretion of water purification of the air	39
40	The density of a solid is usually compared with that of air hydrogen water lead oxygen wood nitrogen.....	40
41	The corolla is made up of the petals pistils sepals stamens ovaries receptacles petioles.....	41
42	Lodestones are characterized by their phosphorescence magnetism transparency brilliant coloration.....	42
43	A solid which liberates a gas when mixed with water is said to be effervescent fulminating deliquescent transparent translucent amorphous anhydrous	43
44	The attraction between molecules of two different bodies is called capillarity adhesion magnetism inertia buoyancy cohesion surface tension	44
45	Archimedes' principle has to do with light pumps pulleys inertia motion buoyancy sound	45
46	Precipitates are always poisonous soluble solids liquids gases colorless white	46
47	Substances without crystalline structure are termed inert plastic dense viscous elastic opaque amorphous.....	47
48	A ferment is another name for a bacterium enzyme toxin ptomaine vaccine serum anti-body	48
49	The simplest independent living structure is the nucleus protoplasm cell cell wall embryo molecule atom.....	49
50	The nucleus is believed to play a prominent part in excretion digestion respiration heredity locomotion storage of food nerve conduction	50

Score in Part I _____

PART II

DIRECTIONS. On this page and the following pages there are 20 diagrams and several statements about each diagram. Part of each statement is left blank. You are to fill each blank so as to make a true statement. Make the statements as complete and definite as possible. In most cases you will need to write but **ONE WORD** in each blank. You will be given 25 minutes to do this part of the test.

Begin here.

FIGURE 1

- a This figure illustrates the facts of the a
 b The greatest distance that portion A of the tube can be placed vertically above the level of the water at B, if the apparatus is to work successfully, is about feet at sea level. b

FIGURE 2

The tube shown has been filled with mercury and then inverted in a dish filled partially with mercury.

- a Such an apparatus is called a a
 b The height of the column of mercury from B to C at sea level is about inches. b
 c The pressure of the air in the part of the tube from A to B equals about pounds per square inch. c
 d The pressure of the air on the surface of the mercury in the dish is about pounds per square inch. d

FIGURE 3

- a This apparatus illustrates the of gases when heated. a
 b When the flame is taken away, the water in the vessel will in the tube due to the of the air as its is lowered. b

FIGURE 4

- a In this lever the power or force is applied at a
 b The fulcrum is placed at the point marked b
 c The mechanical advantage of this lever as drawn is than 1. c

FIGURE 5

This diagram illustrates the phases of the moon.

- a When the moon is at position A, it is called..... a
- b When the moon is at position B, it is called..... b
- c When the moon is at position C, it is called..... c
- d When the moon is at position D, it is called..... d
- e The time required for a complete revolution of the moon about the earth is approximately.....days. e

FIGURE 6

In this drawing of a grasshopper:

- a The head is marked by the letter a
- b The thorax is marked by the letter..... b
- c The abdomen is marked by the letter..... c
- d The spiracles are marked by the letter..... d
- e The ovipositor is marked by the letter..... e

FIGURE 7

- a In the barometric map shown at the left, the region shown is termed a a
- b The more or less circular curved lines are called..... b
- c A wind starting to blow southward from the center of this area, in the northern hemisphere, will be turned to the..... due to the..... of the earth. c
- d The weather in this area is likely to be..... d

FIGURE 8

In this figure:

- a An amœba is marked by the letter a
- b Bacteria are marked by the letter b
- c Bread mold is marked by the letter c
- d Yeast plants are marked by the letter d
- e A paramecium is marked by the letter..... e
- f Spirogyra is marked by the letter f

FIGURE 9

In this drawing of a steam engine:

a	The fly wheel is marked by the letter	.....	a
b	The piston is marked by the letter	.....	b
c	The steam chest is marked by the letter	.....	c
d	The cylinder is marked by the letter	.....	d
e	The sliding valve is marked by the letter	.....	e

FIGURE 10

In this diagram of the action of a prism on a ray of light, the violet rays of the spectrum are shown at A

a	The orange rays of the spectrum are shown at	.....	a
b	The blue rays of the spectrum are shown at	.....	b
c	The green rays of the spectrum are shown at	.....	c
d	The red rays of the spectrum are shown at	.....	d

FIGURE 11

a	This is a diagram of a	.....	a
b	The valve which opens on the down stroke is lettered	.....	b
c	The device shown at A is termed the	.....	c
Due to the..... of the air in A, the flow of water continues during the..... stroke of the piston.			c

FIGURE 12

a	The mechanical advantage of this pulley system is	.....	a
b	The rule for the mechanical advantage of any pulley system is that the mechanical advantage is equal to the number of times the cord passes to and from the..... pulley.	.....	b
c	Disregarding friction, the force needed to lift the 100-pound weight shown is..... pounds.	.....	c

FIGURE 13

- a In the apparatus shown, some hydrochloric acid has just been poured into the thistle tube so as to act on the bits of zinc in the flask. The gas which is burning at A is..... a
- b This gas is..... than air. b
- c The compound which is being formed in the flask is..... c

FIGURE 14

- a The gas meter shown here registers a total of..... a
cubic feet.

FIGURE 15

- a In the flask shown at A there is a solution of molasses to which some yeast has been added. The gas which is being collected at B is..... a
- b If this gas is passed into....., a..... b
..... will be formed.
- c There will be formed in the liquid in the flask at A a quantity of..... c

FIGURE 16

In this map of the chief wind zones of the earth:

- a The trade winds of the northern hemisphere are lettered..... a
and those of the southern hemisphere are lettered.....
- b The westerly winds of the northern hemisphere are lettered..... b
and those of the southern hemisphere are lettered.....

FIGURE 17

- a* This diagram illustrates the giving off of..... *a*
by the leaves of plants.
- b* This process is called..... *b*
- c* The rate of this process in the living plant is partly controlled by the action of the.....found in the..... *c*
of leaves.

FIGURE 18

- a* A green water plant has just been placed in the apparatus shown and placed in the sunlight. The gas which is being collected at A is..... *a*
- b* A glowing splint placed in this gas will..... *b*
- c* This illustrates a phase of the physiological process known as..... *c*

FIGURE 19

In this potato, the food materials which are contained are shown in rough proportions by the parts A, B, C, D, and E.

- a* The fat content is the section marked by the letter..... *a*
- b* The carbohydrate content is the section marked..... *b*
- c* The water content is the section marked..... *c*
- d* The protein content is the section marked..... *d*

FIGURE 20

- a* This apparatus illustrates the.....of water by..... *a*
- b* The gas which is being collected at A is..... *b*
- c* The gas which is being collected at B is..... *c*
- d* The correctness of your answer to item *c* can be proved by showing that the gas collected at B..... *d*

Number of blanks correctly filled _____ $\div 2 =$ Score in Part II _____