

A STUDY OF  
THE FACTORS UNDERLYING THE INTERCORRELATIONS OF  
"VERBAL", "MATHEMATICAL", AND "FORM PERCEPTION" TESTS

by  
*with*  
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## CHAPTER I

### INTRODUCTION

#### THE PROBLEM

Is the mental ability of any human individual a unitary power measurable in terms of a single score, or is it a composite consisting of various kinds of ability (generally referred to as mental abilities) which may be differentiated one from another? It is with this question that the present experimental study is concerned. The specific purpose of this research is to determine whether or not the scores on "Form Perception" tests give evidence of a mental ability (or abilities) different from the ability or abilities required for success in other types of tests and in school examinations.

#### PREVIOUS STUDY

The problem of the nature of mental ability has engaged the thought of psychologists and philosophers for many centuries. Not, however, until the present century has there been any quantitative experimental study of the matter. In 1904, Spearman reported research which may be said to mark the transition from pure philosophical theorizing about the nature of mental ability to a scientific approach to the problem. As early as 1890, there had begun a scientific interest in the measurement of individual differences in mental ability, and with the creation of the Binet-Simon scale in 1905, tests for

measuring so-called "General Intelligence" were introduced into the practical field of Education, but interest in the experimental investigation of the nature or organization of mental ability developed more slowly.

In view of the complex, intangible nature of the problem it is not surprising that most psychologists hesitated to make it a subject of experimental study. Regarding the difficulty of the task, Kelley has said, "The study of the nature and scope of mental traits is as broad as the entire field of Psychology and just about as evasive as the all-pervasive ether"<sup>1</sup>; the Gestalt psychologists consider that all analytical or quantitative studies of the matter are useless; however, in spite of the difficulty of the undertaking and the discouraging influences of critics, Spearman has unwaveringly pursued the quantitative investigation begun in 1904, and in 1927, he published "The Abilities of Man", which gives an account of his work and theory. This is the most outstanding contribution in this field. The following year, another outstanding experimental contribution to the study of the nature of mental ability was reported by Kelley in "Crossroads in the Mind of Man." These two studies, perhaps more than any others, have given a great impetus to the quantitative study of this difficult problem. These and other investigations and current theories are discussed in Appendices, A and B, pages 82-122.

Sufficient experimental study has now been completed

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1. T.L. Kelley, Crossroads in the Mind of Man. page 1

to justify the quantitative method of studying mental ability. Indeed, it appears that the most promising approach to the problem is through "factor analysis". (By "factor analysis" is meant the analysis of the intercorrelations of test scores made for the purpose of determining what factors underlie the correlations obtained). Various new methods of "factor analysis"<sup>1</sup> have very recently been advanced; these have given additional impetus to the study of "group factors" in mental ability. Unfortunately, some of these new methods appear to be less reliable than they appeared at first,<sup>2</sup> but it is anticipated that further refinement of technique will be made which will effect greater harmony of experimental results than exists at present. There is an evident trend towards harmony of findings and theory, but differences still appear to exist. Perhaps the most extreme instance of these differences is found on comparing Kelley's conclusions with those of Spearman. Spearman concluded that there exists a general factor common to all activities of an intellectual type while Kelley concluded that it is quite within the realm of possibility that no general factor at all exists. It is therefore obvious that further research is needed before these differences can be reconciled.

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1. The most outstanding new methods are;- The Thurstone technique published in 1931 and simplified in 1933; The Hotelling technique in 1933; and Thomson's modified form of the Hotelling technique, 1934. (See Bibliography No. 47, 49, 20 and 43.)

2. For an analysis of Thurstone's technique, see footnote pages 61-63.

Research studies with "Performance Tests"<sup>1</sup> have given fairly consistent evidence that "Performance Tests" measure some ability or abilities (usually designated Mechanical Ability) different from what is tested by the General Intelligence Tests. Moreover, very little controversy arises over the acceptance of such special abilities as musical ability, and sensory and motor abilities, but there is much less consistent evidence of, or belief in the existence of certain mental abilities, such as a "Verbal" or "Mathematical" ability.

#### PRESENT STUDY

The present study deals with the intercorrelations of scores on "Verbal", "Mathematical", and "Form Perception" tests. The tests were given to first and second year High School pupils and the data obtained have been analyzed for the purpose of determining what factors need be postulated in order to account for the intercorrelations found. The statistical analysis of the data has resulted in further evidence of the existence of "group" factors in scores on mental tests. These factors appear to have definite psychological significance; they are interpreted as indicating the existence of mental abilities other than the general ability "g" and independent specific abilities. Whether or not these special abilities are innate or acquired is not dealt with in this study but

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1. Such studies are reported in the following books: "Mechanical Aptitude" by Cox; "Aptitude Testing" by Hull; "Mechanical Ability" by Anderson and other Minnesota Psychologists; Studies by the National Institute of Industrial Psychology; and many others.

that they exist, in the case of most of the pupils studied, (age range 11 to 15 years) is clearly indicated.

Lest there be confusion regarding the concepts 'factor', 'ability' and 'capacity', it should be noted that the former is a statistical concept, while the latter two are psychological concepts. Studies in "factor analysis" may tell us whether or not it is necessary to postulate more than one "group" factor in order to account for correlations but great caution must be used in attempting to interpret what mental abilities these statistical factors represent. Furthermore mere statistical analysis does not tell us whether the factors are due to innate capacities or to abilities which have been partly acquired, or whether they are mere artifacts. Therefore, while the statistical study of factors is a very valuable aid to an understanding of the nature of mental abilities or traits, the warnings given by Flexner, in his brilliant book, "Universities", are timely. In speaking of research he says, "Endless counting will produce no theory, no principles, no ideas." "The two processes, the making of hypotheses and the gathering of data must go on together--reacting upon each other."<sup>1</sup>

These warnings of Flexner are particularly applicable to research such as is being discussed in this thesis. The interpretation of statistical factors should be viewed, not as a final solution to the problem, but merely as tentative evidence supporting the hypothesis that there are various

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1. Flexner, A. "Universities". Oxford Press, 1930, pp. 125 and 12.

mental abilities, as well as a general ability common to all.

PRACTICAL SIGNIFICANCE OF THESE STUDIES AND NEED FOR FURTHER RESEARCH

Attempts to differentiate mental abilities are highly important from the practical standpoint of Educational and Vocational guidance. If psychology is to render satisfactory service in diagnosing human individuals it is necessary to know whether mental ability is of such a unitary character that it may be measured in terms of a single total score, on a so-called general intelligence test, or whether it is composed of abilities of various kinds, each requiring measurement.

In spite of the fact that there has been (and is) no generally accepted theory of the nature of mental ability, and no satisfactory definition of what intelligence is, nor any entirely dependable criterion for determining the validity of the tests constructed, the construction and use of so-called Intelligence Tests proceeded rapidly after their introduction by Binet and Simon in 1905. In constructing these "Intelligence" tests, it has been the custom of most Psychologists to assemble a heterogeneous group of tests (with, it is usually admitted, little knowledge of what many of the tests were testing) and after certain experimental and statistical procedure, to produce what is known as a Standardized Intelligence Test. It is a well-known fact that the intercorrelations between some of the components of these tests are frequently very low (that is to say that individuals who do well on one type of item or sub-test do not

necessarily do well on another type) while the correlations between some of the components are high: yet the practice of adding together the scores on all the items of the test, and considering only the total score obtained by any individual as a measure of his intelligence, has been remarkably widespread, especially in the United States. Whenever this procedure has been criticized adversely, (Spearman describes it as the acme of meaninglessness) the reply has usually been to the effect that the tests "work" in practice and that that is sufficient proof of their validity, and ample justification for their use. There is however, much evidence in the practical field to show that sometimes the tests do not "work". Many a child who has been branded with a relatively low I.Q. on the basis of these Standardized Intelligence Tests has proved to be more successful in life than many who have been rated more highly on the same test, and vice versa.

It is therefore highly important that we learn more about the nature of mental ability before putting confidence in tests purported to test "that ability." It is with the recognition of this need in view that the following study has been made.

CHAPTER II  
PRELIMINARY STUDY

As a preliminary study a visual "Form Perception" test, consisting of geometric figures drawn on paper, was devised and given to 70 pupils (33 girls and 37 boys) who were in the second year of a Scottish High School.

This "Form Perception" test consisted of eleven sub-tests which may be classified under the following four headings:

- (a) Judgment of length
- (b) Analysis and synthesis of form
- (c) Reversal of figures
- (d) Separation of overlapping figures

An analysis of the data obtained showed that some items were too easy and others too difficult for subjects of this age (12 to 15 years). Accordingly, unsuitable parts were eliminated when revising the test and more items similar to the ones found suitable were added in order to make a battery of "Form Perception" tests, each with items of sufficient number and range of difficulty to provide for a fairly normal distribution of scores and relatively high reliability.

Since the revised tests are not fundamentally different from the original ones, but only modifications and extensions of the same types, a description of the original test will be

omitted. A sample of the revised tests is to be found in Appendix D.

Although this preliminary study was made primarily for the purpose of determining the relative difficulty of items used in the test and no special caution was taken in selecting the subjects, the following observations are of some interest:

(1) Boys showed a marked superiority over girls in regard to these tests. The highest score obtained by the boys was 75 (possible score 83) while for the girls the highest score obtained was 61. The average score for the boys was 35.3 while for the girls it was 15.5. In every one of the eleven sub-tests the average score for the boys was higher than that for the girls.

These figures should not be accepted as truly representative of the extent of difference in this ability due to sex difference. The more extensive and more reliable study which follows indicates that these figures greatly exaggerate a difference which apparently does exist. This excessive difference may be due to either or both of the following factors: firstly, the boys' group was probably of slightly higher average intelligence than that of the girls, and, secondly, all of the boys had studied Algebra and Geometry, while none of the girls had studied either.

(2) The scores obtained on the "Form Perception" test

were then correlated with the marks in school subjects assigned by the teachers for the previous term. These correlations are recorded in Table I.

Table I

CORRELATIONS OF THE "FORM PERCEPTION" TESTS  
WITH SCHOOL SUBJECTS

	<u>Eng</u>	<u>Hist</u>	<u>Geog</u>	<u>Arith</u>	<u>Sc</u>	<u>Alg</u>	<u>Geom</u>	<u>Art</u>	<u>Needlework</u>	<u>Cookery</u>
Boys	.09	.25	.30	.19	.22	.31	.42	.16	--	--
Girls	.21	.01	.22	.02	.12	--	--	.38	.29	-.24

Most of the above correlations are too low to be considered significant; only one (.42) exceeds 4 times its probable error. However the following observation seems worthy of note:

The two highest correlations of the test are with Algebra and Geometry, in the case of the boys, and with Art and Needle Work, in the case of the girls, and not with English or History in either case; therefore, it seems that what little consistency there is in these correlations is mostly in accordance with the assumption that "Form Perception" tests test some ability other than that which makes for success in tests of a "Verbal" character.

Having devised a battery of "Form Perception" tests which, after revision, gave promise of a high degree of reliability, the next step was to give these tests, along with other mental tests of the more generally used types, to a large group of subjects. Accordingly, for the main study now to be

described a large battery of tests was constructed. This battery consists of tests which, according to the nature of their content, have been classified as "Verbal", "Mathematical", and "Form Perception". These tests were administered to nearly 400 High School pupils of the first and second years. The scores thus obtained provide the data for the main study which is reported in the following pages.

2. The Subjects

The subjects selected for this research were a representative sample of American school children ranging in age from 13 years, 3 months, to 14 years, 6 months. They are pupils who had completed the primary school courses and were in the first or second year of the experimental high school at Pittsfield, Massachusetts. Above 1000 students had completed the previous year of a large, non-selective experimental school which was difficult to find. It was possible to obtain

## CHAPTER III

### THE MAIN EXPERIMENTAL STUDY

#### A. Purpose of the Study

The purpose of this experimental study is to examine the scores obtained on "Verbal", "Mathematical", and "Form Perception" tests in order to determine what factors need be postulated to account for the intercorrelations of these tests.

The chief objective is to see whether or not "Form Perception" tests give evidence of an ability or abilities other than the ability or abilities measured by mental tests which are chiefly verbal or mathematical in content, or by teachers' examinations in school subjects.

#### B. The Subjects

The subjects selected for this research constitute a representative sample of Scottish school children ranging in age from 11 years, 2 months, to 15 years, 8 months. They are pupils who had completed the Primary School course and were, at the time of testing (1931), in the first and second years of the experimental High School at Kirkcaldy, Scotland. A more ideal situation for conducting the research than this large Scottish experimental school would be difficult to find. It was particularly suitable

both because of the unique nature of the school itself and because of the excellent co-operation and able assistance of its principal, Dr. F.M. Earle.<sup>1</sup>

A description of this interesting school may be found in the International Education Review.<sup>2</sup> All that is necessary to relate here is that, following the report (1927) of the Advisory Committee of the Board of Education on the Education of the Adolescent, the county of Fife transformed its High School at Kirkcaldy from a typical "selective" (academic) Secondary School into a "non-selective" Post-Primary School which provides not only academic courses but technical, commercial, and domestic courses as well, all under the one roof and within one single school organization. The pupils of this school thus provide a good representative sample of the total Post-Primary School population.

The intelligence quotients of these pupils, as measured by the Group Intelligence Tests of the National Institute of Industrial Psychology, fall, with a few exceptions, within the range 85 to 140.

The classification of pupils according to courses taken is given in Table II. The nature of the courses taken by each class is indicated briefly in the footnote on the next page.

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<sup>1</sup>The writer wishes to acknowledge her gratitude to Dr. Earle for his very generous assistance.

<sup>2</sup>Earle, F.M., A Scottish Non-Selective Post-Primary School, International Education Review, 1932-33 (first half).

Table II

THE CLASSES OF THE KIRKCALDY HIGH SCHOOL  
WHICH WERE USED FOR THIS STUDY

Girls I (first year)				Boys I (first year)			
Class	n	Average Age	Average I.Q.	Class	n	Average Age	Average I.Q.
A	32	12 yrs., 3 mos.	118	A	36	12 yrs., 4 mos.	120
C	31	12 " 0 "	103	E <sub>1</sub>	41	12 " 0 "	108
D	34	12 " 1 "	103	E <sub>2</sub>	36	12 " 8 "	100+ (est.)
Class B is a mixed class of Boys and Girls having n = 36; average age 12 yrs., 4 mos.; and average I.Q. 112.							
Girls II (second year)				Boys II (second year)			
Class	n	Average Age	Average I.Q.	Class	n	Average Age	Average I.Q.
A	23	13 yrs., 6 mos.	116	A	24	13 yrs., 6 mos.	118
B	24	13 " 2 "	109	B	31	13 " 4 "	112
C	22	13 " 7 "	104	E <sub>1</sub>	33	13 " 2 "	106
D	24	13 " 4 "	74	E <sub>2</sub>	38	13 " 9 "	105

Table II includes all the pupils enrolled in the classes described. Some pupils were absent for all or part of the time in

Footnote: The courses offered by the Kirkcaldy High School to first and second year pupils are as follows:

- A. (For boys and girls) A literary course including one modern language and Latin.
  - B. (For boys and girls) A literary course with one modern language but handwork instead of Latin.
  - C. (For girls only) A commercial course with French.
  - D. (For girls only) A domestic course with no modern language.
  - E. (For boys only) A technical course with no modern language.
- The above classification is applicable to both first and second years but all of the classes of pupils in the first year do much the same range of work except for the differences caused by the omission of a foreign language by the D and E groups and the

which the tests were being given. Since for this study it was essential that subjects should have scores on every one of the tests, it was necessary to eliminate the data of all persons whose records were incomplete, whether incompleteness was due to part time absence, indistinct printing of the tests, or any other cause.

After the necessary eliminations were made, the reduced group which provided the data for the analysis herein recorded consisted of a total of 321 subjects which are described in the following table:

Table III

THE SUBJECTS WHOSE SCORES HAVE PROVIDED  
THE DATA FOR THIS STUDY

Group	n	Age			Average I.Q. (approximate)
		Minimum	Maximum	Average	
Girls I	90	11 yrs. 4 mos.	14 yrs. 8 mos.	12 yrs. 5 mos.	108
Boys I	100	11 " 2 "	14 " 4 "	12 " 5 "	110
Girls II	61	12 " 1 "	15 " 8 "	13 " 8 "	101
Boys II	70	12 " 2 "	15 " 2 "	13 " 7 "	110
Total	321	11 " 2 "	15 " 8 "	13 " 0 "	107

C. THE TESTS

As already stated the tests have been classified under three headings "Verbal", "Mathematical", and "Form Perception". One exception to this classification is that test number XVI, although it requires accuracy in perceiving form, is of such simplicity as to be more properly called a "Speed" Test than a "Form Perception" Test.

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omission of Geometry by the C and D groups. Geometry is omitted by the C and D groups in Form II also, but all boys in both years take Geometry. Differentiation of courses becomes more marked in the second year when alternate subjects are begun.

A sample item of each of the tests (with answers) is given here; the instructions have been considerably condensed. The tests in full are given in Appendix A.

"VERBAL" TESTS.

I. Opposites.

SOFT is opposite in meaning to Loft, Card, Lard, Hard.

II. Word Meaning.

AGED means the same or nearly the same as

Strong, Dark, Old, Happy.

III. Word Pairing.

(Select the most suitable word to use with the first word)

GREEN (Cow, Grass, Wood, Water)

IV. Definitions.

(Define in two or three words) Thigh, Attic, etc.

V. Sentence Completion. (A) (The content is of a logical nature.)

(Complete the sentence so as to make the best sense by underlining one word in each set of three.)

Temperature		<u>melt</u>
Cold	is necessary to	see ice.
<u>Heat</u>		drink

VI. Sentence Completion. (B) (The content is of a literary nature.)

	<u>robust</u>	robust
James was of	handsome build and	healthy appearance
	healthy	<u>handsome</u>

	<u>upright</u>	<u>healthy</u>
of	robust character and	upright mind
	energetic	energetic

VII. Comprehension.

(Read the story and answer the questions at the end.)

A donkey once said to a fox, "How I wish I could run as fast as the horse." The fox replied, "You could if you tried harder and talked less."

How many animals are mentioned? ..... 3

Which animal did not speak? .....horse

VIII. (This test was not printed in time to be used in the battery.)

IX. Classification.

(This test was eliminated because of unsatisfactory distribution of scores)

X. Analysis.

COAT is to WEAR as Bread is to Water, Eat, Starve, Cook

XI. Similarities.

(Underline three words which represent objects of the same class.)

Coat, Foot, Hat, Gloves, Soap, Chair

XII. (This test was not printed in time to be used.)

"MATHEMATICAL" TESTS.

XIII. Number Series.

(A) (Continue the series by writing in the brackets the two numbers that should come next.)

1, 3, 5, 7, 9, 11, ..... (13) (15)

(B) (Underline two of the five numbers on the right which continue the series started on the left.)

17, 19, 21, 23, ..... 24, 25, 26, 27, 28.

(C) (Underline the quantity, or the number that would be in the middle of each row if all the quantities or numbers of that row were put in order of size.)

(i) foot, inch, mile, furlong, yard

(ii) 3      9      6      15      12

XIV. Number Combinations.

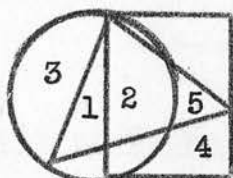
Note. (This test is modelled after the part of the International Intelligence test in which "rotators" are used. In this case instead of actual rotators being given to the pupils only drawings of them were given. Since the instructions were rather complicated they were read aloud and illustrated and then a preliminary trial was given to make sure that pupils understood what they were supposed to do.)

The instructions, summarized, are as follows: In imagination turn the rotators so that the sum of the dots on the



"FORM PERCEPTION" TESTS.<sup>1</sup>

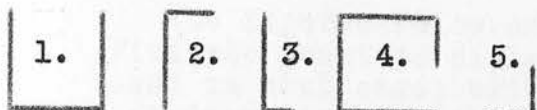
XVII. Following Instructions.



What number is in both the circle and the triangle but not in the rectangle?.....1.

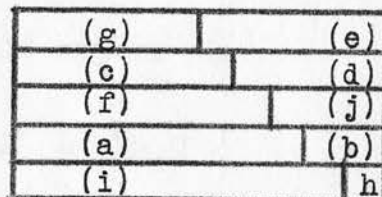
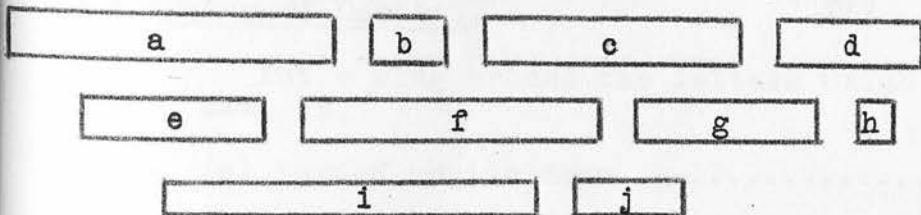
XVIII. Judgment of Length.

(A) Arrange the figures so that the total lengths of each figure are in order from the longest to the shortest.



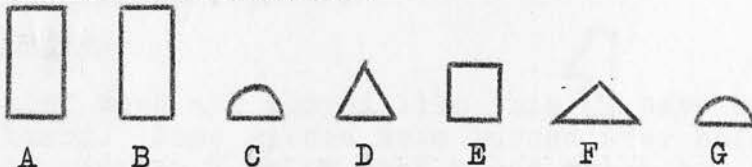
The longest is number.....4  
 The 2nd " " " .....1  
 " 3rd " " " .....2  
 " 4th " " " .....3  
 " shortest " " " .....5

(B) The ten pieces given on the left below, may be fitted together to look just like the figure on the right. In each section of this large figure write (inside the bracket) the letter name of the piece that would have to be used to make the pieces fit just the way they do here. Do not measure the pieces.



XIX. Synthesis of Geometric Figures.

(A)



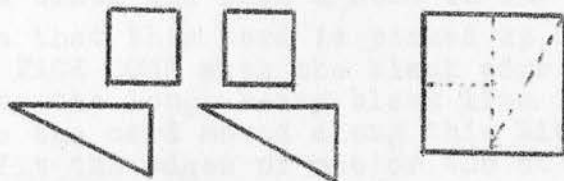
Sketch the figure formed by putting together figures selected from the above. These small figures must be joined in such a way that equal sides fit together.

Sketch A and C.

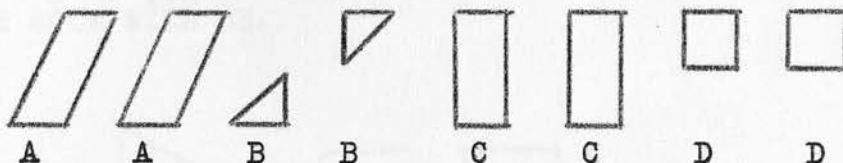


<sup>1</sup>In this battery of "Form Perception" tests three (XVII D, XIX B, XXII B) are not original, but are reproductions of tests by Otis and Thurstone. Test XXII A contains some items taken from tests by Burt.

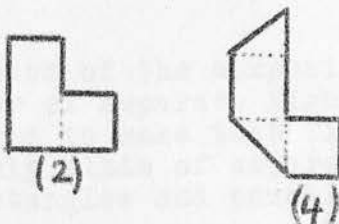
(B) Sketch the appearance of the square on the right after the small pieces have been fitted into it.



XX. Analysis of Geometric Forms.



The figures below are made up of the above parts. Find the least possible number of parts that have been used in each case; write that number under the figure and draw lines to show what parts have been used each time.




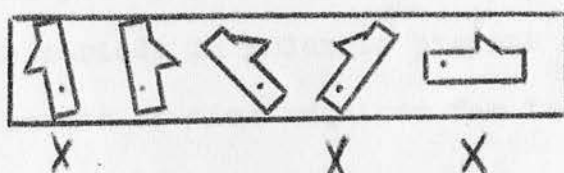
XXI. Reversed Letters.

Put a ring around the letters which would appear the same if,

- (a) turned upside down.....F A L **(B)** C
- (b) turned over right to left or left to right..R D etc.
- (c) turned both upside down and left to right..C D W etc.

XXII. Reversed Figures.

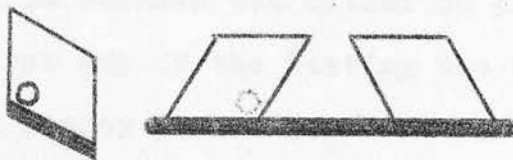
(A) Pieces of wood all shaped like this  have been nailed to a board. Some pieces were turned over before being nailed. Put an X below each piece which has the same side towards you as in the drawing above.



- (B) Assume that the lozenge shaped figure with a circle in it represents a small card with one of its edges printed black and with a hole in one corner.

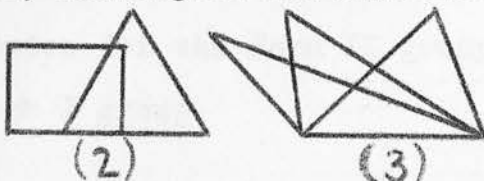
Imagine that this card is picked up TURNED OVER, and placed FACE DOWN with the black edge of the card touching the long, heavy black line to the right. Imagine the card moved along this black line until its edges fit the edges of one or the other of the lozenge shaped outlines.

With your pencil DRAW A CIRCLE IN THE CORNER WHERE THE HOLE WILL BE.



### XXIII. Overlapping Figures.

Write underneath each of the composite figures below what is the least number of separate figures, overlapping or not overlapping, required to make that figure, and to show all the lines. The only kinds of separate figures used are squares, triangles, rectangles and parallelograms.



#### D. Administration of the Tests

All the tests were administered by the writer, with the assistance of the Kirkcaldy H. S. Staff, within three consecutive days. The subjects were divided into two groups, namely, (a) First year pupils (Form I), (b) Second year pupils (Form II). These two groups were tested in alternate periods in order to prevent fatigue of the subjects. The total length of time required for testing each group

was equivalent to half of a school day for each of three consecutive days.

The order of giving the tests was the same for both groups. Care was taken to "sandwich" in tests of widely varying types. This variation in the order of presentation of the tests added interest to the task and did much to offset fatigue and prevent any constant error in results due either to practice or fatigue.

During the first day of the testing the first year group was allowed a slightly longer period for each test than that allowed to the second year group. It was then decided that this concession to first year pupils was not necessary and for the remainder of the tests the time allowed was the same for both groups. The time allowed for each test is given in Appendix B. The total time in which the pupils were actually working on the tests was 3 hours and 49 minutes for the Form II group and 4 hours and 3 minutes for the Form I group.

#### E. Scoring

The objective type of scoring was possible for all tests except the following three: Definitions (IV), Synthesis of Figures (XIX A and B), and part of the Comprehension Test (VII). Even in these three there was practically no possibility of variation in the score due to subjective judgment. The rule in scoring all tests, except number XV, was to give one point for each item answered correctly. In the case of test XV, the Problems Test, some complex problems were allotted two or three points according to the number of major steps required in the solution of the problem.

Test IX was discarded after a goodly number of papers had been scored because it was found that the range of scores was so small as to make the test unsatisfactory.

F. Analysis of the Data obtained from the Battery of Tests

(1) The Distribution of Scores:

The distribution of scores is approximately normal for each of the tests used except XXII B. For this one test, the distribution of scores was heavily skewed to the left and there were several zero scores, thus indicating that the test was too difficult for many of the pupils tested. The range of scores for each test and graphs showing the distribution of scores for the groups of tests selected for the final analyses are given in Appendix B.

(2) The Intercorrelations of the Tests and their Analyses:

All coefficients of correlation have been computed by the Pearson Product-Moment Method. Most of the computations have been re-checked by a highly competent person.

Coefficients of correlation have been found for the following:

- (a) The three main groups of tests. Tables IV and V.  
(Each of the four groups of subjects computed separately.)
- (b) The twenty-three single tests. Table VI.  
(Second year boys only.)
- (c) The groups of tests (6 variables). Tables X to XIII.  
(Four groups of subjects.)
- (d) Scores combined in four different ways. Tables XV to XVIII.  
(Second year boys only.)
- (e) The revised groups of tests (final arrangement). Tables XX to XXIII. (Four groups of subjects.)

Most of these correlation matrixes have been analysed by both the Spearman and Thurstone techniques. These matrixes and their analyses are recorded in the following pages.

(a) THE THREE MAIN GROUPS OF TESTS

Before proceeding to the lengthy task of finding the inter-correlations of all the single tests, the raw scores were added together so as to have for each pupil the total scores on each of the three main types of tests, namely, "Verbal"<sup>1</sup>, "Mathematical", and "Form Perception". The intercorrelations of these three groups of tests were computed for each of the four groups of subjects. The coefficients of correlation are given in Tables IV and V.

Table IV

COEFFICIENTS OF CORRELATION OF THE THREE MAIN GROUPS OF TESTS  
Second Year Pupils

Group of Tests	Boys II (n = 70)			Girls II (n = 61)		
	1.	2.	3.	1.	2.	3.
1. "Verbal" (I to VII)	—	.7469 (±.036)	.4126 (±.067)	—	.6062 (±.055)	.5883 (±.056)
2. "Mathematical" (XIII to XV)	.7469	—	.6386 (±.048)	.6062	—	.7172 (±.042)
3. "Form Perception" (XVII to XXIII)	.4126	.6386	—	.5883	.7172	—

<sup>1</sup>The scores had been tabulated in such a way that considerable time was saved by omitting tests X and XI from the "Verbal" group. Since there still remained seven tests in the "Verbal" group this seems justifiable. Test XVI was omitted since it was not classified under any of the three groups.

For each of the two second year groups the correlations in Table IV show the same tendency, namely: The correlations between the "Verbal" and "Form Perception" tests (Boys:  $r = .41$ , Girls:  $r = .59$ ) are lower than the correlations between "Verbal" and "Mathematical" (Boys:  $r = .64$ , Girls:  $r = .61$ ), or between "Mathematical" and "Form Perception" tests (Boys:  $r = .64$ , Girls:  $r = .72$ ). This tendency is more marked for the boys than for the girls.

While these raw correlations are inconclusive in themselves, they are significant and give support to the assumption that "Form Perception" tests measure some ability other than that measured by "Verbal" tests.

Table V

COEFFICIENTS OF CORRELATION OF THE THREE MAIN GROUPS OF TESTS  
First Year Pupils

Group of Tests	Boys I (n = 100)			Girls I (n = 80)		
	1.	2.	3.	1.	2.	3.
1. "Verbal" (I to VII)	—	.7120 ( $\pm .033$ )	.5587 ( $\pm .046$ )	—	.7294 ( $\pm .035$ )	.6681 ( $\pm .042$ )
2. "Mathematical" (XIII to XV)	.7120	—	.6831 ( $\pm .036$ )	.7294	—	.6436 ( $\pm .044$ )
3. "Form Perception" (XVII to XXIII)	.5587	.6831	—	.6681	.6436	—

The correlation coefficients of "Verbal with "Form Perception" tests are greater for the first year subjects (Boys:  $r = .56$ , Girls:  $r = .67$ ) than for the second year boys ( $r = .41$ ). This may be interpreted as indicating that first year pupils give more evidence of a general ability or "g" factor than do the second year boys and less evidence of a special factor.

Conclusions based on the analysis of Tables IV and V:

In this preliminary analysis the "Form Perception" tests give evidence of differentiation of mental abilities. Differentiation is greater for the boys than for the girls and is greater for second year boys than for first year boys. That is to say, the evidence of special abilities is greatest for the older boys and least for the younger girls.

These results are in harmony with those of Burt and those of the National Institute of Industrial Psychology. In a report<sup>1</sup> of the latter the following statement is made: "It may be that in solving the problems in which space relations enter, girls depend more upon general intelligence than do boys." After further study of the scores on "Performance" tests in relation to scores on "Verbal" tests, the report continues thus: "It is probable that special abilities tend to show themselves more definitely about the age of puberty than previously." The authors conclude that, for pupils younger than 13 or 14 years of age, success in tests depends mainly on general intelligence, while differentiation of abilities appears to develop later.

Burt<sup>2</sup> also concluded that differentiation of abilities was a matter of maturation and that, although boys and girls are

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<sup>1</sup>Earle, F.M., Milner, M., et al. The use of Performance Tests of Intelligence in Vocational Guidance. London: H.M. Stationery Office, 1929. Pages 41 and 66.

<sup>2</sup>Burt, C., Mental and Scholastic Tests (Reports to the London County Council). P.S. King and Company, 1921. Pages 193-199.

equal as regards mental ages, sex differences<sup>1</sup> occur in the mean scores for the component tests of a scale such as the Binet Intelligence Scale.

On the basis of these various findings it seems reasonable to expect that the greatest evidence of either specific or group factors would be found for the group of older boys (that is the group Boys II). Accordingly, the coefficients of correlation for each of the separate tests have been found for the group Boys II.

#### (b) THE SINGLE TESTS

The intercorrelations of the separate tests<sup>2</sup> were then computed for one group of subjects (Boys II). and are given in Table VI.

<sup>1</sup> Burt suggests that these differences may be due to social factors as much as to inborn abilities. However, in this study no attempt is made to distinguish between inherited and acquired traits.

<sup>2</sup> One of the sub-tests in Problems, namely XVB, has been eliminated and the remaining sub-tests in Problems A, C, and D have been combined in order to reduce the number of variables in the matrix. The sub-test B was eliminated because of its evidence of low reliability and because it was found that its correlations with the sub-tests A, C, and D were each less than .4, while the intercorrelations of the sub-tests A, C, and D were each greater than .4. The sub-tests of test XIII, another "Mathematics" test, were also combined and considered as one test. However, none of the "Form Perception" sub-tests have been combined; each is considered as a separate test. This makes the number of "Form Perception" variables almost the same as the number of "Verbal" variables, while the number of "Mathematics" variables is fewer. This is as it should be since we are concerned chiefly with a comparison of "Form Perception" and "Verbal" tests.

TABLE VI  
 COEFFICIENTS OF CORRELATION (Pearson's Product - Moment Method)  
 (N = 70 boys in the second year of the Kirkcaldy High School, Scotland, 1931-1932)

Test No. and Name	Variable No.	1	2	3	4	5	6	7	8	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
I. Opposites	1	-	.680	.618	.637	.529	.595	.592	.660	.555	.578	.445	.645	.336	.265	.212	.015	.370	.355	.315	.354	.319	.130	.083
II. Word Meaning	2	.680	-	.725	.622	.524	.551	.618	.612	.505	.396	.368	.574	.291	.307	.188	.011	.132	.119	.226	.354	.369	.155	.087
III. Word Pairing	3	.618	.725	-	.580	.540	.666	.569	.583	.602	.406	.333	.569	.368	.327	.200	.174	.172	.255	.175	.301	.440	.227	.118
IV. Definitions	4	.637	.622	.580	-	.578	.596	.533	.573	.457	.549	.345	.800	.283	.331	.356	.345	.401	.393	.447	.411	.292	.279	.093
V. Sentence CompletionA	5	.529	.524	.540	.578	-	.655	.378	.551	.492	.375	.237	.579	.307	.377	.155	.312	.270	.320	.381	.289	.182	.282	.170
VI. Sentence CompletionB	6	.595	.551	.666	.596	.655	-	.420	.507	.763	.548	.337	.612	.366	.330	.226	.247	.231	.143	.301	.401	.326	.172	.213
VII. Comprehension	7	.592	.618	.569	.533	.378	.420	-	.632	.460	.316	.552	.539	.346	.301	.272	.131	.347	.235	.246	.164	.414	.244	.067
X. Analogies	8	.660	.612	.583	.573	.551	.507	.632	-	.582	.595	.504	.698	.366	.408	.227	.147	.342	.371	.419	.455	.370	.240	.120
XI. Classification	9	.555	.505	.602	.457	.492	.763	.460	.582	-	.437	.350	.507	.452	.228	.114	.165	.272	.198	.279	.337	.165	.163	.139
XIII. Number Sequence	10	.578	.396	.406	.549	.375	.548	.316	.595	.437	-	.379	.752	.260	.446	.279	.274	.256	.297	.484	.343	.212	.072	.127
XIV. Number Combinations	11	.445	.368	.333	.345	.237	.337	.552	.504	.350	.379	-	.466	.314	.228	.113	.043	.344	.353	.327	.123	.413	.020	.011
XV. Problems	12	.645	.574	.569	.800	.579	.612	.539	.698	.507	.752	.466	-	.353	.465	.318	.375	.460	.431	.619	.488	.348	.266	.147
XVI. Speed	13	.336	.291	.368	.283	.307	.366	.346	.366	.452	.260	.314	.353	-	.397	.222	.330	.287	.218	.359	.024	.136	.157	.092
XVII. Following Directions	14	.265	.307	.327	.331	.377	.330	.301	.408	.228	.446	.228	.465	.397	-	.258	.342	.259	.346	.354	.289	.316	.138	.055
XVIII.(A) Judgment of Length	15	.212	.188	.200	.356	.155	.226	.272	.227	.114	.279	.113	.318	.222	.358	-	.387	.494	.284	.475	.240	.284	.015	.250
XVIII.(B) Judgment of Length	16	.015	.011	.174	.345	.312	.247	.131	.147	.165	.274	.043	.375	.330	.342	.387	-	.354	.410	.493	.337	.101	.316	.022
XIX. (A) Synthesis of Figures	17	.370	.132	.172	.401	.270	.231	.347	.342	.272	.256	.344	.460	.287	.259	.494	.354	-	.559	.588	.314	.263	.268	.027
XIX. (B) Synthesis of Figures	18	.355	.119	.255	.393	.320	.143	.235	.371	.198	.297	.353	.431	.218	.346	.284	.410	.559	-	.644	.300	.315	.221	.208
XX. Analysis of Figures	19	.315	.226	.175	.447	.381	.301	.246	.419	.279	.484	.327	.619	.359	.354	.475	.493	.588	.644	-	.356	.208	.162	.192
XXI. Reversing letters	20	.354	.354	.307	.411	.289	.401	.164	.455	.337	.343	.123	.488	.024	.289	.240	.337	.314	.300	.356	-	.132	.259	.052
XXII. (A) Reversing figures	21	.319	.369	.440	.292	.182	.326	.414	.370	.165	.212	.413	.348	.136	.316	.284	.101	.363	.315	.208	.132	-	.220	.052
XXII. (B) Reversing figures	22	.130	.155	.227	.279	.282	.172	.244	.240	.163	.072	.020	.266	.157	.138	.015	.316	.268	.221	.162	.259	.220	-	.112
XXIII. Overlapping figures	23	.083	.087	.118	.093	.170	.213	.067	.120	.139	.127	.011	.147	.092	.055	.250	.022	.027	.208	.192	.052	.052	.112	-

Analysis of Table VI (Intercorrelations of the Single Tests):

The number of coefficients of correlation in this matrix of 23 variables is so great as to make a complete tetrad analysis a tedious task. Shorter methods of analysis, namely, those of Kelley<sup>1</sup>, Hotelling<sup>2</sup>, and Thurstone<sup>3</sup>, were therefore considered. It was decided to use the Thurstone Multiple Factor Analysis technique<sup>4</sup> which had enjoyed much popularity since it was advanced in 1931. This method of analysis is less time-consuming than analysis by the Spearman tetrad criterion and, presumably, is of more value in that it indicates more precisely, how many general or group factors must be postulated in order to account for the correlations given in any matrix.

Before proceeding with the analysis by the Thurstone technique a few of the tetrad differences which were obviously significant and which, therefore, give evidence of the presence of some factor other than a general factor or "g<sup>m</sup>", and independent

<sup>1</sup>Kelley, T. L., *Crossroads in the Mind of Man*. California, Stanford University Press, 1928.

<sup>2</sup>Hotelling, H., *Analysis of a Complex of Statistical Variables into Principal Components*. *J. Educ. Psychol.*, Vol. XXIV, September and October, 1933, pp. 498-520.

<sup>3</sup>Thurstone, L.L., *Multiple Factor Analysis*. *Psychol. Rev.*, Vol. XXXVIII, September, 1931. pp. 406-427.

<sup>4</sup>Note: (a) By using this method the writer discovered that the Thurstone technique is defective; therefore the final conclusions are not based on the Thurstone method of Analysis but on Analysis by the Spearman tetrad criterion.

(b) Since completing this thesis, there has appeared a favourable review of the Hotelling Method with suggested improvements by Prof. Godfrey Thomson. (*J. Educ. Psych.* May, 1934)

specific factors were noted and are recorded in Table VII.

(i) Partial analysis of Table VI by the Spearman Technique:<sup>1</sup>

The notation used in designating the tetrads throughout this thesis is that used by Kelley<sup>2</sup> in which the subscripts define the tetrad precisely as follows:

$$t_{1234} = r_{12}r_{34} - r_{13}r_{24}$$

$$t_{1243} = r_{12}r_{34} - r_{14}r_{23}$$

$$t_{1342} = r_{13}r_{24} - r_{14}r_{23}$$

The method of finding the probable error<sup>3</sup> of tetrad differences due to sampling, devised by Spearman and Holzinger, and which has recently been reviewed by Garrett<sup>4</sup> and declared adequate, has been used throughout this study.

A few of the largest tetrad differences contained in the matrix of correlations given in Table VI are recorded in Table VII. The probable error of each of these tetrad differences is also given. In this and all other tetrad analyses reported in this study, a tetrad difference is considered significant if it

<sup>1</sup>Spearman, C., The Abilities of Man. London, MacMillan and Company, 1927.

<sup>2</sup>Kelley, T.L., Crossroads in the Mind of Man. p. 47.

<sup>3</sup>The Spearman-Holzinger formula for finding the probable error of a single tetrad difference is as follows:

$$PE_{t_{1234}} = \frac{.6745}{\sqrt{N}} \left[ r_{12}^2 + r_{13}^2 + r_{24}^2 + r_{34}^2 - 2(r_{12}r_{13}r_{23} + r_{12}r_{14}r_{24} + r_{13}r_{14}r_{34} + r_{23}r_{24}r_{34}) + 4r_{12}r_{13}r_{24}r_{34} \right]^{\frac{1}{2}}$$

In this formula N is the number of cases in the sample.

<sup>4</sup>Garrett, H.E., The Sampling Distribution of the Tetrad Equation. J. of Educ. Psychol., Vol. XXIV, October, 1933.

exceeds  $3\frac{1}{2}$  times its P.E. Each of the tetrad differences given in Table VII exceeds  $3\frac{1}{2}$  times its P.E. and, therefore, each is significant.

Table VII

## SOME SIGNIFICANT TETRAD DIFFERENCES IN TABLE VI

Tetrad	Tetrad Difference	Probable Error
<sup>t</sup> 2 3 18 19	.446	±.060
<sup>t</sup> 2 3 19 18	.409	±.059
<sup>t</sup> 1 2 18 19	.358	±.059
<sup>t</sup> 1 2 19 18	.401	±.060
<sup>t</sup> 2 3 17 18	.371	±.062
<sup>t</sup> 2 3 18 17	.385	±.063
<sup>t</sup> 1 2 17 19	.316	±.061
<sup>t</sup> 1 2 19 17	.358	±.062
<sup>t</sup> 10 12 17 18	.310	±.058
<sup>t</sup> 10 12 18 17	.283	±.057

(The subscripts refer to the numbers of the variables as given in Table VI.)

It should be remembered that the above is not a complete list of the significant tetrad differences. Enough has been given, however, to show that some factor or factors other than one general factor, or "g", as defined by Spearman, must be postulated in order to account for the correlations.

(ii) Analysis of Table VI by the Thurstone Technique:

A summary of the steps required in using the Thurstone Multiple Factor Analysis technique may be found in the Psychological Review, Volume XXXVIII, September, 1931.

The First Factor Loadings for each of the twenty-three variables have been computed by Thurstone's method and are recorded below.

Table VIII

FIRST FACTOR LOADINGS OF THE TESTS IN TABLE VI  
AS COMPUTED BY THE THURSTONE MULTIPLE FACTOR TECHNIQUE

Group	The First Factor Loading for Each Test									
"Verbal"	I	II	III	IV	V	VI	VII	X	XI	
	.74	.68	.71	.78	.68	.73	.67	.79	.66	
"Mathematical"	XIII	XIV	XV							
	.67	.54	.86							
"Form Perception"	XVII	XVIII A	XVIII B	XIX A	XIX B	XX	XXI	XXII A	XXII B	XXIII
	.56	.47	.45	.57	.57	.65	.53	.49	.36	.25
The "Speed" test, XVI, which has not been included in any of the above groups has a First Factor Loading .52.										

The largest of the above loadings is test XV which has a loading .86, therefore, this test, (variable no. 12) which is a "Problems" test, is the first "Pivot" test according to the Thurstone technique and terminology.

Proceeding with step (6) of the analysis, in which one is to select all of the tests which correlate within the range  $\pm .50$  with the first "Pivot" test, we find that there are the following nine: XIV, XVI, XVII, XVIII A, XVIII B, XXI, XXII A, XXII B, XXIII.

The "Pivot" test of this group, designated the second "Pivot" test, is number XVII (variable no. 14).

Since there are no tests that correlate negatively with this second "Pivot" test, it is impossible to proceed with the analysis further except to show, if desired, that each of the Second Factor Loadings is equal to zero.

On the basis of the Thurstone analysis one must conclude that there is no second general factor underlying the correlations studied.

Conclusions from the Two Analyses of Table VI:

(1) A partial analysis of the coefficients of correlation for the twenty-three single tests, computed for Boys' II by the Spearman technique, gives clear evidence that some general or group factor or factors other than one common factor must be postulated in order to account for the correlations.

(2) The analysis by the Thurstone Multiple Factor technique leads to the conclusion that it is not necessary to postulate more than one general or group factor in order to account for the correlations.

We shall not attempt to discuss this obvious conflict of results until after the data has been analysed further.

It was considered unnecessary to analyse the data for each of the four groups of subjects in the extensive manner used for the Boys' II group. On the strength of the analysis of the data of this one group, some tests were eliminated and others

grouped as described in the following two sections.

#### Eliminations of Tests:

Tests XXIIB and XXIII were eliminated because of their consistently low correlations. The highest correlation coefficient of the former with any one test was .316 while that of the latter was .250. Moreover, the skewness of distribution of test XXIIB, which has been noted previously, would have been sufficient reason for having discarded it earlier as a test too difficult for subjects of this age.

Test XIV was eliminated for the following two reasons:

(1) while the other two tests in the "Mathematical" group, XIII and XV, correlated highly (.752) with one another, test XIV had correlations of .379 and .466 with these other two tests of that group. It seemed wise, metaphorically speaking, to prune this "Mathematical" group of its dead wood before going further. (2) several subjects of the first year group of girls had received only three of the four pages of this test and hence their scores on test XIV were of no value.

Since test XVI has been considered not properly belonging to any one of the three main groups or types of tests, it has been eliminated in order to simplify further analysis.

#### Grouping of Tests:

The remaining tests have been grouped so as to have two groups of each of the three main types. These groups are designated thus:  $V_1$   $V_2$  ("Verbal"),  $M_1$   $M_2$  ("Mathematical"),  $FP_1$   $FP_2$  ("Form Perception"). The tests composing each of these six

variables are indicated below. The manner of grouping has been somewhat arbitrary; however, the First Factor Loadings, as recorded in Table VIII, were duly considered when combining the tests. These loadings and the various groupings of tests are given in Table IX.

Table IX

TABLE SHOWING HOW THE TESTS HAVE BEEN GROUPED  
(The First Factor Loadings are those computed for Table VI)

"Verbal"			"Mathematical"			"Form Perception"			
Group Name	Test No.	1st Factor Loadings	Group Name	Test No.	1st Factor Loadings	Group Name	Test NO.	1st Factor Loadings	
V <sub>1</sub>	I	.74	M <sub>1</sub>	XIII	.67	FP <sub>1</sub>	XIXA	.57	
	II	.68		(ABC)			XIXB		.57
	III	.71					XXI		.53
	IV	.78					XXIIA		.49
	Av.	.73							Av.
V <sub>2</sub>	V	.68	M <sub>2</sub>	XV	.86	FP <sub>2</sub>	XVII	.56	
	VI	.73		(ACD)			XVIII A		.47
	VII	.67					XVIII B		.45
	X	.79					XX		.65
	XI	.66							
	Av.	.71							Av.

The scores have been combined into groups as indicated in Table IX for each of the four groups of subjects (Boys' II, Girls' II, Boys' I, and Girls' I).

### (c) THE GROUPS OF TESTS

Intercorrelations of these six variables (V<sub>1</sub> V<sub>2</sub> M<sub>1</sub> M<sub>2</sub> FP<sub>1</sub> FP<sub>2</sub>) have been found for each of the four groups of subjects and are recorded in Tables X, XI, XII, and XIII.

The following four tables give the coefficients of correlation of the six groups of tests. The variables, which are the same in each of the four tables, are as follows:

		Variable No.
"Verbal"	$V_1$ = Tests I, II, III, IV	1
	$V_2$ = " V, VI, VII, X, XI	2
"Mathematical"	$M_1$ = " XIII(A,B,C)	3
	$M_2$ = " XV (A,B,C)	4
"Form Perception"	$FP_1$ = " XIX(A&B), XXI, XXIIA	5
	$FP_2$ = " XX, XVII, XVIII(A&B)	6

Table X

CORRELATION COEFFICIENTS		Boys II (n = 70)				
Variable	1. $V_1$	2. $V_2$	3. $M_1$	4. $M_2$	5. $FP_1$	6. $FP_2$
1. $V_1$	—	.830	.533	.727	.505	.333
2. $V_2$	.830	—	.596	.739	.551	.435
3. $M_1$	.533	.596	—	.752	.411	.478
4. $M_2$	.727	.739	.752	—	.652	.577
5. $FP_1$	.505	.551	.411	.652	—	.629
6. $FP_2$	.333	.435	.478	.577	.629	—

Table XI

CORRELATION COEFFICIENTS		Girls II (n = 61)				
Variable	1. $V_1$	2. $V_2$	3. $M_1$	4. $M_1$	5. $FP_1$	6. $FP_2$
1. $V_1$	—	.721	.259	.514	.393	.450
2. $V_2$	.721	—	.332	.645	.572	.596
3. $M_1$	.259	.332	—	.486	.300	.375
4. $M_2$	.514	.645	.486	—	.697	.618
5. $FP_1$	.393	.572	.300	.697	—	.556
6. $FP_2$	.450	.596	.375	.618	.556	—

Table XII

CORRELATION COEFFICIENTS		Boys I (n = 100)				
Variable	1. $V_1$	2. $V_2$	3. $M_1$	4. $M_2$	5. $FP_1$	6. $FP_2$
1. $V_1$	—	.802	.573	.618	.377	.587
2. $V_2$	.802	—	.649	.583	.470	.604
3. $M_1$	.573	.649	—	.700	.452	.617
4. $M_2$	.618	.583	.700	—	.562	.636
5. $FP_1$	.377	.470	.452	.562	—	.613
6. $FP_2$	.587	.604	.617	.636	.613	—

Table XIII

CORRELATION COEFFICIENTS		Girls I (n = 90)				
Variable	1. $V_1$	2. $V_2$	3. $M_1$	4. $M_2$	5. $FP_1$	6. $FP_2$
1. $V_1$	—	.819	.612	.687	.414	.608
2. $V_2$	.819	—	.685	.777	.507	.682
3. $M_1$	.612	.685	—	.711	.474	.645
4. $M_2$	.687	.777	.711	—	.566	.682
5. $FP_1$	.414	.507	.474	.566	—	.652
6. $FP_2$	.608	.682	.645	.682	.652	—

Analysis of Tables X, XI, XII, and XIII by the Thurstone Method:

These four correlation matrixes have been analysed by the Thurstone Multiple Factor Analysis technique. The First Factor Loadings of the six variables for each of the four groups of subjects are given in the following table:

Table XIV

## FIRST FACTOR LOADINGS OF THE SIX VARIABLES

	V <sub>1</sub>	V <sub>2</sub>	M <sub>1</sub>	M <sub>2</sub>	FP <sub>1</sub>	FP <sub>2</sub>
Boys II	.81	<u>.86</u>	.78	<u>.92</u>	.77	.71
Girls II	.73	<u>.84</u>	.60	<u>.86</u>	.77	.78
Boys I	.81	<u>.84</u>	.82	<u>.84</u>	.71	.83
Girls I	.83	<u>.89</u>	.82	<u>.88</u>	.72	.85
Average	.79	<u>.86</u>	.75	<u>.87</u>	.74	.79

(In the above table the variables with the largest loadings, that is the first "Pivot" tests, are underlined in red ink; the second largest are underlined in black ink.)

From this table it may be seen that the variable which has the largest average of First Factor Loadings is M<sub>2</sub> (that is, Problems, Test XV); while the variable with the second largest average of First Factor Loadings is V<sub>2</sub> (that is, Tests V to XI of the "Verbal" group). For each group of subjects the variables M<sub>2</sub> and V<sub>2</sub> have either the largest or next to largest First Factor Loadings. It may be concluded, therefore, that the variables V<sub>2</sub> and M<sub>2</sub> give evidence of a particularly strong general factor. The variable that gives the least evidence of a strong general factor is the "Form Perception" variable, FP<sub>1</sub>. However, all of these First Factor Loadings are sufficiently high to be ample evidence of a high reliability of the tests.

When we attempt to proceed further with the Thurstone method of analysis for each of the correlation matrixes, given in Tables X, XI, XII, and XIII, we encounter an insurmountable obstacle even more speedily than in the analysis of the large matrix (Table VI). This time it is impossible to proceed with

step (6) of the analysis, except in the case of one of four matrixes, since in none of the three is there a variable whose correlation with the "Pivot" test of that matrix is as small as .50. In the case of the fourth matrix, namely, the Girls II group, the correlation between the "Pivot" test,  $M_2$ , and the variable  $M_1$ , is .486, so in the case of this one matrix, step (6) may be taken. However, in the case of all four matrixes it is impossible to proceed with step (7) since there are no negative correlations.

Conclusion from the Analysis of Tables X, XI, XII, and XIII:

The Thurstone method of analysis gives no evidence of any general or group factor other than one general factor common to all.

Revision of the Variables:

It was then decided to disentangle the "Form Perception" tests which intercorrelated highly among themselves from the "Form Perception" tests showing low intercorrelations. With this end in view a re-study of correlation coefficients of the twenty-three single variables given in Table VI was made.

It was found that Tests XIXA, XIXB, and XX had intercorrelations each greater than .5 while all other "Form Perception" test intercorrelations were less than .5. Moreover, the First Factor Loadings, computed by the Thurstone method (Table VIII), were larger for these three variables than for any of the other variables of the "Form Perception" group.

It was then found that by combining the parts A and B of Test XIX, the correlation with Test XX was greater than when each part was correlated separately. The intercorrelations of the three tests were as follows:

$r_{XIXA\ XIXB} = .559$ ;  $r_{XIXA\ XX} = .588$  and  $r_{XIXB\ XX} = .644$  while the correlation of XX with XIX, when parts A and B were combined, was .705. The parts A and B of Test XVIII were also combined and the total score on XVIII correlated with XIX (A & B) and with XX. These correlations are as follows:

$$r_{XVIII\ XIX} = .511 \text{ and } r_{XVIII\ XX} = .567$$

These correlations with XVIII are considerably smaller than those between XIX and XX.

Accordingly, Test XIX (parts A and B combined) has been substituted for group  $FP_1$  and Test XX was substituted for  $FP_2$ . These new variables will be called  $fp_1$  and  $fp_2$  respectively. That is to say that while the capital letters, FP, have been used to designate groups of "Form Perception" tests, the small letters, fp, are used to designate single "Form Perception" tests. ( $fp_1 =$  test XIX (A & B) while  $fp_2 =$  test XX.)

It was then a moot point whether the variables  $V_1$  and  $V_2$  should remain as they were, that is, continue to be groups of tests, or whether the two single "Verbal" tests having the largest intercorrelation coefficients (in this case Tests II and III whose  $r = .725$ ) should be substituted for the groups  $V_1$  and  $V_2$  and be designated  $v_1$  and  $v_2$ .

A decision regarding this matter was delayed until the following four possibilities, A, B, C, and D, were tried out for the Boys II group of subjects. ( $M_1$  and  $M_2$  are kept constant throughout.)

(d) THE TESTS COMBINED IN FOUR DIFFERENT WAYS

The following four arrangements of variables have been examined:

- |                                  |      |   |
|----------------------------------|------|---|
| A. <u>"Verbal" tests grouped</u> | with | <u>"Form Perception" tests grouped</u>            |
| $V_1$ (Tests I to IV)            |      | FP <sub>1</sub> (Tests XIXA, XIXB, XXI, XXIIA)    |
|                                  | with |   |
| $V_2$ (Tests V to XI)            |      | FP <sub>2</sub> (Tests XX, XVII, XVIIIA, XVIIIIB) |
| B. <u>"Verbal" tests single</u>  | with | <u>"Form Perception" tests grouped</u>            |
| $v_1$ (Test II)                  |      | FP <sub>1</sub> (as in A above)                   |
|                                  | with |   |
| $v_2$ (Test III)                 |      | FP <sub>2</sub> (as in A above)                   |
| C. <u>"Verbal" tests grouped</u> | with | <u>"Form Perception" tests single</u>             |
| $V_1$ (as in A above)            |      | fp <sub>1</sub> (Test XIX A&B)                    |
|                                  | with |   |
| $V_2$ (as in A above)            |      | fp <sub>2</sub> (Test XX)                         |
| D. <u>"Verbal" tests single</u>  | with | <u>"Form Perception" tests single</u>             |
| $v_1$ (as in B above)            |      | fp <sub>1</sub> (as in C above)                   |
|                                  | with |   |
| $v_2$ (as in B above)            |      | fp <sub>2</sub> (as in C above)                   |

The above four ways of arranging the variables have been tried for one group of subjects, Boys II; the correlations resulting from each arrangement are given in Tables XV, XVI, XVII, and XVIII.

Table XV <sup>1</sup>

## CORRELATION COEFFICIENTS, ARRANGEMENT A (Boys II)

(Both the "Verbal" and the "Form Perception" tests are groups of tests)

Variable	1. V <sub>1</sub>	2. V <sub>2</sub>	3. M <sub>1</sub>	4. M <sub>2</sub>	5. FP <sub>1</sub>	6. FP <sub>2</sub>
1. V <sub>1</sub>	—	.830	.533	.727	.505	.333
2. V <sub>2</sub>	.830	—	.596	.739	.551	.435
3. M <sub>1</sub>	.533	.596	—	.752	.411	.478
4. M <sub>2</sub>	.727	.739	.752	—	.652	.577
5. FP <sub>1</sub>	.505	.551	.411	.652	—	.629
6. FP <sub>2</sub>	.333	.435	.478	.577	.629	—

Table XVI

## CORRELATION COEFFICIENTS, ARRANGEMENT B (Boys)II)

(Single "Verbal" tests with grouped "Form Perception" tests)

Variable	1. v <sub>1</sub>	2. v <sub>2</sub>	3. M <sub>1</sub>	4. M <sub>2</sub>	5. FP <sub>1</sub>	6. FP <sub>2</sub>
1. v <sub>1</sub>	—	.725	.396	.574	.390	.234
2. v <sub>2</sub>	.725	—	.406	.569	.434	.270
3. M <sub>1</sub>	.396	.406	—	.752	.411	.478
4. M <sub>2</sub>	.574	.569	.752	—	.652	.577
5. FP <sub>1</sub>	.390	.434	.411	.652	—	.629
6. FP <sub>2</sub>	.234	.270	.478	.577	.629	—

<sup>1</sup>This table is the same as Table X.

Table XVII

CORRELATION COEFFICIENTS, ARRANGEMENT C (Boys II)  
 (Grouped "Verbal" tests with single "Form Perception" tests)

Variable	1. $V_1$	2. $V_2$	3. $M_1$	4. $M_2$	5. $fp_1$	6. $fp_2$
1. $V_1$	—	.830	.533	.727	.326	.329
2. $V_2$	.830	—	.596	.739	.412	.432
3. $M_1$	.533	.596	—	.752	.324	.484
4. $M_2$	.727	.739	.752	—	.520	.619
5. $fp_1$	.326	.412	.324	.520	—	.705
6. $fp_2$	.329	.432	.484	.619	.705	—

Table XVIII

CORRELATION COEFFICIENTS, ARRANGEMENT D (Boys II)  
 (Both the "Verbal" and the "Form Perception" tests are single tests)

Variable	1. $v_1$	2. $v_2$	3. $M_1$	4. $M_2$	5. $fp_1$	6. $fp_2$
1. $v_1$	—	.725	.396	.574	.153	.226
2. $v_2$	.725	—	.406	.569	.212	.236
3. $M_1$	.396	.406	—	.752	.324	.484
4. $M_2$	.574	.569	.752	—	.520	.619
5. $fp_1$	.153	.212	.324	.520	—	.705
6. $fp_2$	.226	.236	.484	.619	.705	—

For each of the preceding four correlation matrixes (Tables XV, XVI, XVII, and XVIII) the two largest tetrad differences are recorded in the following table:

Table XIX

THE LARGEST TETRAD DIFFERENCES OF EACH OF THE  
CORRELATION MATRIXES (TABLES XV, XVI, XVII, XVIII)

Tetrad	the four arrangements of variables							
	A		B		C		D	
	T.D.	P.E.	T.D.	P.E.	T.D.	P.E.	T.D.	P.E.
$t_{1256}$	.302	±.071	.351	±.069	.444	±.078	.475	±.077
$t_{1265}$	.339	±.066	.355	±.070	.449	±.077	.463	±.079

From the above table it may be seen that arrangements C and D give more significant tetrad difference than arrangements A or B. That is, the tetrad differences were greater when the "Form Perception" variables consisted of the single tests (XIX and XX) than when they consisted of the groups of tests.

The least significant tetrad differences (T.D.'s) are obtained from arrangement A in which both pairs of variables are the groups of tests. This is the arrangement that was used when computing Tables XV to XVIII. It is, therefore, evident that a revision of variables is desirable.

The most significant T.D.'s are obtained from arrangement D in which both pairs of variables are single tests. Arrangement D, however, gives only slightly more significant T.D.'s than arrangement C in which the "Verbal" variables are groups of tests

and the "Form Perception" variables are single tests.

The reliability of data under the C arrangement is greater than under the D arrangement. Therefore, arrangement C was decided upon as the most suitable of the four arrangements of variables; it has been used for each of the four groups of subjects as shown in Tables XX to XXIII. That is to say, in the following tables the "Verbal" variables are groups of tests, as they were in Tables X to XIII, but the "Form Perception" variables are changed from groups of tests ( $FP_1$  and  $FP_2$ ) to single tests ( $fp_1$  and  $fp_2$ ), that is to Tests XIX and XX respectively.

( $M_1$  and  $M_2$ , it will be remembered, have been left unchanged.)

#### (e) THE REVISED GROUPS OF TESTS (Final Arrangement)

The following four tables give the final arrangement of variables used in this study. These matrixes are analysed fully by both the Thurstone and Spearman methods of showing what factors underlie the correlations.

In these tables (XX to XXIII) the variables are as follows:

$V_1$  (Tests I to IV);  $V_2$  (Tests V to XI)  
 $M_1$  (Test XIII) ;  $M_2$  (Test XV)  
 $fp_1$  (Test XIX) ;  $fp_2$  (Test XX)

Table XX<sup>1</sup>

CORRELATION COEFFICIENTS Boys II (n = 70)  
(Final arrangement of variables)

Variable	1. V <sub>1</sub>	2. V <sub>2</sub>	3. M <sub>1</sub>	4. M <sub>2</sub>	5. fp <sub>1</sub>	6. fp <sub>2</sub>
1. V <sub>1</sub>	—	.830	.533	.727	.326	.329
2. V <sub>2</sub>	.830	—	.596	.739	.412	.432
3. M <sub>1</sub>	.533	.596	—	.752	.324	.484
4. M <sub>2</sub>	.727	.739	.752	—	.520	.619
5. fp <sub>1</sub>	.326	.412	.324	.520	—	.705
6. fp <sub>2</sub>	.329	.432	.484	.619	.705	—

Table XXI

CORRELATION COEFFICIENTS Girls II (n = 61)  
(Final arrangement of variables)

Variable	1. V <sub>1</sub>	2. V <sub>2</sub>	3. M <sub>1</sub>	4. M <sub>2</sub>	5. fp <sub>1</sub>	6. fp <sub>2</sub>
1. V <sub>1</sub>	—	.721	.259	.514	.283	.370
2. V <sub>2</sub>	.721	—	.332	.645	.460	.553
3. M <sub>1</sub>	.259	.332	—	.486	.272	.178
4. M <sub>2</sub>	.514	.645	.486	—	.594	.585
5. fp <sub>1</sub>	.283	.460	.272	.594	—	.393
6. fp <sub>2</sub>	.370	.553	.178	.585	.393	—

<sup>1</sup>This table is the same as Table XVII.

Table XXII

CORRELATION COEFFICIENTS Boys I (n = 100)  
(Final arrangement of variables)

Variable	1. $V_1$	2. $V_2$	3. $M_1$	4. $M_2$	5. $fp_1$	6. $fp_2$
1. $V_1$	—	.802	.573	.618	.323	.479
2. $V_2$	.802	—	.649	.583	.445	.499
3. $M_1$	.573	.649	—	.700	.432	.482
4. $M_2$	.618	.583	.700	—	.474	.609
5. $fp_1$	.323	.445	.432	.474	—	.644
6. $fp_2$	.479	.499	.482	.609	.644	—

Table XXIII

CORRELATION COEFFICIENTS Girls I (n = 90)  
(Final arrangement of variables)

Variable	1. $V_1$	2. $V_2$	3. $M_1$	4. $M_2$	5. $fp_1$	6. $fp_2$
1. $V_1$	—	.819	.612	.687	.379	.482
2. $V_2$	.819	—	.685	.777	.499	.580
3. $M_1$	.612	.685	—	.711	.442	.586
4. $M_2$	.687	.777	.711	—	.547	.627
5. $fp_1$	.379	.499	.442	.547	—	.654
6. $fp_2$	.482	.580	.586	.627	.654	—

The preceding four matrixes have been analysed both by the Thurstone and Spearman techniques.

Analysis of Tables XX to XXII by the Thurstone Multiple Factor technique::

The First Factor Loadings obtained on analysing each of these matrixes by the Thurstone technique are given in the following table. The averages of the loadings given previously in Table XIV are also included in order to facilitate comparison.

Table XXIV

FIRST FACTOR LOADINGS FOR THE VARIABLES IN THE REVISED MATRIXES (TABLES XX TO XXIII)

	V <sub>1</sub>	V <sub>2</sub>	M <sub>1</sub>	M <sub>2</sub>	fp <sub>1</sub>	fp <sub>2</sub>
Boys II	.79	<u>.84</u>	.78	<u>.92</u>	.69	.75
Girls II	.72	<u>.84</u>	.58	<u>.87</u>	.68	.70
Boys I	.80	<u>.84</u>	.81	<u>.84</u>	.70	.78
Girls I	.81	<u>.89</u>	.82	<u>.88</u>	.72	.80
Average	.78	<u>.85</u>	.75	<u>.88</u>	.70	.76
Averages in Table XIV	.79	<u>.86</u>	.75	<u>.87</u>	FP <sub>1</sub> .74 <sup>1</sup>	FP <sub>2</sub> .79 <sup>2</sup>

The writer is reluctant to attempt to interpret the meaning of variations in factor loadings obtained by the Thurstone method. This matter is dealt with later when discussing a hypothetical case where it is shown that caution is needed in interpreting the loadings obtained. However, after carefully examining not only the loadings obtained for each variable but also the correlation matrixes from which they were obtained, it seems safe to conclude the following:

1. Here, as in Table XIV, all variables give evidence of a general factor common to all the tests. (Only one average loading is less than .74 and the smallest correlation in any of the four matrixes is .259.)

2. Variables  $M_2$  and  $V_2$  (the Problems tests and the "Verbal" tests involving logical processes) are more strongly saturated with the first factor (which is probably Spearman's "g") than are the other variables.

3. The variable  $M_1$  (number sequence) and the "Form Perception" variables are least strongly saturated with the first factor.

4. A comparison of the averages given in Table XXIV shows that the First Factor Loadings for the "Form Perception" tests are less when the "Form Perception" variables are single tests ( $fp_1$  and  $fp_2$ ) than when they are groups of tests ( $FP_1$  and  $FP_2$ ). A detailed comparison of Tables XXIV and XIV shows that for three of the four groups of subjects this condition exists.

It would thus appear that these single "Form Perception" tests ( $fp_1$ , XIX and  $fp_2$ , XX) are less saturated with a general factor than are the groups of "Form Perception" tests ( $FP_1$  and  $FP_2$ ) and that they are better measures of some special ability than are the groups of tests.

Proceeding with the Thurstone method of analysis (step 6) we find that this time there are a few correlations with the "Pivot" tests that lie within the range  $\pm .5$ . These are shown in the following table:

Table XXV

Group	"Pivot" Test	Variables whose Correlation with "Pivot" are less than .50
Boys II	$M_2$	none
Girls II	$M_2$	$M_{1m}$ ( $r = .486$ )
Boys I	$M_2$ ] equal $V_2$ ]	$fp_1$ ( $r = .474$ )
		$fp_1$ ( $r = .445$ ) and $fp_2$ ( $r = .499$ )
Girls I	$V_2$	$fp_1$ ( $r = .499$ )

In none of the four matrixes, however, are there negative correlations so it is impossible to proceed further with the analysis; and hence only one general factor need be postulated in order to account for the correlations.

Conclusion based on the Thurstone Method of Analysis:

Not more than one general factor need be postulated in order to account for the correlations given in any of the four matrixes (Tables XX to XXIII).

(The relative amounts of this general factor computed for each variable have been noted and discussed in the two preceding pages.)

Analysis of Tables XX to XXIII by the Spearman Two-Factor technique:

The correlation matrixes for each of these four tables were then analysed by the Spearman Two-Factor technique.

The tetrad differences for each of the four matrixes were computed. The distributions of these tetrad differences are

recorded in Table XXVII. They are illustrated graphically on the pages following (Figures 1 to 4).

The Probable Error<sup>1</sup> of the Distribution or Group of tetrads was found for each matrix. These probable errors are given in the following table:

Table XXVI

THE PROBABLE ERRORS OF THE DISTRIBUTION OF TETRADS  
FOR TABLES XX, XXI, XXII, AND XXIII

Matrix	P.E. of the Distribution	Median tetrad
Boys II	±.0414	+.075
Girls II	±.0453	+.051
Boys I	±.0339	+.087
Girls I	±.0343	+.060

In each case the median exceeds the Probable Error of the Distribution. The distributions, therefore, are not likely to be due to chance alone but rather to some significant tetrad differences.

<sup>1</sup>Spearman, Abilities of Man. Appendix (xi), Formula 16A.  
Formula for the Probable Error of the Distribution of tetrads:

$$\overline{PE}_t = \frac{1.349}{\sqrt{N}} \left[ \bar{r}^2(1 - \bar{r})^2 + (1 - R)S^2 \right]^{\frac{1}{2}}$$

where  $\bar{r}$  = the mean of the  $C_2^n$  intercorrelations

$S^2$  = the variance of the  $C_2^n$  intercorrelations (standard deviation squared)

$$R = 3\bar{r} \frac{n-4}{n-2} - 2\bar{r}^2 \frac{n-6}{n-2} \quad (n \text{ is the number of variables correlated})$$

$N$  = number of cases



Table XXVII  
DISTRIBUTIONS OF TETRAD DIFFERENCES  
FOR TABLES XX TO XXIII

Tetrad Differences	Frequency			
	Boys II Table XX	Girls II Table XXI	Boys I Table XXII	Girls I Table XXIII
.40 — .44	2	—	—	—
.35 — .39	0	—	1	—
.30 — .34	3	—	1	1
.25 — .29	6	—	0	1
.20 — .24	5	1	7	1
.15 — .19	3	5	6	10
.10 — .14	2	4	6	8
.05 — .09	9	14	10	3
.00 — .04	15	21	14	21
-.00 — -.04	15	21	14	21
-.05 — -.09	9	14	10	3
-.10 — -.14	2	4	6	8
-.15 — -.19	3	5	6	10
-.20 — -.24	5	1	7	1
-.25 — -.29	6	—	0	1
-.30 — -.34	3	—	1	1
-.35 — -.39	0	—	1	—
-.40 — -.44	2	—	—	—

These distributions are shown graphically in Figures 1, 2, 3, and 4.

Interpretation of the Distributions:

It is quite generally accepted that, in so far as the distributions do not coincide with the normal curve, the tetrads are not due to chance. The greater the deviations from the normal curve, the greater is the evidence of significant tetrad differences and, therefore, of a general or group factor or factors other than "g" underlying the correlations.

Figures 1, 2, 3, and 4 may be interpreted more meaningfully

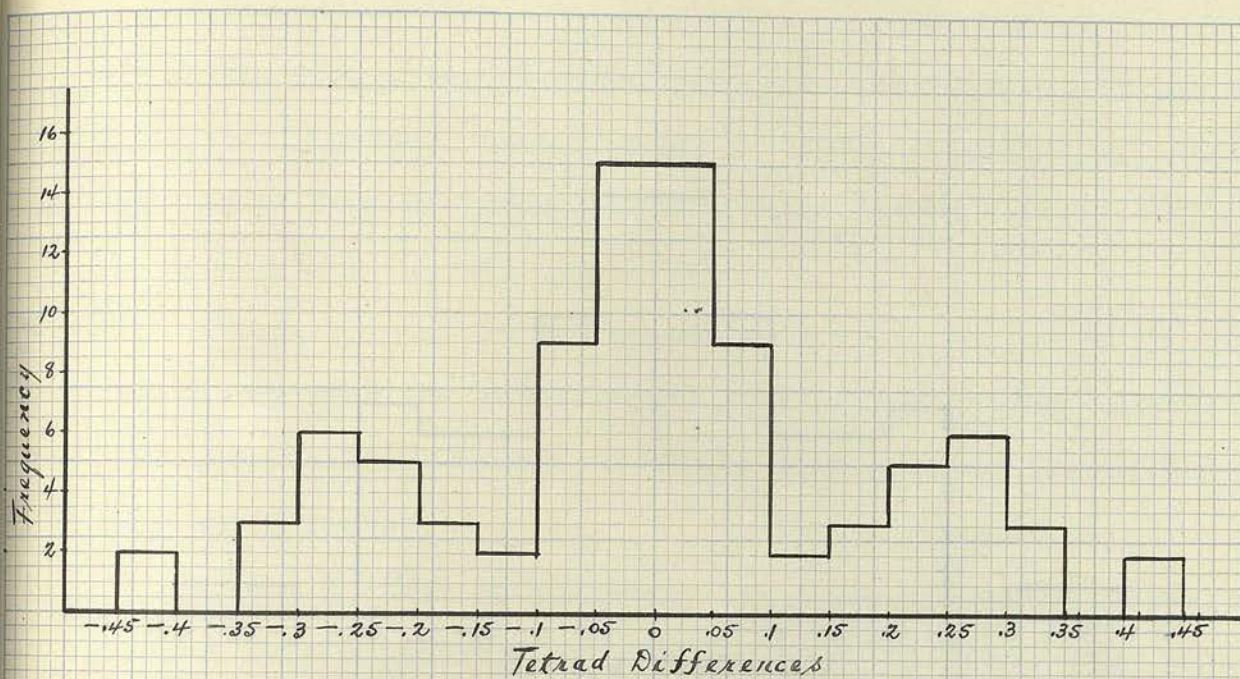


Figure 1. Distribution of Tetrad Differences in Table XX, Boys II

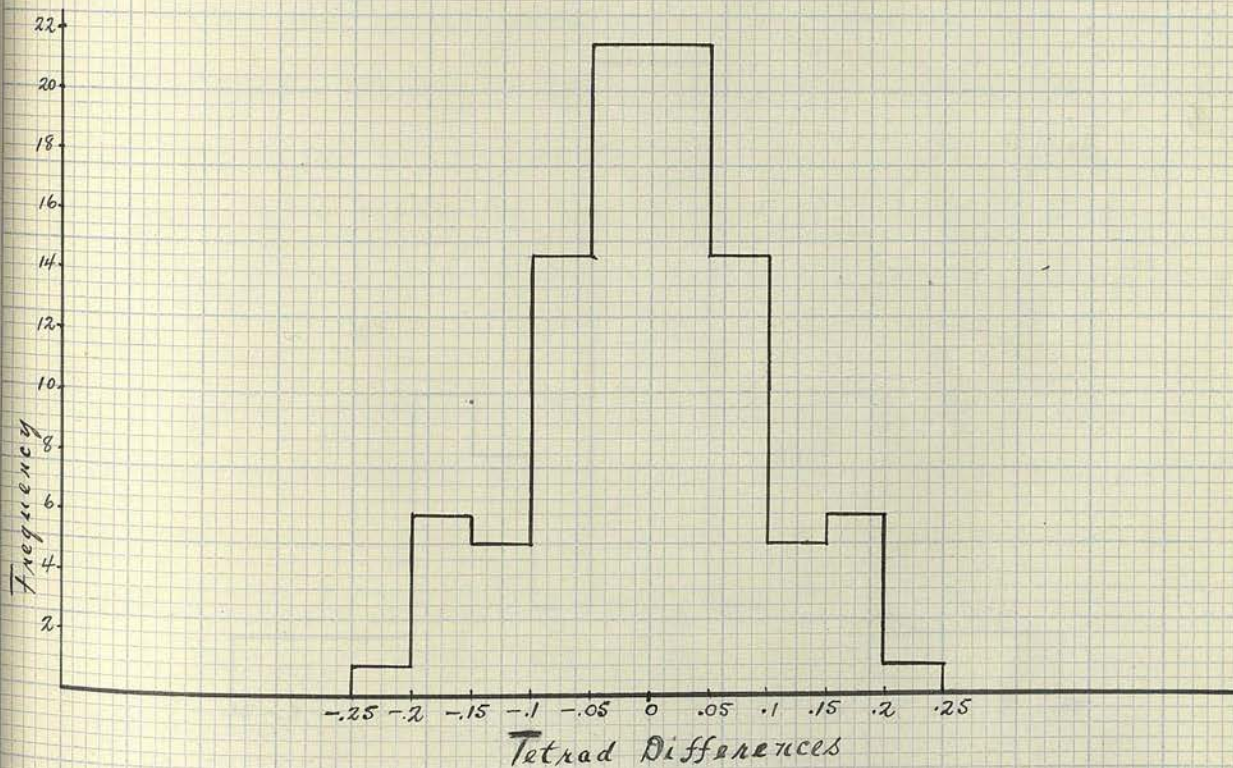
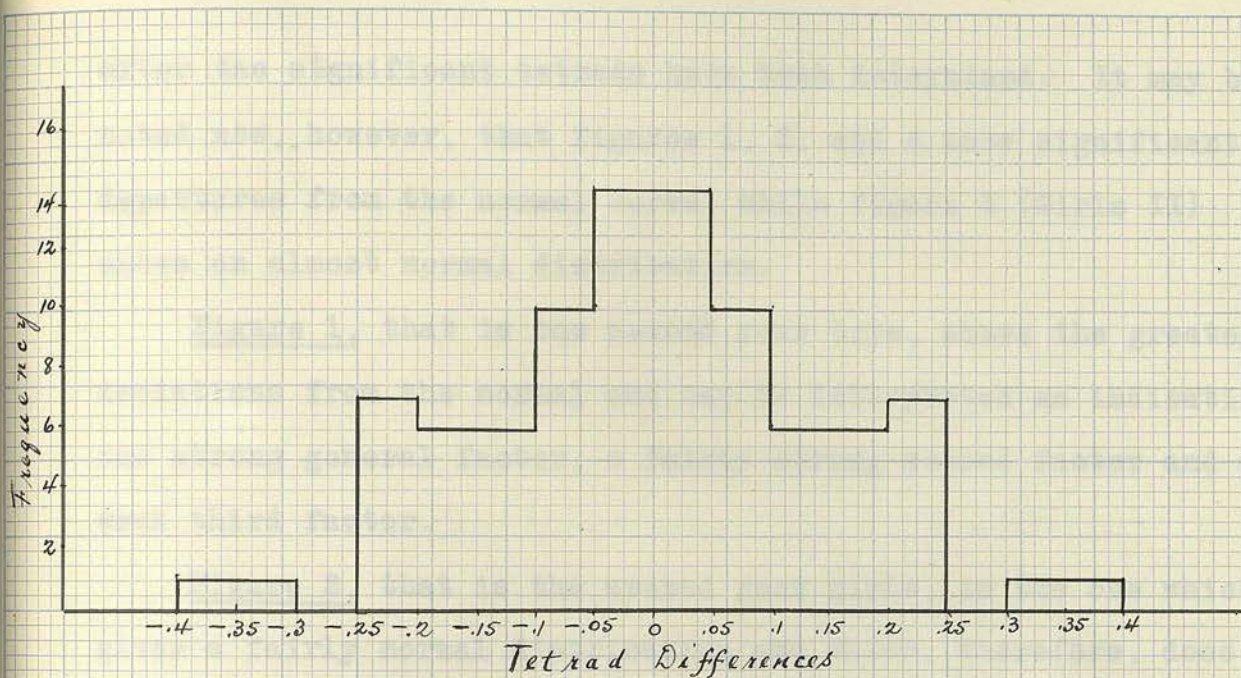
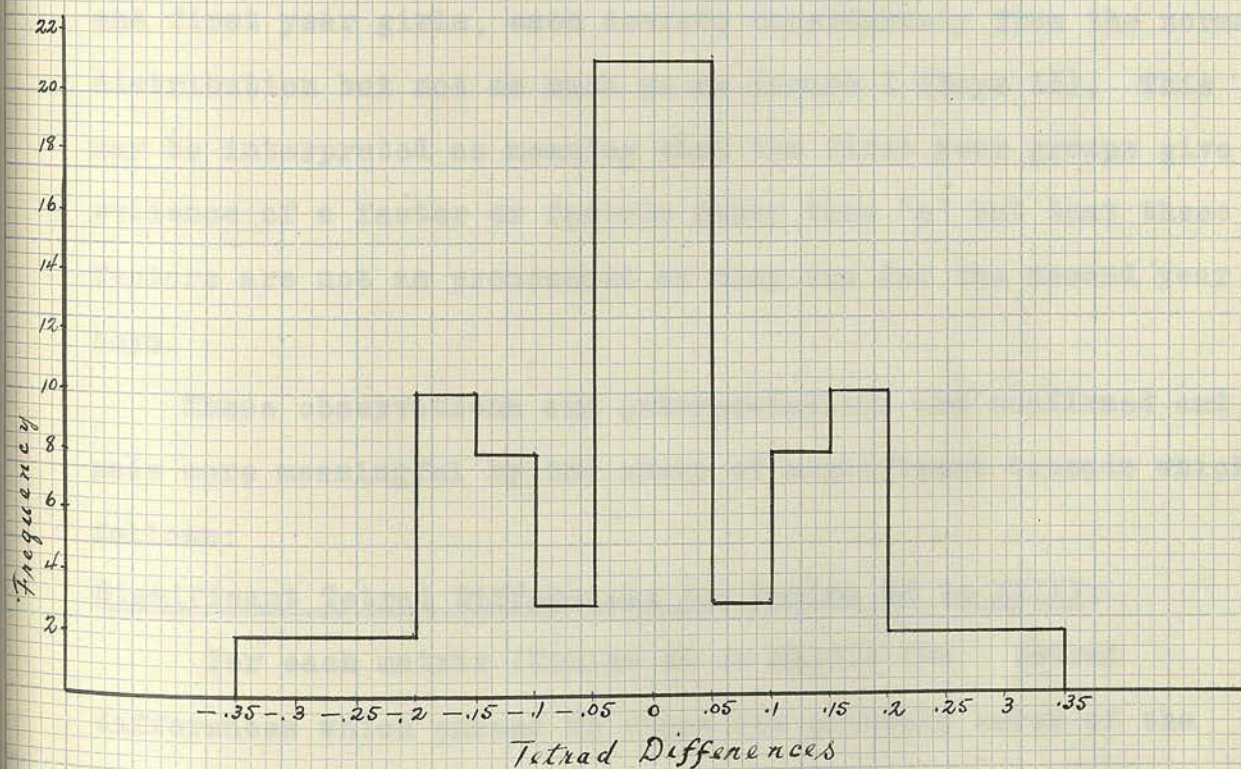


Figure 2. Distribution of Tetrad Differences in Table XX, Girls II



**Figure 3.** Distribution of Tetrad Differences in Table XX, Boys I



**Figure 4.** Distribution of Tetrad Differences in Table XX, Girls I

after the significant tetrads have been determined. It may be noted now, however, that figures 1, 3, and 4 show significant departures from the normal curve, while figure 2 (Girls II) shows an almost normal distribution.

Figure 1, that is the second year boys, shows the greatest deviations from the normal and may be interpreted as indicating one strong general factor, a fairly strong second factor and a weak third factor.

Figure 2, that is the second year girls, is the one which gives a fairly normal distribution and which, therefore, does not give evidence of any but one general factor.

Figures 3 and 4, the distributions for the first year boys and first year girls, each deviate considerably from the normal distribution but not as much so as figure I (Boys II). This may be interpreted as meaning that the first year groups give evidence of a factor or factors other than "g" but that these factors are not as pronounced as they are for the second year boys.

These observations and interpretations are confirmed and made more meaningful by the study of significant tetrads which follows:

Significant Tetrad Differences for Tables XX to XXIII:

For each matrix (Tables XX to XXIII) the tetrad differences which exceed  $3\frac{1}{2}$  times the probable error of the distribution of tetrads for that matrix were then selected and

the probable error of each of these single tetrads was computed.

As previously stated, each tetrad difference which exceeds  $3\frac{1}{2}$  times its individual probable error is considered significant. The significant tetrad differences for each matrix are recorded in Table XXVIII.<sup>1</sup>

An analysis of Table XXVIII reveals that the patterns for three of the four groups show certain marked similarities which are definitely significant. The one group that presents quite a different pattern from the others is the group Girls II. Its only significant tetrad difference is  $t_{1254}$  and this single tetrad is not significant in any of the other three groups. A probable reason for this exception is given in a footnote<sup>2</sup> where it is pointed out that the data of this group are less reliable than that of the other groups.

The significant pairs of tetrads, as given in Table XXVIII, may be summarized as follows:

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<sup>1</sup>In a few cases one of the three possible T. D.'s formed from four variables is significant while the second one is almost but not quite  $3\frac{1}{2}$  times its P. E. In Table XXVIII all the T. D.'s are recorded in pairs; the one tetrad of a pair which is not quite significant is not underlined while all those which exceed  $3\frac{1}{2}$  times their P. E. are underlined.

<sup>2</sup>This one group, Girls II, has a considerably lower average I. Q. than any of the other groups. In a previous section describing the subjects used in this research (see Tables II and III), it was noted that the average I. Q. of each class of pupils composing the group selected for study exceeded 100 except in the case of one class of second year girls which had an average I. Q. of 74. Moreover, this group, Girls II, has a smaller number of cases than any of the other groups and hence the data are less reliable than for the other groups.

Table XXVIII

SIGNIFICANT TETRADS AND THEIR PROBABLE ERRORS  
WHICH OCCUR IN TABLES XX, XXI, XXII, and XXIII

Tetrads		Tetrad Differences and their P.E.'s			
		Boys II	Girls II	Boys I	Girls I
A	$t_{1256}$	<u>.444</u> $\pm$ .078		<u>.355</u> $\pm$ .054	<u>.316</u> $\pm$ .060
	$t_{1265}$	<u>.449</u> $\pm$ .077		<u>.303</u> $\pm$ .061	<u>.295</u> $\pm$ .061
	$t_{1456}$	<u>.311</u> $\pm$ .072		<u>.201</u> $\pm$ .046	<u>.212</u> $\pm$ .049
	$t_{1465}$	<u>.342</u> $\pm$ .063		<u>.171</u> $\pm$ .047	<u>.186</u> $\pm$ .051
B	$t_{3456}$	<u>.329</u> $\pm$ .063		<u>.188</u> $\pm$ .052	<u>.188</u> $\pm$ .044
	$t_{3465}$	<u>.278</u> $\pm$ .068		<u>.223</u> $\pm$ .045	<u>.145</u> $\pm$ .051
	$t_{2456}$	<u>.266</u> $\pm$ .068			<u>.195</u> $\pm$ .052
	$t_{2465}$	<u>.296</u> $\pm$ .060			<u>.191</u> $\pm$ .052
C	$t_{2356}$	<u>.221</u> $\pm$ .068		<u>.204</u> $\pm$ .048	<u>.156</u> $\pm$ .053
	$t_{2365}$	<u>.280</u> $\pm$ .057		<u>.202</u> $\pm$ .048	<u>.192</u> $\pm$ .047
	$t_{1356}$	<u>.218</u> $\pm$ .068		<u>.213</u> $\pm$ .044	<u>.178</u> $\pm$ .051
	$t_{1365}$	<u>.269</u> $\pm$ .057		<u>.162</u> $\pm$ .051	<u>.187</u> $\pm$ .047
D	$t_{1234}$	<u>.230</u> $\pm$ .035		<u>.227</u> $\pm$ .040	
	$t_{1243}$	<u>.191</u> $\pm$ .047		<u>.160</u> $\pm$ .054	
	$t_{1246}$	<u>.200</u> $\pm$ .064		<u>.180</u> $\pm$ .051	
	$t_{1264}$	<u>.271</u> $\pm$ .052		<u>.209</u> $\pm$ .045	
E	$t_{1245}$		<u>.192</u> $\pm$ .065		
	$t_{1254}$		<u>.246</u> $\pm$ .061		
	$t_{1236}$	<u>.172</u> $\pm$ .061			
	$t_{1263}$	<u>.206</u> $\pm$ .058			

There are 2 pairs of tetrads which have significant T.D.'s for all three groups of subjects. These are:

$t_{1256}$ ,  $t_{1265}$ ;  $t_{1456}$ ,  $t_{1465}$  (Section A)

There are 2 pairs of tetrads which have significant T.D.'s for two groups of subjects. These are:

$t_{3456}$ ,  $t_{3465}$ ;  $t_{2456}$ ,  $t_{2465}$  (Section B)

There are 4 pairs of tetrads which have significant T.D.'s for one group of subjects. These are:

$t_{2356}$ ,  $t_{2365}$ ;  $t_{1356}$ ,  $t_{1365}$  and (Section C)

$t_{1234}$ ,  $t_{1243}$ ;  $t_{1246}$ ,  $t_{1264}$  (Section D)

(Where significant T.D.'s occur singly instead of in pairs, they are not noted in this summary.)

The following generalizations may be made:

(i) In all of these tetrads, except the last four (Section D), the combination of variables 5 and 6 occurs. Variables 5 and 6 are "Form Perception" tests. It, therefore, follows that these "Form Perception" tests, XIX and XX, do give evidence of some general or group factor other than "g".

(ii) Tetrads in Section D and in the first half of Section A give evidence of a weaker group factor being present due to the "Verbal" tests in the case of the two boys' groups but not in the case of the girls'.

These observations are corroborated by another method of summarizing the significant tetrads as shown in the following table:

Table XXIX

FREQUENCY OF OCCURRENCE OF VARIOUS PAIRS OF VARIABLES  
IN THE SIGNIFICANT TETRADS

r	Frequency of Occurrence in Significant Tetrads (Possible Occurrence 12)				
	Boys II	Girls II	Boys I	Girls I	Total
12	6	1	5	2	14
13	2	0	2	2	6
14	3	0	3	2	8
15	2	1	2	3	8
16	5	0	2	3	10
23	2	0	2	1	5
24	4	1	2	2	9
25	3	0	2	3	8
26	3	0	2	3	8
34	4	0	3	1	8
35	3	0	2	3	8
36	4	0	3	3	10
45	3	1	2	3	9
46	4	0	4	3	11
56	10	0	9	10	29
Total	58	4	45	44	151

Analysis of Table XXIX reveals the following:

(i) In the column of totals to the right the combination of variables 5 and 6 (the "Form Perception" tests) occurs in significant tetrads 29 times. This frequency is more than twice as great as that for any other combination of variables. This pair of variables, 5 and 6, is consistently the most frequent for all groups of subjects except Girls II.

(ii) The combination 1 and 2 (the "Verbal" tests) gives the next greatest total frequency of occurrence but this total is less than half that of the "Form Perception" pair. This pair is conspicuous only in the case of the two boys' groups.

(iii) The totals in the row at the foot of the various columns show that the number of significant tetrad differences is greatest for the group Boys II and least for Girls II. The two first year groups have almost equal totals, each of which is less than that for the second year boys.

Conclusions based on the Spearman Method of Analysis:

1. In the case of three of the four groups studied, namely, Boys II, Boys I, and Girls I, there is definite evidence of a second general factor (or group factor as it is usually called, since it underlies some tests but not all) underlying the correlations.

This second factor is indicated by the "Form Perception" tests. This factor is more marked in the case of the second year boys than for either of the first year groups of subjects.

2. In the case of the two groups of boys, there is evidence of still another group factor. This third factor, which is weaker than the second one, is precipitated by the "Verbal" tests.
3. The second year girls present a pattern curiously different from the other three groups. (A probable explanation of this exception has been given previously.)

G. SUMMARY OF CONCLUSIONS BASED ON THE ANALYSIS OF TABLES XX TO XXIII BY BOTH THE THURSTONE AND SPEARMAN TECHNIQUES:

(a) Analysis of the data for each of the four groups of subjects by the Thurstone Multiple Factor technique leads to the conclusion that only one general factor need be postulated in order to account for the correlations obtained.

(b) Analysis by the Spearman tetrad difference criterion, of the same data as in (a) for the same groups of subjects, leads to the conclusion that in the case of three of the four groups it is necessary to postulate a second general or group factor and that, for at least two of the groups of subjects, a third group factor must be postulated.

Conflict of Results:

These conflicting results, arrived at by two different methods of analysing the same data, challenged the writer to seek an explanation for the conflict. Further study of the correlation matrixes led her to question the reliability of the conclusion arrived at by the Thurstone method of analysis. No error could be found in the calculation. Therefore, the writer devised a hypothetical case in which the correlation coefficients are such as to present an almost ideal example of correlations due to more than one general factor. This hypothetical case, which is given in the footnote<sup>1</sup>, proves that the Thurstone method of factorial analysis is inadequate. Therefore, conclusion (a), given above, must be considered void while the conclusions stated in (b) appear correct.

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<sup>1</sup>Hypothetical case: The following hypothetical matrix has been

Footnote Continued:

devised in order to provide an example in which it is evident that a different factor is operating in the "Verbal" tests than that in the "Form Perception" tests.

Table XXX

## CORRELATION COEFFICIENTS OF HYPOTHETICAL DATA

Variable		a	b	c	d	e	f
"Verbal"-----	a	—	.9	.5	.5	.1	.1
	b	.9	—	.5	.5	.1	.1
"Mathematics"-----	c	.5	.5	—	.9	.5	.5
	d	.5	.5	.9	—	.5	.5
"Form Perception"-----	e	.1	.1	.5	.5	—	.9
	f	.1	.1	.5	.5	.9	—
First Factor Loading		.69	.69	.87	.87	.69	.69

This hypothetical case has been analysed by the Thurstone technique. (The First Factor Loadings are recorded in the table.) It is impossible to proceed with step (7) of the analysis since there are no negative correlations. It is, therefore, necessary to draw one of the two following conclusions: either (a) That only one general factor need be postulated to account for these correlations or

(b) That the Thurstone method of factorial analysis is inadequate.

That the first conclusion is erroneous is indicated by the following:

(1) The correlations hypothesized were chosen so as to present a case in which it was evident that the correlations were due to more than one general or group factor.

(2) Analysis by the tetrad difference criterion results in tetrad differences as great as .8 while the distribution of tetrads gives clear indication of group factors besides one general factor.

That the Thurstone method of factorial analysis is unreliable is definitely proved by Thurstone's own formula<sup>1</sup> which

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<sup>1</sup>Thurstone, L.L., The Theory of Multiple Factors. Ann Arbor, Michigan; Edwards Brothers, Inc. 1932. p.29.

Footnote Continued;

is as follows;

$$r_{ab} = a_{11} + a_{22} + a_{33} - \dots - a_{nn}$$

When only one factor need be postulated in order to account for the correlations in any given data, then

$$r_{ab} = a_{11} ; \text{ that is, } r_{ab} - a_{11} = 0$$

Substituting for the data of the hypothetical case, we have

$$.9 = .69 \times .69 ; \text{ that is, } .9 - .476 = 0$$

This is obviously impossible.

Conclusion;

One is, therefore, forced to conclude that the Thurstone method of Multiple Factor Analysis is not to be relied upon as a method of determining the number of general factors underlying all correlation matrixes. Whether or not the technique may be relied upon when analysing matrixes with negative correlations is a matter which will not be dealt with here. The above evidence is conclusive proof, however, that the technique should not be used when the correlations are all positive.

Furthermore, the usual interpretation of the meaning or significance of First Factor Loadings needs to be viewed with great caution.

In the hypothetical case the fact that the First Factor Loadings for variables a, b, e, and f are fairly high (.69) is due not to a strong general factor underlying all the correlations of any one variable but to the strong group factors common to each pair, a, b, and e, f. Hence, it is highly important that loadings computed by this method be not considered absolute measures of the amount of the first general factor attributable to any given variable. A loading can be interpreted only in the light of the correlations composing it.

Note 1; This precaution was taken when interpreting the loadings obtained from the experimental data used in this thesis.

Note 2; Since Thurstone published the Multiple Factor Analysis technique in 1931, he has advanced "A Simplified Method of Multiple Factor Analysis" (published by University of Chicago Press in 1933) which in some small degree overcomes the limitations of the method discussed here. However, it still holds that the analysis of a correlation matrix does not give a unique solution, but only the simplest possible solution to account for the correlations.

The Ultimate Conclusions are as follows:

(1) The "Form Perception" tests do give evidence of an ability different from that required for success in the "Verbal" tests.

(2) There is a general factor common to all the tests<sup>1</sup>: it is necessary to postulate also a second and third general or group factor in order to account for the correlations of the tests found in this study.

(3) For three of the four groups of subjects (Boys II, Boys I, and Girls I), it was found that a group factor underlies the correlations of certain of the "Form Perception" tests (particularly tests in the Analysis and Synthesis of Form). This group factor is strongest in the case of the group of older boys. Several of the "Form Perception" tests, however, give no evidence of a group factor but only of one general factor and separate specific factors.

(4) Another group factor of lesser strength, but wider in scope than the factor noted in (3), is indicated by the "Verbal" tests for the two groups of boys.

(5) The "Mathematical" tests do not give consistent evidence of a group factor. This seems to be due to the fact that the

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<sup>1</sup>Of the 253 correlation coefficients in Table VI, only one is negative and it is so small as to be insignificant. No negative correlations occur in any of the other tables.

Problems test is so highly saturated with the first general factor or "g", that it correlates highly with practically all the other tests.

In the next section the scores on the tests are studied in relation to success in school subjects as measured by teachers' marks.

## H. THE RELATION OF SCORES ON THE TESTS TO MARKS IN SCHOOL SUBJECTS

### The Data:

The school marks for the then current term were obtained from the teachers and correlated with scores on the tests.

The school marks are subject to the unreliabilites which usually accompany subjective marking. There was no attempt to get highly accurate marks from the teachers. The teachers, in fact, did not know that any special use was to be made of the marks; they were merely asked by their Principal for a list of the term class marks in each subject. The marks, therefore, are subject to various errors but, since no teacher taught more than one class of one year, the chances of a constant error for all groups studied is very small.

The test scores used are those used in computing the correlations given in Tables XX, XXI, XXII, and XXIII and, therefore, the intercorrelations of variables 1 to 6 in the following matrixes are the same as those already given. It has been necessary to repeat them in order to see the relation of the correlations of these six test variables with the school-subjects' variables.

### The Intercorrelations of the Tests and School Subjects:

These correlation coefficients for each of the four groups of subjects are given in the following tables:

In these tables the variables 7, 8 and 9 represent English and History, Mathematics, and Science, respectively.

Table XXXI

CORRELATION COEFFICIENTS OF TEST SCORES AND SCHOOL MARKS  
(Boys II n = 70)

Variable	1. $V_1$	2. $V_2$	3. $M_1$	4. $M_2$	5. $fp_1$	6. $fp_2$	7. E.&H.	8. Math.	9. Sc.
1. $V_1$	—	.830	.533	.727	.326	.329	.685	.496	.541
2. $V_2$	.830	—	.596	.739	.412	.432	.621	.433	.539
3. $M_1$	.533	.596	—	.752	.324	.484	.596	.590	.452
4. $M_2$	.727	.739	.752	—	.520	.619	.654	.632	.600
5. $fp_1$	.326	.412	.324	.520	—	.705	.296	.481	.499
6. $fp_2$	.329	.432	.484	.619	.705	—	.407	.574	.406
7. E.&H.	.685	.621	.596	.654	.296	.407	—	.571	.417
8. Math.	.496	.433	.590	.632	.481	.574	.571	—	.590
9. Sc.	.541	.539	.452	.600	.499	.406	.417	.590	—

Table XXXII

CORRELATION COEFFICIENTS OF TEST SCORES AND SCHOOL MARKS  
(Girls II n = 61)

Variable	1. $V_1$	2. $V_2$	3. $M_1$	4. $M_2$	5. $fp_1$	6. $fp_2$	7. E.&H.	8. <sup>1</sup> Math.	9. Sc.
1. $V_1$	—	.721	.259	.514	.283	.370	.536	.228	.372
2. $V_2$	.721	—	.332	.645	.460	.553	.581	.359	.530
3. $M_1$	.259	.332	—	.486	.272	.178	.346	.441	.502
4. $M_2$	.514	.645	.486	—	.594	.585	.564	.371	.656
5. $fp_1$	.283	.460	.272	.594	—	.393	.309	.140	.361
6. $fp_2$	.370	.553	.178	.585	.393	—	.295	.292	.441
7. E.&H.	.536	.581	.346	.564	.309	.295	—	.384	.633
8. Math.	.228	.359	.441	.371	.140	.292	.384	—	.433
9. Sc.	.372	.530	.502	.656	.361	.441	.633	.433	—

<sup>1</sup>Since some of the girls had not studied Algebra or Geometry, the Arithmetic score has been taken to represent the Mathematics score in the case of all the girls of both groups.

Table XXXIII

CORRELATION COEFFICIENTS OF TEST SCORES AND SCHOOL MARKS  
(Boys I n = 100)

Variable	1. V <sub>1</sub>	2. V <sub>2</sub>	3. M <sub>1</sub>	4. M <sub>2</sub>	5. fp <sub>1</sub>	6. fp <sub>2</sub>	7. E.&H.	8. Math.	9. Sc.
1. V <sub>1</sub>	—	.802	.573	.618	.323	.479	.634	.683	.669
2. V <sub>2</sub>	.802	—	.649	.583	.445	.499	.588	.655	.682
3. M <sub>1</sub>	.573	.649	—	.700	.432	.482	.468	.616	.615
4. M <sub>2</sub>	.618	.583	.700	—	.474	.609	.513	.684	.632
5. fp <sub>1</sub>	.323	.445	.432	.474	—	.644	.330	.506	.513
6. fp <sub>2</sub>	.479	.499	.482	.609	.644	—	.354	.538	.580
7. E.&H.	.634	.588	.468	.513	.330	.354	—	.596	.567
8. Math.	.683	.655	.616	.684	.506	.538	.596	—	.757
9. Sc.	.669	.682	.615	.632	.513	.580	.567	.757	—

Table XXXIV

CORRELATION COEFFICIENTS OF TEST SCORES AND SCHOOL MARKS  
(Girls I n = 90)

Variable	1. V <sub>1</sub>	2. V <sub>2</sub>	3. M <sub>1</sub>	4. M <sub>2</sub>	5. fp <sub>1</sub>	6. fp <sub>2</sub>	7. E.&H.	8. Math.	9. Sc.
1. V <sub>1</sub>	—	.819	.612	.687	.379	.482	.599	.491	.629
2. V <sub>2</sub>	.819	—	.685	.777	.499	.580	.553	.496	.604
3. M <sub>1</sub>	.612	.685	—	.711	.442	.586	.559	.482	.553
4. M <sub>2</sub>	.687	.777	.711	—	.547	.627	.597	.532	.636
5. fp <sub>1</sub>	.379	.499	.442	.547	—	.654	.322	.423	.331
6. fp <sub>2</sub>	.482	.580	.586	.627	.654	—	.362	.519	.482
7. E.&H.	.599	.553	.559	.597	.322	.362	—	.405	.644
8. Math.	.491	.496	.482	.532	.423	.519	.405	—	.589
9. Sc.	.629	.604	.553	.636	.331	.482	.644	.589	—

Analysis of the Tables XXXI to XXXIV by the Spearman Method:

An analysis of these matrixes by the tetrad difference criterion shows somewhat less consistent patterns than were found for the intercorrelations of the tests alone. However, some significant tetrad differences do occur. These significant TD's, introduced by the school subjects, are given in Table XXXV. This table does not include the TD's due to the intercorrelations of the tests themselves since they have been given previously in Table XXVIII.

Significant Tetrad Differences. (Summary of Table XXXV)

There is 1 pair of tetrads which has significant TD's for two groups of subjects (the two Boys' groups)  
These are:

$t_{5678}$  and  $t_{5687}$  (Section A)

There are 2 pairs of tetrads which have significant TD's for one group of subjects (a boys' group in each case)

$t_{5689}$ ,  $t_{5698}$  and  $t_{1268}$ ,  $t_{1286}$  (Section B)

There are 5 single tetrads which have significant TD's for two groups of subjects. These all contain the combination of variables 1 and 2. They are:

$t_{1298}$ ;  $t_{1258}$ ,  $t_{1285}$ ;  $t_{1259}$ ,  $t_{1295}$  (Section C)

There are 9 remaining single TD's which are significant for only one group of subjects. Of these nine the combination of variables 1 and 2 is present six times.

As in Table XXVIII, the group Girls II presents a curious variation for the patterns for the other groups.

GENERALIZATIONS AND CONCLUSIONS BASED ON ANALYSIS OF TABLES XXXI TO XXXIV.

(1) When the school marks are correlated with the test scores, the tetrad patterns do not show the same high degree

Table XXXV

SIGNIFICANT TETRAD DIFFERENCES WHICH OCCUR IN  
TABLES XXXI TO XXXIV DUE TO SCHOOL SUBJECTS

Tetrads	Tetrad Differences and their Probable Errors			
	Boys II	Girls II	Boys I	Girls I
A				
t <sub>5678</sub>	<u>.233</u> ±.058		<u>.206</u> ±.048	
t <sub>5687</sub>	<u>.207</u> ±.059		<u>.205</u> ±.048	
B				
t <sub>5689</sub>	<u>.221</u> ±.046		<u>.195</u> ±.050	<u>.181</u> ±.052
t <sub>5698</sub>	<u>.130</u> ±.067		<u>.212</u> ±.047	<u>.213</u> ±.048
t <sub>1268</sub>	<u>.334</u> ±.062			<u>.186</u> ±.046
t <sub>1286</sub>	<u>.262</u> ±.075			<u>.160</u> ±.055
C				
t <sub>1289</sub>	<u>.223</u> ±.066		<u>.141</u> ±.059	<u>.185</u> ±.048
t <sub>1298</sub>	<u>.256</u> ±.059		<u>.169</u> ±.039	<u>.170</u> ±.051
t <sub>1258</sub>	<u>.258</u> ±.059		<u>.194</u> ±.037	
t <sub>1285</sub>	<u>.195</u> ±.070		<u>.102</u> ±.052	
t <sub>1259</sub>	<u>.238</u> ±.058		<u>.191</u> ±.039	
t <sub>1295</sub>	<u>.191</u> ±.066		<u>.113</u> ±.050	
D				
t <sub>1238</sub>	<u>.259</u> ±.055			<u>.165</u> ±.050
t <sub>1283</sub>	<u>.194</u> ±.068			<u>.179</u> ±.047
t <sub>1248</sub>	<u>.210</u> ±.048			
t <sub>1284</sub>	<u>.158</u> ±.059			
t <sub>1279</sub>				<u>.165</u> ±.050
t <sub>1297</sub>				<u>.179</u> ±.047
t <sub>1759</sub>	<u>.206</u> ±.046			
t <sub>1795</sub>	<u>.182</u> ±.059			
t <sub>4679</sub>				<u>.116</u> ±.050
t <sub>4697</sub>				<u>.174</u> ±.042
t <sub>3679</sub>				<u>.108</u> ±.052
t <sub>3697</sub>				<u>.177</u> ±.041
t <sub>1239</sub>		<u>.225</u> ±.069		
t <sub>1293</sub>		<u>.238</u> ±.062		
t <sub>1249</sub>		<u>.201</u> ±.062		
t <sub>1294</sub>		<u>.233</u> ±.059		

of consistency for the various groups of subjects as was present when the correlation coefficients of test scores alone were considered.

(2) Again, however, the group Boys II shows a greater differentiation of ability than any of the other groups, while Girls II show the least; and again, Boys I show slightly greater differentiation than do Girls I.

(3) The most consistently significant tetrad differences are the four which contain the combination of variables 5 and 6, ("Form Perception" tests). They are as follows:-

$t_{5678}$ ,  $t_{5687}$  and  $t_{5689}$ ,  $t_{5698}$

That is to say, that the "Form Perception" tests again give evidence of a general factor other than "g".

The variables 7 and 8, which appear in the first and most significant of these tetrads represent the school subjects English and History, and Mathematics, while the variables 8 and 9, represent Mathematics and Science. The latter pair give slightly less significant tetrad differences than the former.

Therefore, one may conclude that success in these "Form Perception" tests is slightly more closely related to success in Science than to success in English and History. Since however, both the Science and the English and History give significant tetrad differences when correlated with the "Form Perception" tests, we must conclude that success in the "Form Perception" tests, is not closely related to success (as measured by these teachers' marks) in any of the school subjects considered in this study.

(4) The variables 1 and 2 ("Verbal" tests) give marked evidence of a group factor in the case of the second year boys and some evidence of it for all four groups of subjects. The most significant of the tetrad differences having this pair of variables are as follows:

$t_{1268}$ ,  $t_{1286}$  and  $t_{1289}$ ,  $t_{1298}$ .

The other tetrads containing variables 1 and 2, which have significant tetrad differences for more than one of the four groups are as follows:

$t_{1258}$  and  $t_{1259}$

In the above six significant tetrads the variable 7, (English and History) does not occur at all. The variables which do occur with the "Verbal" pair, namely 5, 6, 8 and 9, are the "Form Perception" tests and the school subjects, Science and Mathematics. (The latter variable (8) occurs in every one of the first nine most significant tetrads).

It therefore appears that the "Verbal" tests have considerable in common with the school subjects, English and History, but that they measure some ability different from that measured by the teachers' marks in Mathematics and Science.

(5) The analysis does not reveal a group factor due to the "Mathematical" tests (variables 3 and 4).

Tables XXXI to XXXIV show some inconsistencies in the intercorrelations among the various school subjects. Con-

sequently conclusions based on these marks in school subjects<sup>1</sup>, should be considered as subject to modification when more reliable measures of success in school subjects are obtained. However the conclusions stated in the preceding section seem justifiable, and in the opinion of the writer, it is quite likely that further refinements of measures and methods in the future, will produce results which will give still greater evidence of the existence of group factors tending to make for success in various phases of the school curriculum.

These conclusions are supported by those of Dr. Earle who, after intercorrelating the marks in each of the school subjects for the third year pupils as well as for the first and second year pupils, stated, in the report referred to in the footnote below:

"There can be no doubt whatever as to the existence of "group" factors at the Third Year stage." Writing of the

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<sup>1</sup> A more detailed analysis of the school marks for these pupils, (an analysis in which intercorrelations for each of the separate school subjects have been found) has been made by Dr. Earle. In his report to the Scottish Council for Research in Education, January, 1933, Dr. Earle reports the following:

"Both First Year Boys and First Year Girls fail to show a higher relation between English, History and Grammar than between English and Science or English and Mathematics. Only in the case of Second Year Boys is there a definitely higher relation between the English subjects than between English and Science or Mathematics.

"But Mathematics and Science are more highly related to each other than they are to English, a result which is consistent with all the other results so far considered.

"This peculiarity in regard to tests in English and History is due without doubt to the unreliability of the measures used."

results obtained for the first and second year pupils (the same data as used in this thesis), he says: "They demonstrate the existence of differences in ability in individuals as early as the first year of a Post-Primary Course and they show that these differences become more marked in the second year. They also provide a satisfactory basis for the belief that the abilities required in English and History differ from those required in Mathematics even in the first year."

### I. Summary of Chapter III, the Experimental Study

The Subjects were 321 pupils of the First and Second Years of a Scottish Post-Primary School. (Average age 13 years.)

The Data consist of (a) the scores on a large battery of tests (total number of items is 1154), which have been classified under the three headings "Verbal", "Mathematical" and "Form Perception", (b) the marks in school subjects assigned by teachers.

The data have been divided on the basis of sex and school year, into four groups, namely, Boys I, Girls I, Boys II and Girls II. The data for each group of subjects have been analysed separately throughout the study.

#### Procedure and Observations.

(1) The scores obtained from the tests were grouped into the main classes given above ("Verbal", "Mathematical", and "Form Perception"). The intercorrelation of these three groups of tests were computed for each of the four groups of subjects and were found to support the thesis that "Form Perception" tests test some ability or abilities other than that tested by the so-called "Verbal" tests. The Second Year boys showed the greatest differentiation while the First Year Girls showed the least.

(2) The intercorrelation coefficients for each of the separate tests (23 variables) were found for the Second Year boys. An analysis of this large correlation matrix, by the Thurstone Multiple Factor technique, revealed only one general factor underlying the correlations while a partial analysis by the Spearman tetrad criterion showed that some group factors as well as one general

factor need be postulated in order to account for the correlation found.

(3) On the basis of the analysis of the correlations of the single tests made for Boys II, some tests were eliminated and others grouped so as to have two groups of each of the three main types of tests, i.e., two "Verbal"; two "Mathematical"; and two "Form Perception." These six variables were designated

$V_1, V_2; M_1, M_2; \text{ and } FP_1, FP_2$ , respectively.

(4) Intercorrelation coefficients of these six variables were then computed for each of the four groups of subjects, and the four correlation matrixes were analysed by the Thurstone technique, which, as in the previous analysis, revealed no second general factor.

(5) It seemed desirable to investigate various arrangements of the variables. Accordingly four arrangements were analysed and compared for the one group, Boys II. This resulted in changing the "Form Perception" variables from groups of tests to the two single tests which intercorrelated most highly. (These single tests, Tests XIX and XX, were designated  $fp_1$  and  $fp_2$ )

(6) Intercorrelation coefficients of this final arrangement of variables were then found for each of the four groups of subjects. These matrixes were fully analysed by both the Thurstone and Spearman techniques.

(7) Analysis by the Thurstone technique revealed no second general factor while the Spearman technique gave clear indication of one due to the "Form Perception" tests for all groups of subjects except Girls II, and indication of a third group factor, introduced by the "Verbal" tests, in the case of each of the groups of Boys,

(8) This conflict of results challenged the writer to question the validity or reliability of the Thurstone Multiple Factor Analysis technique. Accordingly she devised and analysed a hypothetical case which proves conclusively that the Thurstone method of factor analysis is inadequate.

(9) The conclusions arrived at by the Spearman method of analysis are accepted as the correct ones. Even if some of the current criticisms of the Spearman theory and technique should, in future, prove to be justifiable, there will not likely be grounds for refuting or disproving major findings as arrived at by the method used in this study.

(10) The test scores were next correlated with the teachers' marks in school subjects. The correlation coefficients thus obtained were analysed by the tetrad criterion and again the "group" factors, or as Spearman prefers to call them overlapping "specific" factors were seen to be present.

### Conclusions.<sup>1</sup>

(1) Since all of the coefficients of correlation of both the tests and the school subjects are positive, that would seem sufficient evidence of a general factor common to all the tests and the school subjects.

(2) At least two "group" factors, as well as the "general" and "specific" factors, are clearly indicated and are discussed in (3) and (4) below. The "Form Perception" tests do give evidence of ability other than that required for success in the

"Verbal" and "Mathematical" tests and school subjects.

<sup>1</sup>. All conclusions are based on data attained from High School pupils ranging in age from 11 to 15 years (average age; 13 years).

(3) Certain "Form Perception" tests give evidence of a "group" factor, of limited range, in the case of each of three of the four groups of subjects. This "group" factor, which we will designate an "FP" group factor, is not equally prominent in all the "Form Perception" tests. An analysis of the correlations of the separate tests shows that there are various "specific" factors. This "FP" group factor is strongest for tests of Analysis and Synthesis of Form.

(4) The "Verbal" Tests give evidence of a "group" factor in each of the two Boys' groups; and there is some indication of it in the case of the Second Year Girls. This factor which we will designate a "V" factor, is not as dominant as is the "FP" factor but it is much more extensive.

(5) The tests, as analysed in this study give no clear evidence of a "Mathematical" group factor. The data, however give one reason to think that, if the separate "Mathematical" sub-tests had been correlated with the other tests, two "group" factors would likely have been precipitated--one a "Problems" or "Reasoning" factor with very high "g" saturation, the other a "Numerical" or "Number Sequence" factor with less "g" saturation.

(6) An analysis of the test data in relation to marks on school subjects indicated that the "FP" factor is not closely related to success in any of the school subjects considered, but that it is slightly more closely related to success in Science than to success in English and History. The "V" factor (usually called a "Verbal" factor) has considerable in common with English and History but is quite different from ability measured by teachers' marks in Mathematics and Science.

### Interpretation.

These results may be interpreted as meaning that differentiation of mental ability does exist as early as the First Year of High School (average age  $12\frac{1}{2}$  years). Differentiation is greater for the boys than for the girls and is greater for the IIInd year boys than for the Ist year boys. The IIInd year girls, however, fail to show greater differentiation than the Ist year girls.

To venture to interpret what these various abilities are is to tread on very speculative ground at the present time. Whether these "group" factors are due to differences in one's ability to deal with different types of content, or whether due to differences in the structure of the tests involving different types of psychological processes, or whether such psychological factors as perseveration, oscillation, and speed are the cause of these "group" factors, it is impossible to ascertain until further research elucidates the matter. Current studies will be discussed in the next chapter.

In the meantime it is important to recognize that the existence of differentiable mental abilities seems to be well established.

Caution: The statement that the existence of differentiable mental abilities is established should not be taken to mean that all persons show equal differentiation of mental abilities. Some individuals may show marked differentiation while others may show very little. That is to say for some individuals the general ability "g" may be so dominant as to eclipse any evidence

of special abilities if such exist, while for others the general ability may be eclipsed by the special abilities. For instance in this study some subjects stood consistently in the same quartile for all the tests, thus indicating a dominant "g" factor (perhaps due to persistence of motive), while some others stood in the highest quartile for some tests and in the lowest for others. Whether this variation in the dominance of the general ability is due to inherent differences in the nature of this ability or whether due to perseverance and various other personality traits need not be discussed here. It is important, however, that cognizance should be taken of these individual variations if we are to avoid the errors of former psychologists who claimed that general intelligence was the all-important factor. The results obtained do show that a large proportion of individuals give evidence of "group" factors in mental ability, but the fact should not be overlooked that some individuals do not give such evidence of differentiation.

#### Practical Significance.

As previously stated in the introductory chapter it is highly important for practical purposes of educational and vocational guidance that we know more of the nature of mental ability in order to be able to measure it more adequately. The conclusions resulting from the present study give support to the theory that there are "group" factors in mental ability and that it is therefore necessary to abandon the practice of measuring ability in terms of a single score or I. Q., obtained from a heterogeneous battery of tests or test-items, and to

recognize that various component abilities must be measured and seen in their relationship to each other and to the total setting if psychological diagnosis of the individual is to be worthy of the name.

## APPENDICES

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## APPENDIX A.

SOME CURRENT RESEARCH.

Besides the extensive researches into the nature of mental ability made by Spearman and Kelley, the research studies made by the London Institute of Industrial Psychology, by Burt, Cox, Hull, Rogers, Davey, Anderson, by Patterson et al. of Minnesota, and more recently by Line, Fortes, Stephenson, Jorgenson, Alexander and others, form valuable contributions to the endeavour to differentiate mental abilities. A review and discussion of most of the important researches in this field up to 1928 appears in Kelley's "Crossroads in the Mind of Man" and will not be included here. Of the more recent studies, that of Stephenson is the most comparable to the present study.

Stephenson gave a battery of verbal and of non-verbal group tests to 1037 girls. The batteries consisted of a total of 306 items or test units; the subjects ranged in age from 8 years 6 months to 13 years, 11 months. Of this group, 88% were within the age range 10 to 12 years inclusive; the average age was 11 years, 3 months. Attention should be called to the fact that this average is almost two years younger than that of the subjects used in the present study (see p.15). In making further comparison of the procedure of the two studies it is worthy of note that while Stephenson used about three times as many subjects as did the present writer, the tests used by the latter consisted of more than three times as many test units (ratio 1154;306), and the total testing time was more than three times as long.

The following are some of Stephenson's conclusions:-

"1. The non-verbal and verbal subtests have a high correlation, amounting to .82 for a summed correlation for many subtests of both kinds. The fact stands in opposition to the opinions that have sometimes depicted the two abilities as independent.

.....

"5. On closer examination the evidence was against any group factor in the non-verbal tests, but was in favour of one group factor extending rather evenly throughout the verbal subtests.

"6. On the whole the indications are that this V factor extends through all verbal abilities and therefore may be called a general factor, V, (as contrasted with the universal general factor which is found in both verbal and non-verbal subtests alike)....."

For the most part the findings of the two studies are in remarkable harmony. Both studies demonstrate the existence of a factor common to the verbal and non-verbal tests, while the "V" factor postulated by Stephenson appears to be the same as the "V" factor found by the present writer. Regarding the non-verbal factor, however, the findings differ, but the difference may reasonably be attributed to the age difference of the subjects.

1. Regarding Stephenson's conclusion No.1 it should be noted that the high correlation of .82 is much higher than the correlation actually found. The actual correlation was  $.65 \pm .03$  and it was found by correlating only four of the eight non-verbal tests with seven of the verbal tests. Then Stephenson writes, "assuming that other subtests would provide correlations similar to those in Table 1, (that is similar to the eleven tests selected (, a battery of very many non-verbal subtests would correlate .82 with a battery of very many verbal subtests.)" Since the subtests which Stephenson excluded from his group are ones which inter-correlated on the whole somewhat less highly than the ones selected, the justifiability of such an assumption seems questionable. The correlation actually obtained, namely .65, is in remarkable agreement with the correlation found by the writer for the groups of First Year pupils (see p.25;  $r = .67$  for the First Year girls and .56 for First Year boys.)

In point 5 of his conclusions, Stephenson states that the evidence is against any group factor in the non-verbal tests, while the present writer finds that, for three of the four groups of subjects tested, a group factor does underlie the correlations of certain of the "Form Perception" tests. Several of the "Form Perception" tests, however, give no evidence of a group factor but only of one general factor and independent specific factors. Hence, both agree in concluding that there is no single factor (apart from "g") which is common to all non-verbal (or to all "Form Perception") tests, but our conclusions differ in that the present writer postulates a group factor common to a few, though not to all of the non-verbal ("Form Perception") tests, while Stephenson postulates no group factor among them. The group factor found in the present study is strongest in the case of the group of second year boys, the average age of which is 14 to 15 months greater than that of the first year pupils. This latter fact, coupled with the fact that the subjects used by Stephenson were still younger than the youngest group used by the writer, would seem to indicate that the difference in the findings in the two studies is due to age differences. Stephenson's findings, viewed in conjunction with those of the present study, give further support to the belief that differentiation of abilities is a matter of maturation and that it develops earlier in boys than in girls.

It would seem that Professor Burt was close to the truth of the matter when in his Presidential address to the British

Association for the Advancement of Science in 1923, he said; "Nor do these special abilities, though presumably inborn, declare themselves at so young an age as the more general. Specialization during the first twelve years of childhood is the exception rather than the rule; the young child contains the germ of every faculty; age alone betrays our idiosyncracies. Adolescence is pre-eminently the period when many of the localized talents and special interests seem for the first time to mature."

Many studies, with subjects older than those used by the writer, notably studies of the National Institute of Industrial Psychology<sup>1</sup>, of Cox<sup>2</sup>, and Hull<sup>3</sup>, and the Minnesota Mechanical Ability Study<sup>4</sup>, have indicated the existence of abilities different from the ability required for tests that are chiefly verbal in content. There is however, even with the more mature subjects, no acceptable evidence of any one broad factor common to all non-verbal tests<sup>5</sup> (except the "g" factor".)

Therefore while for teen age and adult subjects, group factors of various breadths appear to underlie non-verbal and even "Form Perception" tests, no one group factor is common to them all and also since all verbal tests appear to have a common factor, other than "g", it would seem that some non-verbal tests, such as certain of "Form Perception" ones would probably give purer measures of "g" than do verbal ones. This hypothesis has already been

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<sup>1</sup>,<sup>2</sup>,<sup>3</sup> and <sup>4</sup> Bibliography; 10,8,21, and 31.

<sup>5</sup>. The tests used in these last named studies have been mostly "Performance" tests and "Mechanical Ability" tests.

supported by the work of Line<sup>1</sup> and of Fortes<sup>2</sup>. In fact these latter psychologists and Spearman consider that "Form Perception" tests when constructed along certain lines, are so little affected by "group" factors as to be almost pure measures of "g".

It is evident that further research is needed before conclusions can be made with confidence. Not only is it necessary to have more data analysed by methods more reliable than now exist, but it is highly important that the influence of additional factors<sup>3</sup> such as environment, speed, motivation, perseveration, oscillation, structure and method of presentation of tests, and various personality factors be investigated and given due consideration in future studies.

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1. and 2. Bibliography 29 and 12.

3. Some recent important contributions regarding these additional factors are to be found in Bibliography, numbers: 25, 30, 33, 34, 40 and 51.

## APPENDIX B

### CURRENT THEORIES

Although there is by no means unanimity of opinion regarding the nature of mental ability, and the results of experimental studies frequently appear to be much at variance with one another, yet there is a trend towards harmony that is very promising. In a recent letter to Professor Spearman, Dr. Otis asked (somewhat optimistically undoubtedly, but none the less significantly); "Are we not now all in agreement that there is a general factor common to all intellectual activities, that there are many factors each specific to one and only one ability and that there are still other factors called group factors that are common to some but not to all of these?"<sup>1</sup> Of this statement, however, Spearman says, "So far as it goes, there appears to me nothing wrong about it", but he also says, "This triple classification becomes futile unless some limiting condition be introduced".<sup>2</sup> Many other psychologists refuse to accept this threefold classification even when limitations are introduced. Hence, while there is a tendency for widely divergent theories to be converging, it is evident that agreement has not yet been reached. It is the purpose of this chapter to outline present day theories and discuss briefly the outstanding controversial issues.

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<sup>1</sup> and <sup>2</sup>.Spearman, The Factor Theory and Its Troubles. J. of Educ. Psychol. Nov. 1933. p.598.

A discussion of current theories of the nature of mental ability inevitably centres around the work of Spearman. Spearman's study published in 1904, marks the turning point from purely philosophical theorizing about the nature of mental ability to the present method of formulating theory on the basis of mathematical analysis of quantitative data.<sup>1</sup> These newer theories are called "factor theories" since they describe ability in terms of component factors.

#### RESEMBLANCE OF NEW THEORIES AND OLD

Although this chapter does not deal with early theories, it is of interest to note that many of the current theories bear striking resemblances to the older ones. Old theories recur repeatedly dressed in new clothes. A good illustration of this fact is found in comparing the "group factors"<sup>2</sup> postulated in most current theories with the "faculties" of the classical Psychologists. "Faculty" Psychology was supposed to have been given the final death blow by James at the end of the 19th century, but as Murphy has said in his "History of Psychology", "The faculty Psychology has been buried repeatedly

<sup>1</sup>It should be noticed that the practice of finding mathematical correlations between tests was introduced in 1901 by Wissler and followed by Thorndike in 1902, i.e. two years prior to Spearman's epoch-making publication. It is also true that Spearman is undoubtedly greatly indebted to Wundt, the father of experimental Psychology, but that does not minimize the importance of his contribution.

<sup>2</sup>A "group factor", as defined by Spearman is "a commonality among specific factors". It is more frequently expressed as "a factor that is common to some intellectual activities but not to all of them."

and has come from the grave, put on its apparel and gone on again." Spearman expressed the same idea when he said "faculties have a way of losing every battle but always winning the war." It does seem as though "group factors" of current Psychology bear considerable resemblance to the obsolete "faculties". They are, however, arrived at in a totally different manner, namely by the method of precise mathematical analysis, instead of by mere introspection, and they are viewed as representing aspects of mental functioning or processes, rather discrete modes of functioning. When Psychologists who hold "group factor" theories have been accused of expelling faculties from Psychology only to re-admit some of them through the back door in the guise of group factors, the reply has quite properly been made that such factors must satisfy the "tetrad janitor" or other statistical criterion, before being admitted.

### CURRENT THEORIES (FACTOR THEORIES)

The most widely reputed current theories of mental ability are the following:

- (a) Spearman's Two-Factor Theory. (Frequently described by other Psychologists as a One-Factor Theory).
  - (b) Kelley's Group Factor Theory or Theory of Mental Traits.
  - (c) Thorndike's theory based on the Doctrine of Connectionism.
  - (d) Thomson's Sampling Theory.
  - (e) Thurstone's Theory of Multiple Factors.
- (The Hotelling process of finding the "Principal Components of a Complex of Statistical Variables" also implies a Multiple Factor Theory).
- (f) The Theory of Unique Traits, by Patterson and others of the committee of the Minnesota Study of Mechanical Ability.

The theory of the Gestalt Psychologists cannot be listed as a factor theory,--on the contrary the Gestalt School definitely opposes the analytical methods essential to any factor theory, but since it has had a far-reaching effect on all Psychological thought it should not be omitted from a discussion of current theories.

These theories range from those which definitely assert that there is a general ability common to all mental activity for any given individual to those which almost or entirely reject the idea of there being any central intellectual ability or factor. Hence, in spite of the mathematical basis for the newer theories there still remains the old controversy

as to whether the ability of any individual is general, or specific, or composed of group abilities, or any combinations of these. The theory advanced by Spearman in 1904<sup>1</sup> with its emphasis on one general factor which he called "g", led Thorndike to reply, "one is almost tempted to replace Spearman's statement by an equally extravagant one that there is nothing whatever common to all mental functions or to any part of them".<sup>2</sup> Fortunately the theories of each of these outstanding authorities have gradually been modified so that they are now less diametrically opposed than they were at that early date.

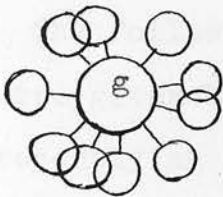
The theories of Spearman, Thorndike and Kelley stand out as types which have been somewhat aptly described as "monarchic", "anarchic" and "oligarchic", respectively. Since the most outstanding feature of Spearman's theory is the assertion that one general ability, or unitary power underlies all activity of the sort that is usually called intelligent, the theory has been described as "monarchic". (it should be noted, however, that Spearman postulates specific factors as well, and that he has been gradually emphasizing more and more the existence, extent and importance of overlapping specific factors, that is group factors. Therefore his theory is more properly called an eclectic theory.)

1. "All branches of intellectual activity have in common one fundamental function (or group of functions), whereas the remaining or specific elements seem in every case to be wholly different from that in all the others". (Am. J. of Psychol. 1904. p.284)

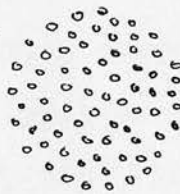
2. Thorndike, Lay and Dean; Am. J. of Psychol. XX. July, 1909. p.368.

Thorndike's theory has been described as "anarchic" because of its emphasis on the complete independence of an infinite number of tiny units with no central factor or "sovereign power"; while Kelley's theory may be described as "oligarchic" since it describes ability in terms of a few major powers or group factors. The latter two types of theories are sometimes referred to as the "sand" and "cobblestone" theories. The metaphor might be continued so as to include Spearman's theory if we added the symbolic term, "bed-rock", to represent the general factor which underlies all mental ability.

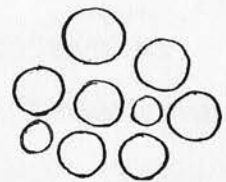
The preceding typical characteristics may be represented diagrammatically as follows:



1.



2.



3.

<u>"MONARCHIC"</u>	<u>"ANARCHIC"</u>	<u>"OLIGARCHIC"</u>
(one central factor)	(infinite number of	(a few independent
also <u>"ECLECTIC"</u>	independent units or	group factors.
("g" + specific +	factors)	The "cobblestone"
group factors)	The "sand" theory.	theory.

The number and arrangement or combination of factors (circles) used varies from individual to individual and from situation to situation. The one factor which is invariably present is the "g" factor in figure I, but while "g" is always present according to this first theory it varies in the extent to which it is dominant in different situations.

We shall now consider, in turn, each of the theories listed on page 90.

SPEARMAN'S TWO-FACTOR THEORY.

Brigham says, "The theory of Two-Factors seems almost universally rejected in theory and accepted in practice."<sup>1</sup> An analysis of the recent literature dealing with factor theories leads one to conclude that much of the recent adverse criticism of the Two-Factor Theory appears to be due to the misleading title which Spearman insists on maintaining for his theory, and to the failure of many critics to recognize that Spearman postulates not only a general factor  $g$ , and independent specific factors but group factors as well, and that, as experimental evidence has warranted it, he has been stressing the importance and extent of these group factors with increasing emphasis.

The following quotation taken from the Presidential address given before the American Psychological Association as recently as September, 1933, is a characteristic interpretation of Spearman's theory.

"Spearman's theory has been called a two-factor method or theory. The two factors involved in it are, first, a general factor common to all of the tests or variables; and second, a factor that is specific for each test or variable. It is less ambiguous to refer to this method as a single factor method because it deals only with one common or general factor. If there are five tests, then the method involves the assumption of one common and five specific factors, or six factors in all."<sup>2</sup>

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<sup>1</sup>. Brigham. A Study of Error. p.33.

<sup>2</sup>. Thurstone. The Vectors of Mind. p.2.

This interpretation is entirely in accordance with the theorem which Spearman advanced in 1904 (see footnote p.91) but it fails to take cognizance of the group factors which he noted in 1906 and which he has studied unflinchingly and postulated with increasing confidence ever since.

Development and Statement of the General Theory.

The theorem formulated in 1904 which postulated only a general factor and independent specific factors was based on Spearman's discovery that if tests of different abilities were applied to a number of individuals and the results of any four of the tests considered, the intercorrelations tended towards a peculiar arrangement, (known as "hierarchy") which could be expressed by the tetrad equation of the form  $r_{ab}r_{cd} - r_{ac}r_{bd} = 0$ .<sup>1</sup> Spearman soon found, however, that frequently the tetrad equation did not equal zero and concluded that in such cases there must be an overlapping of specific factors. This latter observation led him to write in 1906 as follows: "A rather large group of activities might be sufficiently akin to be brought together as a more or less unitary power".<sup>2</sup> Later (1927) he writes more definitely, thus:

"Obviously the specific factors for any two performances can only be independent of each other when these performances are quite different. When on the contrary, two performances are much alike, their respective specific factors will necessarily

1.  $r_{ab}$  is the correlation between tests a and b;  $r_{cd}$  is the correlation between tests c and d; etc. Thus for the correlations given on the right, the tetrad equation is  $.8 \times .2 - .4 \times .4 = 0$  and the tetrad difference (TD) is equal to zero.

Tests:		a	d
b		.8	.4
c		.4	.2

<sup>2</sup>. Zeitschr, F. Psychologic. Vol XLIV, 1906. p.103.

cease to be independent, that is to say, there will be a large overlap in respect of the specific, "s", factors."<sup>1</sup>

This overlapping of specific factors is what Spearman calls a group factor. That is to say, a group factor is that part of specific factors which is common to more than one but less than all of any given set of abilities. In his "The Abilities of Man" Spearman devotes much space to demonstrating and discussing these overlapping specific factors, some of which he describes as "broad group factors." It is therefore evident that Spearman's theory includes two types of cases, namely the simple case in which all the tetrad differences (TD's) of a correlation matrix are zero (within the limits of experimental error), and the more complex case in which the tetrad differences are not equal to zero. The theory may be expressed in terms of the two cases as follows:

(1) Whenever four tests yield tetrad differences which are equal to zero (within the range of experimental error), the intercorrelations among the tests may be thought of as having arisen from a single general factor running through all of the tests, and independent specific factors.

(2) When the tetrad differences are greater than zero (beyond the limits of experimental error), group factors must be postulated in addition to the general factor and independent specific factors.

As experimental evidence accumulated, Spearman observed that the former simple case of performance in which only the

<sup>1</sup>. The Abilities of Man. p.80.

general factor, *g*, and independent or non-overlapping specific factors, "*s*", occurred was relatively infrequent. The latter case, in which there is overlapping of specific factors, is much more commonly found. Moreover, further experimental findings have led Spearman to say that some of these group factors are much "broader" than he had thought previously--so broad in fact, that he has very recently said that some correlations which he had previously considered due to the general factor, "*g*", are now seen to be due partly to these broad overlapping factors.

In view of the very frequent misinterpretation of Spearman's theory we pause to call attention to the following paragraph from his book, "The Abilities of Man", which taken in conjunction with the misleading title, Two-Factor Theory, has frequently led to a partial, and therefore erroneous, interpretation of the theory.

"Whenever the tetrad equation holds throughout any table of correlations, and only when it does so, then every individual measurement of every ability (or of any other variables that enter the table) can be divided into two independent parts which possess the following momentous properties. The one part has been called the "general factor" and denoted by the letter *g*; it is so named because, although varying freely from individual to individual it remains the same for any individual in respect of all the correlated abilities. The second part has been called the "specific factor" and denoted by the letter *s*. It not only varies from individual to individual, but even for any one individual from each ability to another. . . . Here at once we have before us the essence of the whole doctrine, the seedling from which all else has sprung."<sup>1</sup>

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<sup>1</sup>. The Abilities of Man. p.74-75.

It is evident that the introductory clauses in the preceding paragraph, which have been underlined by the present writer, limit the description given, to the simple type of case in which there is no overlapping of specific factors. Many persons fail to give due recognition to the more complex case of overlapping specific factors or group factors, which not only critics, but Spearman as well, declare to be of more frequent occurrence. It is therefore evident that the real cause for dispute concerning Spearman's theory is not the question of the existence of group factors, but rather the question of the breadth and measurement of group factors, and also the question of the existence, measurement and interpretation of the "g" factor.

#### THE TITLE

Since group factors now hold such a prominent place in the theory it would seem less confusing if Spearman were to abandon the title, Two-Factor Theory and substitute some such title as The Three-Type Factor Theory. But Spearman retains the title, Two-Factor, because, he says, all the factors which he postulates may be divided into two groups, namely, (1). A universal, and (2). A non-universal. The non-universal group may be subdivided into a multiplicity of specific factors which in turn overlap in various ways to form group factors. These subdivisions are unstable due to the variations of overlapping; that is to say, they vary according to the nature of the task or activity. The group factors are

not unique, definite entities such as those postulated by Kelley, but variable quantities determined by the situation and problem presented. Spearman therefore chooses to retain the title Two-Factor theory because, he says, "the primary bisection into universal and non-universal factors remains inviolate; it does not depend on any chance composition of a particular set of abilities, but instead marks the most fundamental feature of ability as a whole."<sup>1</sup>

In spite of this explanation, it is not unlikely that the title will continue to be troublesome and lead to misinterpretations of the theory.

#### Group Factors. (Measurement and Interpretation).

Having established the existence of group factors, as noted in the preceding pages, it was obviously desirable to have a technique for determining and measuring these factors which are frequently referred to as the trouble-making factors. Their precise measurement baffles or eludes the most ingenious mathematicians. The technique which Spearman and Holzinger advanced in 1924<sup>2</sup> (which has been used in the present study) appears to be the most reliable method of factor analysis yet advanced. It is admittedly not the refined, accurate tool that Psychology wishes to have. Spearman himself has called attention to its limitations, yet it seems more dependable

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<sup>1</sup>. The Factor Theory and Its Troubles. J. of Educ. Psych. Nov. 1933.

<sup>2</sup>. Bibliography, No.38.

than shorter methods that have been devised more recently,<sup>1</sup> and its further refinement is anticipated. An obstacle and cause for controversy lies in the difficulty of knowing with certainty whether the Tetrad Differences obtained are really due to group factors or merely to experimental errors.

In a study published this year Jorgensen<sup>2</sup> appears to have appraised the technique fairly, though severely, when he said that the tetrad criterion sometimes fails to reveal overlap that does exist and at other times it indicates overlap that does not exist; he even found that for the same test in different groups, widely differing values might be obtained; yet he considers the technique useful when used cautiously. We have previously noted that Garrett<sup>3</sup> recently reviewed the mathematics involved and declared the technique sound. There seems ample justification for concluding that the technique is of real value when used with discretion.

The factors postulated by Spearman in his "The Abilities of Man" are the following:

Verbal, Arithmetical, Mechanical, Psychological, Geometrical, Memorial and Imaginative. Later he speaks of a logical and an inventive type of ability, while a special social ability and ability to appreciate music are also

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1. The method advanced by Thomson in May, 1934, which is a modification of the Hotelling Method, is of too recent formulation to be adequately tested and judged at present time.

2. Bibliography, No.24.

3. Bibliography, No.13.

postulated. Spearman says these factors are not necessarily of a unitary character, in fact he divides the memorial factor into a general memorization factor, a sensory memory, verbal memory, and non-verbal, symbolic memory.

Most of the above factors seem now fairly well established. The chief basis of controversy at the present time is not so much whether or not broad group factors exist but rather whether they exist as independent, inherited entities, or whether they are, as Spearman describes them, merely overlapping specific factors caused by similarities of the various activities in which the individual participates, or whether they are due to differences in the past experience of the individual.

#### The General Factor, "g".

We turn now to consider the general factor, "g" over which there is so much justifiable controversy. Criticism of this factor has been directed towards both the mathematical proof of its existence and the theoretical interpretation of it.

By "g" Spearman means the factor that is common to all the activities that are usually thought of as intelligent. It may be expressed as that which is left causing correlation between all abilities after all other sources of correlation (of a "non-universal" character) have been eliminated. "g", and likewise the "s" factors are not psychological entities, but merely mathematical quantities which may be obtained on analysis of data quite unrelated to ability, but that does not

invalidate the assumption that when they are obtained from tests of mental ability, they serve as measures of some qualitative differences in psychological functions.

Does the "g" factor exist?

Spearman considers that his "general theory" of the "g" and "s" factors is based on sufficient experimental evidence to be no longer really a matter of dispute. He says it is only his "sub-theories" that are open to controversy. The "sub-theories" are merely hypothetical explanations of the "general theory" but even these, he says, seem to be verified by experimental evidence.

Nevertheless the existence of "g" is a debatable matter. Thomson still maintains, as he has done for years, that Spearman's technique neither proves nor disproves the existence of a general factor;<sup>1</sup> The same assertion has recently been made by Thurstone who adds that no technique is necessary to prove the existence of a general factor for it is proved by the fact that all tests of mental ability correlate positively.

In this review no attempt will be made to discuss the mathematical technique involved; only the basic controversial issues are outlined here.

There are now few, if any who would question the soundness of Spearman's fundamental theorem that whenever four tests yield tetrad differences equal to zero the intercorrelations

<sup>1</sup>. Thomson has, during the past year, published a technique, a modified form of the Hotelling Method of "Analysis of a complex of statistical variables into Principal Components" which he concludes, gives Spearman's "g".

among the tests may be thought of as due to some factor common to all four tests and four independent specific factors. There is however, much query and disagreement regarding the common factor. Is this factor which Spearman calls "g" of unitary character? And is the "g" found for one set of tests the same "g" as that found for another set?

Several authorities, particularly Kelley and Thurstone have called attention to the fact that there is no way of proving whether the common factor found is a single unitary quantity or whether there may be several factors within that factor. It has also been pointed out that the common factor found for one set of tests is not necessarily the same as the common factor found for another set of tests; the common part may be due to a group factor, or factors, as well as, or instead of "g". These criticisms seem irrefutable per se, but if the sample of tests analysed be large enough to include all types of intellectual activity and if the correlations are then all positive and give zero tetrad differences, then there would be very little reason to doubt that the common factor found was the same throughout, although there would still be no proof of the unitary character of this common factor; it might be an aggregate of general factors. Spearman claims that these conditions have been approached sufficiently near to warrant the conclusion that the "g" factor he describes is the same throughout.<sup>1</sup>

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<sup>1</sup>. See The Factor Theory and Its Troubles; Uniqueness of G. J. of Educ. Psychol. Feb. 1934. pp.142-153.

The more frequent and more complex case in which the tetrad differences are not zero is still more difficult to analyse. Group factors are so interwoven with the general factor, (if such exists) that it is little wonder that their separation and measurement continue to baffle the most expert and sagacious. The present writer is not optimistic enough to think that these factors will ever yield to exact mathematical measurement but she is convinced that Spearman's method of analysis is useful and more reliable than any other: she also anticipates further refinements of technique that will lead to more accurate measurement of whatever factors exist than is possible at present. As more reliable methods of determining group factors and of partialling out "g" become available we will probably find the "g" saturation of most tests continuing to diminish considerably; unless perchance, at the same time some means be found for controlling all environmental influences; in the meantime, there will, no doubt, continue to be somewhat conflicting results in regard to the existence and extent of "g" and other factors.

Among the most recent reviews of Spearman's theory and technique are those by Irwin<sup>1</sup> and by Brown and Stephenson.<sup>2</sup> The latter two assert that their research establishes the theory of Two-Factors on an adequate statistical basis, while the former, (Irwin), concluded that E. B. Wilson was right when he said that "g" was relative to the set up. Irwin's earlier

<sup>1</sup>. Bibliography, No.22.

<sup>2</sup>. " " , "... 4.

conclusion (1932), namely, that "g" is not determinate but its indeterminacy can be made as small as we please by taking a sufficient number of tests,<sup>1</sup> seems slightly more favourable than this later one. It is evident that perfect agreement has not yet been reached.

Whether there is adequate mathematical proof of the existence of "g" or not, there is much evidence of belief in some kind of general ability or capacity. Even the most outstanding opponents of belief in the "g" factor, notably, Kelley and Thorndike, give evidence of some general factor or ability. Kelley found a general factor in his experimental data (although he refused to attribute it to a "general ability"), and Thorndike speaks of "amounts of intellect" as being some "unified coherent factor in nature".<sup>2</sup> Hull, who probably ranks next to Kelley in adhering to a strict group factor theory admits the probable existence of "g", although he adds that it may be only "a kind of mathematical expression of the totality of all group factors." Garrett, who at one time said that for a given set of tests the general factor might be entirely absent, only group factors being present, has since said, after a very critical analysis of recent data and the mathematics involved, "I am certain of the presence of a general factor in most tests of the intelligence sort."

It has been noted, by both Thorndike and Thomson, that if

an individual is above average in one kind of intellectual

<sup>1</sup>. Bibliography, No.23.    <sup>2</sup>. Measurement of Intelligence, p.63.

he is likely to be above average in another. Moreover, most definitions of intelligence imply belief in some sort of general factor. For instance Burt has described intelligence as an inborn all-round mental efficiency; Stern defines it as a general capacity of the individual consciously to adjust his thinking to new requirements, (he has also said that the general factor is "one of the most certain results of investigation"); Terman describes it as ability to carry on abstract thinking; Calvin says it is ability to learn quickly and easily. All of these definitions and many more are in harmony with Spearman's fundamental theorem that "g" exists, although they do not necessarily agree with Spearman's interpretation of "g". Moreover the common practice of measuring "general intelligence" (I.Q.) in terms of a single total score, unjustifiable as the practice may be and is, is evidence of a widespread belief, in practice, if not in theory, that different individuals have different levels or amounts of general ability.

One seems forced to conclude that whether or not "g" is proven mathematically, there is a widespread acceptance of its existence. There is, however, still much controversy and disagreement regarding its interpretation.

#### Spearman's Interpretation of "G".

Spearman interprets this general factor "g" as a mental energy, a central intellectual power that enters into all mental functioning and is constant for any individual though

varying greatly for different individuals. He found that "it showed itself to be involved invariably and exclusively in all operations of an eductive nature." He doesn't call this central fund of energy, this ability to educe relations and correlates, "intelligence", although it is generally interpreted to be such. Spearman's interpretation of the "g" factor is based on the doctrine of noegenesis, that is, on the following three laws of cognition.<sup>1</sup>

(1). One is aware of one's own experience. That is to say "a person has more or less power to observe what goes on in his own mind. He not only feels, but knows that he feels; he not only strives but knows that he strives; he not only knows but knows that he knows."

(2). "When a person has in mind any two or more ideas he has more or less power to bring to mind any relations that essentially hold between them, that is to say he can educe relations."

(3). "When a person has in mind any idea together with a relation, he has more or less power to bring up to mind the correlative idea, that is to say he can educe correlates."

Spearman says the "g" factor is concerned with two general dimensions, namely Clearness and Speed, and also with two dimensions of span, namely, Intensity and Extensity, but he adds, "it revealed a surprisingly complete independence of all manifestations of Retentivity."<sup>2</sup> Whether or not speed is a dimension of "g" is a much debated matter. Kelley is definitely of the opinion that it is not; he asserts that speed is an independent group factor. The

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<sup>1</sup>. The Abilities of Man. pp.164, 165, 166.

<sup>2</sup>. The Abilities of Man. p.411.

conflicting conclusions seem to be resolved by more recent studies,<sup>1</sup> which indicate that there are two kinds of speed, one being a dimension of "g" and the other a group factor.

#### Other General Factors.

Besides the general factor "g", Spearman postulates two other cognition factors possessing functional unity, namely, Perseveration and Oscillation. By Perseveration he means a form of retentivity which may be described as mental inertia or lag. In his "The Abilities of Man" he calls this factor "c", but later he calls it "p". A person with high perseverative tendencies is not likely to be reputed for quickness. This type of retentivity should not be confused with retentivity of the memorial type or the tendency to retain dispositions. By the third general factor, Oscillation, is meant fluctuations of mental efficiency. This factor is designated by the letter "o". A fourth general factor is postulated by Spearman. This factor is called "w".

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<sup>1</sup>.The most recent study of speed, known to the writer, is that made by J. D. Sutherland. Sutherland concluded that "when problems are of low difficulty, a factor of speed comes into operation", but he says, "there is little evidence for an independent factor of speed when the conditions demand a uniform attitude of securing maximum accuracy at the greatest speed". Much the same conclusion was arrived at by Line and Kaplan a couple of years earlier. After studying intelligence test scores of fifth grade pupils, obtained under different time conditions, they concluded that: "The degree of gain in scores was relative to the difficulty of the material as well as to the intelligence of the subjects, and some indication was obtained of a group speed factor other than speed of thinking, where easy material was being employed."

It is not cognitive in nature but conative, that is to say it is more a matter of volition or will, or "purposive consistency or self-control," rather than mental ability. Spearman says "It has shown itself to be chiefly responsible for the fact of one person's ability seeming to be more "profound" or more inclined to "common sense" than that of other persons otherwise equally capable."<sup>1</sup> He also says, "the intensity of cognition can be controlled by conation," i.e. by the "w" factor. Thus we find that Spearman postulates four general factors in all, but he says that only the "g" factor manifests appreciable individual differences in ordinary tests of intelligence. The present writer would venture to suggest that the significance of these factors has been greatly underestimated and that much more real progress will be made when due recognition is given to them.

Early controversies regarding the proof of the existence of group factors and the "g" factor have been omitted purposely from this account because it seemed more profitable to consider the theory as expressed at present rather than that formulated thirty years ago.

However, it should be noted that well directed, early criticisms, especially those of Thomson with his insistence on the existence and importance of group factors, provided valuable contributions in the development of the theory which should not be overlooked.

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<sup>1</sup>.The Abilities of Man. p.413.



on any general factor. These traits, Kelley believes, are inherited. He therefore considers it highly important from the practical standpoint of eugenics and individual guidance that they be recognized and determined for each individual.

The factors which Kelley postulates, (besides the common factor) are as follows:- Verbal, Arithmetical, Spatial, Memory, Speed and Vivacity.

Both Kelley and Spearman have commented on the remarkable harmony of the experimental findings which each of them made independently. The chief differences are in regard to the Verbal and the Speed factors. Writing in 1927, Kelley said "Spearman's "g" is probably more than half due to a Verbal factor." Since that time Spearman has admitted (as has already been noted) that some of the correlations which he had previously thought to be due to "g" are now seen to be due partly to a Verbal factor and other group factors. Of the differences in conclusions regarding Speed an explanation has already been offered on page 107.

A very important study by Holzinger and Swineford, published in 1932, gives us cause to be very cautious about accepting any definite factor pattern, such as that given by Kelley. The authors analyzed Kelley's data by a different technique than that used by Kelley and concluded that there is nothing unique about the factor pattern found by Kelley. It is possible, they say, to obtain different relative values for each factor and even to find a different number of factors.

They conclude: "there is a lack of uniqueness in pattern fitting by procedures thus far employed. Some other procedures may possibly lead to better results,,but the analysis represented by Professor Kelley's work cited above is clearly inadequate."<sup>1</sup>

However this criticism should not cause us to lose sight of the significance of Kelley's valuable work.

#### THORNDIKE'S THEORY OF CONNECTIONISM

Thorndike has persistently rejected the idea of there being any such general ability as the "g" factor postulated by Spearman. His theory is based on a doctrine of connectionism by which all mental activity is conceived of as due to a summation of a large number of very small units of ability. These tiny units may be connected by bonds in an infinite variety of ways. Thorndike asserts that variations in mental activity are due not to any qualitative differences in the units of ability or processes involved, but merely to the number of bonds or connections (c's) formed among the units. He expresses it thus; "in their deeper nature the higher forms of intellectual operations are identical with mere association or connection forming, depending on the same sort of physiological connections but requiring many more of them. . . .By the same argument the person whose intellect is greater or higher or better than that of another person differs from him in the last analysis in having not a new sort of physiological process but simply a larger number

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<sup>1</sup>.Bibliography, No.19.

of connections of the ordinary sort."<sup>1</sup>

While Thorndike refuses to accept any of the theories which postulate either a general ability or qualitative differences in ability such as underlie group factors, one is disposed to feel that he does so more in the realm of pure theory than in the realm of practice. In 1920 he said, "There is a rough correspondence or correlation such that a man notably intelligent in one respect will usually be above the average in others also;" and in 1926 he wrote "amounts of intellect. . . are amounts of some unified co-herent factor in nature which can be properly isolated from other non-intellectual factors."<sup>2</sup> Such statements, along with Thorndike's extensive use of General Intelligence tests, and particularly his CAVD tests (Completions, Arithmetic, Vocabulary, Direction), lead one to think that he believes in the existence of something that is not so diametrically opposed to the something which Spearman calls "g" as is generally supposed. The chief difference lies in the fact that Spearman thinks of this something as an entity characterized by the three laws of cognition--namely, the ability to apprehend experience, to educe relationships, and to educe correlates; while Thorndike considers that there is no such entity but rather that this something is the number of connections or bonds which the individual is capable of forming and that these connections are not limited to the

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<sup>1</sup>. Measurement of Intelligence, p.415.

<sup>2</sup>. " " " " , p.63.

processes described in the three laws of cognition, but include analyzing, organizing and evaluating. It would seem that this capacity to form connections which Thorndike describes, and the general ability which Spearman postulates are really the same power differently explained or interpreted. This opinion is supported by a study of Holzinger's which led to the conclusion that "Thorndike's CAVD is full of G"<sup>1</sup>. Furthermore, the processes which Thorndike adds, namely, analyzing, organizing and evaluating, appears to be included in the laws of cognition as interpreted by Spearman.

Thorndike's later hypothesis, namely, that there are three types of intelligence, (abstract, mechanical and social) seems difficult or impossible to explain on the basis of the strict doctrine of connectionism which he has so long maintained. This division of ability into types seems to indicate that there is a convergence of Thorndike's theory towards one of group factors. Hence it appears that Thorndike's views are not really so much in opposition to the views of Spearman and Kelley as many of his statements would imply.

#### THOMSON'S SAMPLING THEORY

Thomson considers that an individual's mental ability is dependent on a large number of unitary factors, or abilities inherited in accordance with Mendelian laws, and that in any situation, the individual brings into play a sample of the abilities at his command relevant to that situation.

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1. Bibliography, No.18.

In 1924, Thomson said; "In short, my thesis is that, although people tend, no doubt (though with many exceptions and inequalities) to be generally able, yet there is no such thing as "general ability", no one factor which, by its amount in a man, determines his performance in general and is the sole source of correlation between them,----on the contrary, I prefer to think of the mind as much more complex,---- It has an innumerable array of responses to situations which responses are inter-connected in a tangle of associations, within which tangle are distinguishable various plans or patterns, distinguishable yet not distinct."<sup>1</sup>

In this latter statement one finds the basis for the various interpretations which have been made of Thomson's theory. The assertion that there is an innumerable array of responses inter-connected in a tangle of associations closely resembles Thorndike's theory, while the statement that these responses become organized into patterns indicates that group factors as well as specific factors are postulated. Regarding the precise nature of these group factors as described several years ago, there appears to be some ambiguity. In so far as Thomson attributes Mendelian characteristics to the factors he postulates, the group factors seem comparable to those postulated by Kelley, but otherwise they seem more nearly akin to those now advanced by Spearman. A statement of Thomson's present views on the matter of group factors would be welcomed.

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1. Thomson, G.H. The nature of General Intelligence and Ability-a Symposium. Br. J. of Psychol. xlv. Jan. 1924, pp. 230-231.

In the controversy over the existence of the general factor as postulated by Spearman, Thomson has played an important part. He has been persistent in maintaining that Spearman's mathematical technique neither proves nor disproves the existence of "G". He does not deny the possible existence of a general factor but merely states that its existence is unproven. He has frequently expressed belief in the possibility of there being some tendency towards a central factor, and during the past year has stated that a modified form of the Hotelling technique of factor analysis gives Spearman's "G". In his book, "Instinct, Intelligence and Character," he writes, "if a man is above the average in one line, he is likely to be above average in another. By no means certain to be, in some subjects not likely to be. But hardly ever is the betting actually against him"<sup>1</sup>. He has also said, "if there be a general factor at all, it might be the power to shake down rapidly into good team work", and again.--"if there is a general ability it is the facility with which old responses can be hitched on to new situations, and the readiness with which a response is discarded, almost before it is begun, if it is going to prove unsuccessful. But it may be that nothing general is left at all". Still again he has said that if the samples are large there will of course be factors common to all activities, but if the samples are not large it may be that no single factor may occur in every activity. He adds further, "if, moreover, a number of factors do run through the whole gamut of activities forming a general factor, this group need not be the same for

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1. Thomson, G.H. Instinct, Intelligence, and Character, P.207.

every individual,----One good all round man is not necessarily good all round for the same reason as another".

Long before group factor theories enjoyed the popularity they are enjoying to-day, Thomson insisted that group factors must be postulated; therefore to him much more credit is due than is generally recognized or acknowledged.

#### THURSTONE'S THEORY OF MULTIPLE FACTORS.

This theory may be said to be built around a mathematical technique advanced by Thurstone in 1931, known as "Multiple Factor Analysis". It has been shown in the preceding chapter that this technique is not to be relied upon, but that does not necessarily invalidate the theory. This technique is purported to show how many factors must be postulated in order to account for the correlations of any correlational matrix, and to show the relative significance of each factor indicated. In his book "The Theory of Multiple Factors", Thurstone gives the analysis of the intercorrelations of nine intelligence tests.<sup>1</sup> For the data used he found that the first, second and third factors had indexes of correlation of .512, .069, and .036 respectively. Then he added, "beyond the third factor it does not seem worth while to go because the third factor residuals are very small; but additional factors can be added as long as one has patience and interest."<sup>2</sup>

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1. The tests are those used by the College Entrance Board of Princeton University. They consisted of the following; Definition, Arithmetical Problems, Classification, Artificial Language, Antonyms, Number Series Completion, Analogies, Logical Inference, Paragraph Reading.

2. Thurstone, "The Theory of Multiple Factors" P.

According to this theory factors may range from those which are common to all tests of mental ability to those present in only one test. Thurstone uses the term common or general factor to mean any factor common to two or more tests. He considers that the first factor obtained by his analysis is comparable to Spearman's "g". He emphatically points out however that if two factors are common to all the tests in a battery they do not necessarily combine into a single factor, even though there is no statistical way of separating them. He therefore refuses to accept "g" as the unitary factor which Spearman claims it to be. Thurstone's outstanding contention is that more than one "big" general factor or ability must be postulated in any theory of mental ability. In this respect<sup>1.</sup> he considers his theory very different from Spearman's.

Thurstone is cautious and reluctant when asked to name factors after they have been computed. He ventures to predict, however, that "among the mental abilities it is quite likely that we shall find verbal ability, perceptual relations, and arithmetical ability to be distinct though positively correlated." This statement is not easily interpreted. To say that these abilities are positively correlated is to imply that to some degree they overlap; hence it would appear that they cannot be distinct in the sense of being discrete, independent unities or if that be possible, it is obvious that there is no way of proving that such is the case. Thurstone supports Kelley's view when he says "It is my conviction that the isolation of mental abilities will turn out to be essentially

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1. Vectors of Mind. P.31

a problem in genetics." 2.

### THE THEORY OF UNIQUE TRAITS.

This theory was advanced by Patterson and his Minnesota co-workers in 1930.

Critics of the theory have pointed out that a "unique trait" as described below is only another name for a "group factor" as postulated earlier by Kelley, and that the Minnesota Psychologists have not made any new theoretical contribution. It must be said however, that they have given a clear, concise statement-- a working hypothesis, as they describe it-- which is greatly welcomed by practical workers interested in the problem of Educational and Vocational Guidance.

The two basic assumptions of the theory are as follows;

(1) "The various degrees of success in all the important classes of human behaviour correspond to compounds of relatively unitary traits, combined in various proportions, and (2) These unitary traits can be discovered and measured objectively and are probably not so numerous as to make impossible the task of measuring all of them." "A trait may be judged unique when it meets two statistical requirements. First, the trait as tested must correlate positively with at least one criterion of human endeavour. Second, it must give correlations as low as possible with all other unique traits".

The "unique traits" which the Minnesota research revealed are; Mechanical Ability, Motor Ability, and Intelligence. Regarding the organization of Mechanical Ability it was found that there were many low intercorrelations between different measures of this ability, thus suggesting the presence of highly specific factors and absence of any single common factor. They also found that four of the seven "Mechanical Ability" tests revealed what they called a "quasi-general" factor, which is really only another name for a group factor. These findings for the Mechanical Ability tests are comparable to the findings for Form Perception tests obtained in the present study, in that in each case some of the tests revealed a group factor and some did not. Since some of the Mechanical Ability tests gave no evidence of the "quasi-general" or group factor there seems little justification for calling "Mechanical Ability" a "unique trait", as the Minnesota Psychologists have done.

#### GESTALT THEORY.

The Psychologists of the Gestalt school have not so far interested themselves in such quantitative procedures as are here being discussed. This is partly due to their feeling that psychology is too young a science to have progressed beyond the qualitative stage. But it is also partly due to their suspicion that factor theories involve the point of view of structural analysis. This, of course, is anathema to them. They point out that a human being is much too complex a force and much too

intricately a part of his ever-changing environment to admit of the analytical treatment and mathematical measurement that underlie factor theories. Since he is a living organism, he is a dynamic force incapable of being measured by static or fixed measuring rods.

According to the Gestalt theory, mental ability is a unitary power that must be studied as a whole; it is not a mere summation of various component mental abilities. Even if sometime it should be satisfactorily proven, that these differentiable mental abilities do exist, the Gestaltists point out that it would be erroneous to think that the sum of the measures of the component parts would be a measure of the total ability. The whole ability is something more than the sum of its parts, just as a square is something more than the sum of four straight lines. Moreover, not only do the psychologists of this school denounce efforts at analyzing ability into component parts, but they maintain that the ability of any individual can be determined only when the "total personality" of the individual together with his "total environment" is studied as a whole. They consider that factor theories fail to take cognizance of this important fact. However, if the interpretation of factor theories can maintain a true functional implication where the total functioning personality is preserved and factors are thought of as attributes of the functioning organism, it may be that there need be no radical difference of

opinion between the Gestaltists and psychologists who hold group factor theories, which emphasize the existence and importance of a general factor or factors common to all mental functioning, such as Spearman's "g".

The Gestaltists offer criticisms that are, indeed, timely; their theory comes as a wholesome antidote to offset the mechanistic theories and artificial laboratory methods that have characterized so much psychological thought and endeavour, particularly in America.

However, to refrain from all analytical approaches to the study of human ability just because we are unable to make entirely satisfactory measurements seems inconsistent with the spirit of science. The physician does not desist from analyzing bodily organs and functions though he is aware of the close interrelation of the various parts of the body and the dependence of parts on the whole or total body function. He examines the various units by the best available scientific methods and then after keen observation and study of the individual as a whole, he attempts to synthesize the various unit measures into as meaningful a pattern as his judgment allows. So too, it would seem that psychologists should proceed with efforts at analysis of mental ability in the hope of ever improving existing technique and contributing further useful knowledge, but they should at the same time heed the warning of the Gestaltists regarding the importance of viewing the "total personality" functioning in its "total environment".

## RÉSUMÉ OF CURRENT THEORIES

The review of current theories given in the preceding pages, shows that there is still diversity of opinion regarding the nature of mental ability, even though there is a noticeable trend towards harmony. In the study of so complex a matter as that of human ability, it would, indeed, be surprising if diversity of view did not exist. Many of the differences noted should probably not be regarded as conflicting or controversial, but merely as different ways of looking at an exceedingly complex problem. Each theory has its own distinctive contribution to make. It is doubtful if there will ever be a single satisfying theory that will be acceptable to all, but it seems probable that further research may lead to still greater harmony of view and hence reduce the number of theories that will gain wide acceptance.

APPENDIX c

(a) TIME ALLOWED FOR THE TESTS. (b) SCORES

Test		Time in Minutes		No. of	Scores (Boys II)	
No.	Name	Ist Yr.	IIInd Yr.	Items	Range	Aver.
I	Opposites	11	7	75	24-61	45
II	Word Meaning	6	6	75	16-57	35
III	Word Pairing	4	4	50	10-39	25
IV	Definitions	20	20	50	10-41	20
V	Sentence Completion A	6	6	50	8-49	31
VI	" " B	6	6	50	4-47	30
VII	Comprehension	12	12	35	16-47	28
IX	Classification	6	4	50		
X	Analysis	6	6	55	17-52	40
XI	Classification	7	7	50	6-43	26
XIII	Number Sequence	22	18	75	23-66	48
XIV	" Combinations	12	12	30	8-28	21
XV	Problems	45	45	44 <sup>1</sup>	21-110	51
XVI	Speed	4	4-	116	40-116	82
XVII	Following Directions	15	15	42	25-37	31
XVIII A	Judgment of Length	7	7	40	8-39	24
XVIII B	" " "	7	7	50	10-47	31
XIX A	Synthesis of Figures	12	10	30	4-29	14
XIX B	" " "	7	7	22	2-19	11
XX	Analysis of Figures	12	10	50	4-37	21
XXI	Reversing Letters	3	3	45	0-39	16
XXII A	" Figures	5	5	30	0-16	7
XXII B	" "	4	4	20	0-15	4
XXIII	Overlapping Figures	4	4	20	8-19	14
Total		243	229	1154		

<sup>1</sup>The maximum score in Problems is 144

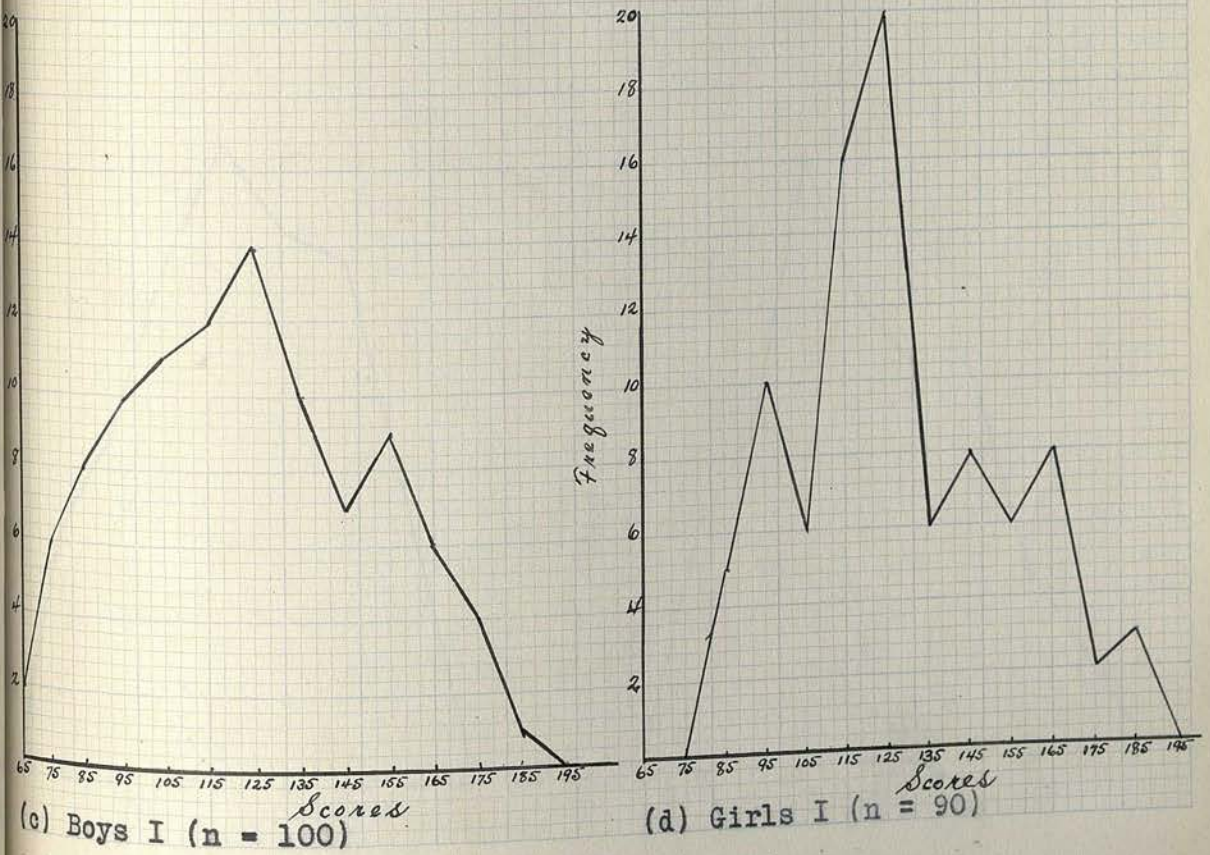
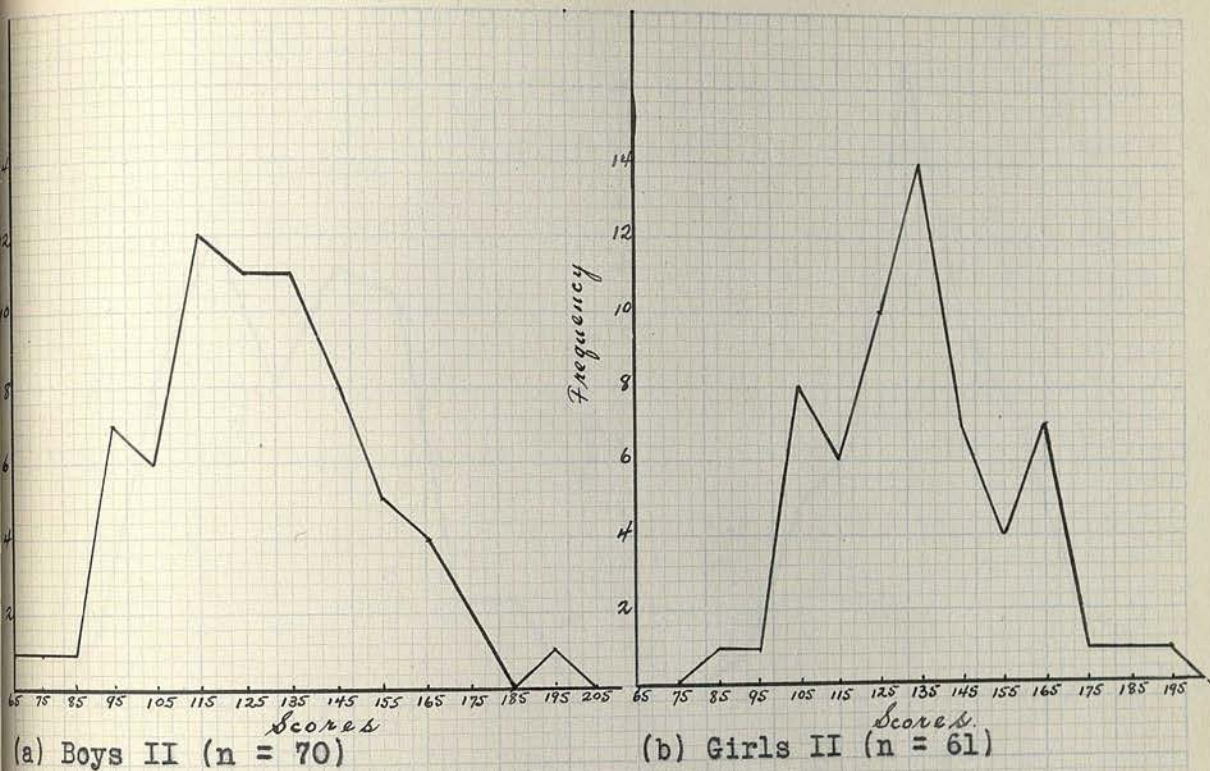


Fig. 5. Distribution of Scores on the "Verbal" Tests "V<sub>1</sub>" (Tests I to IV)

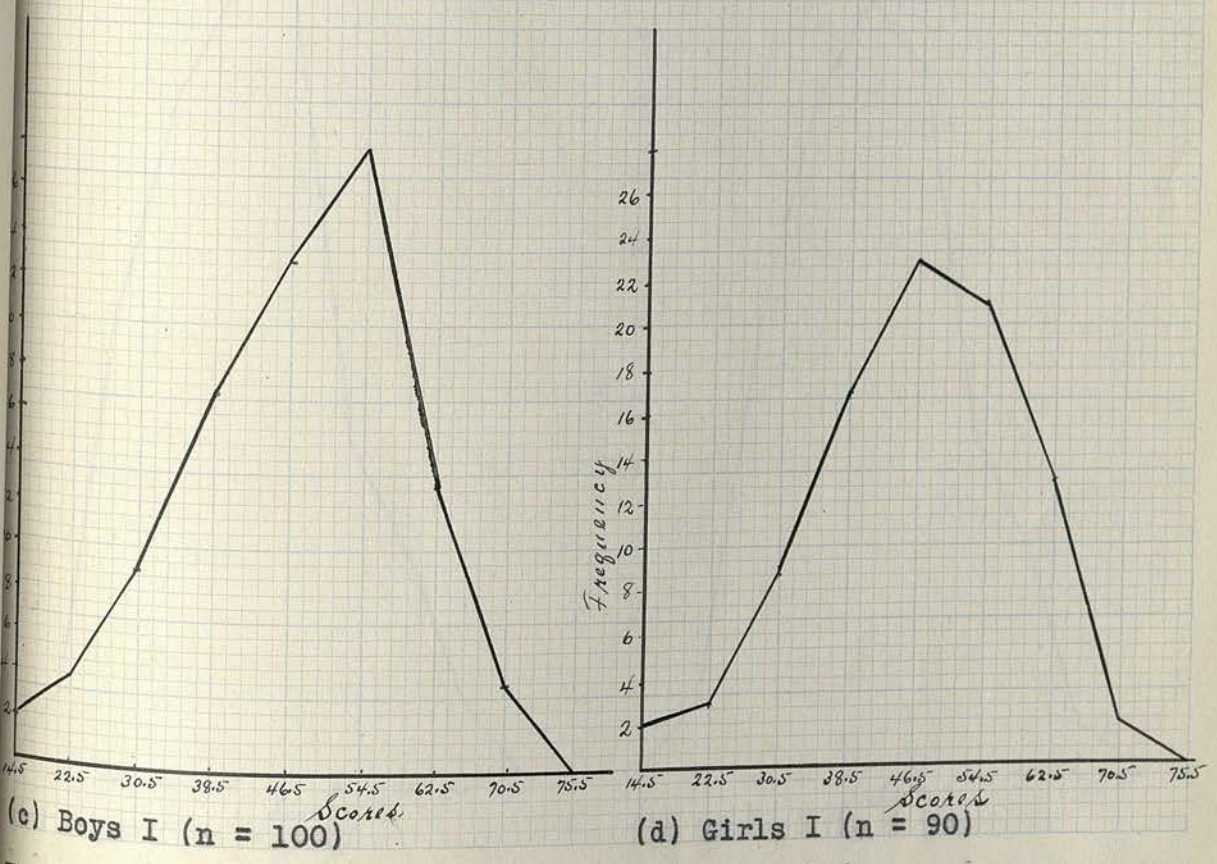
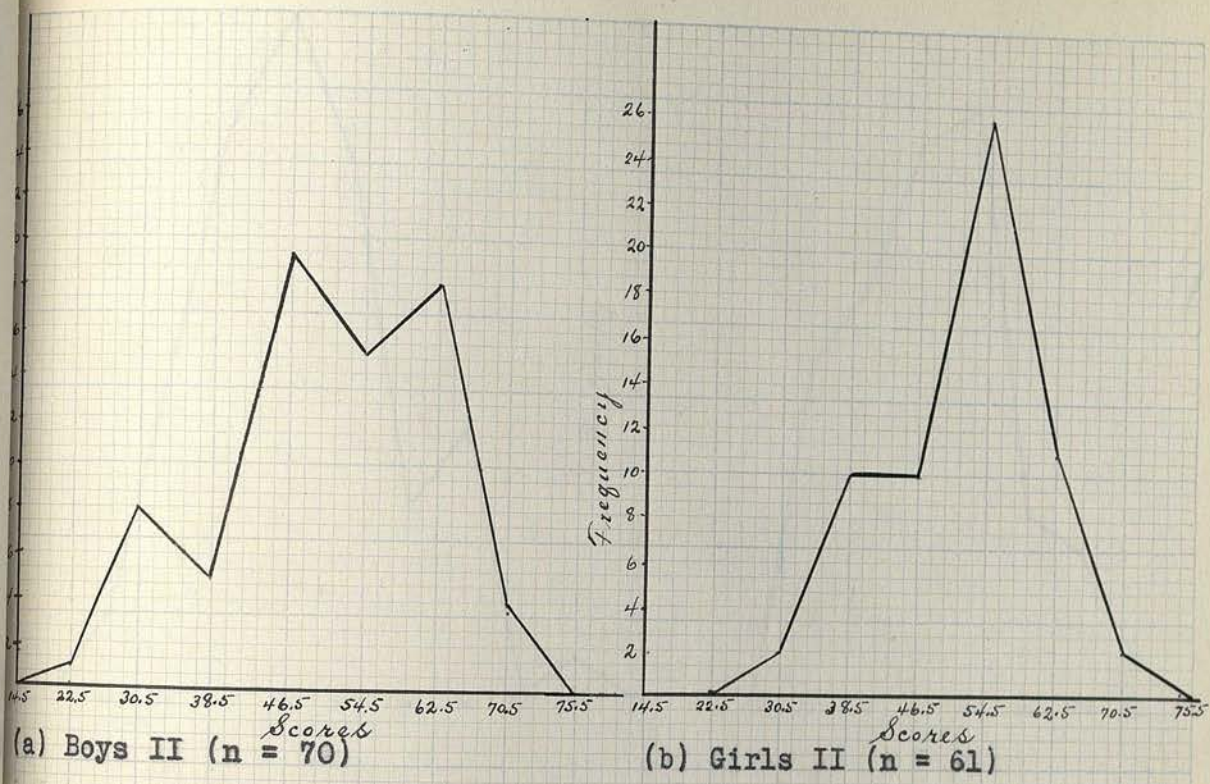
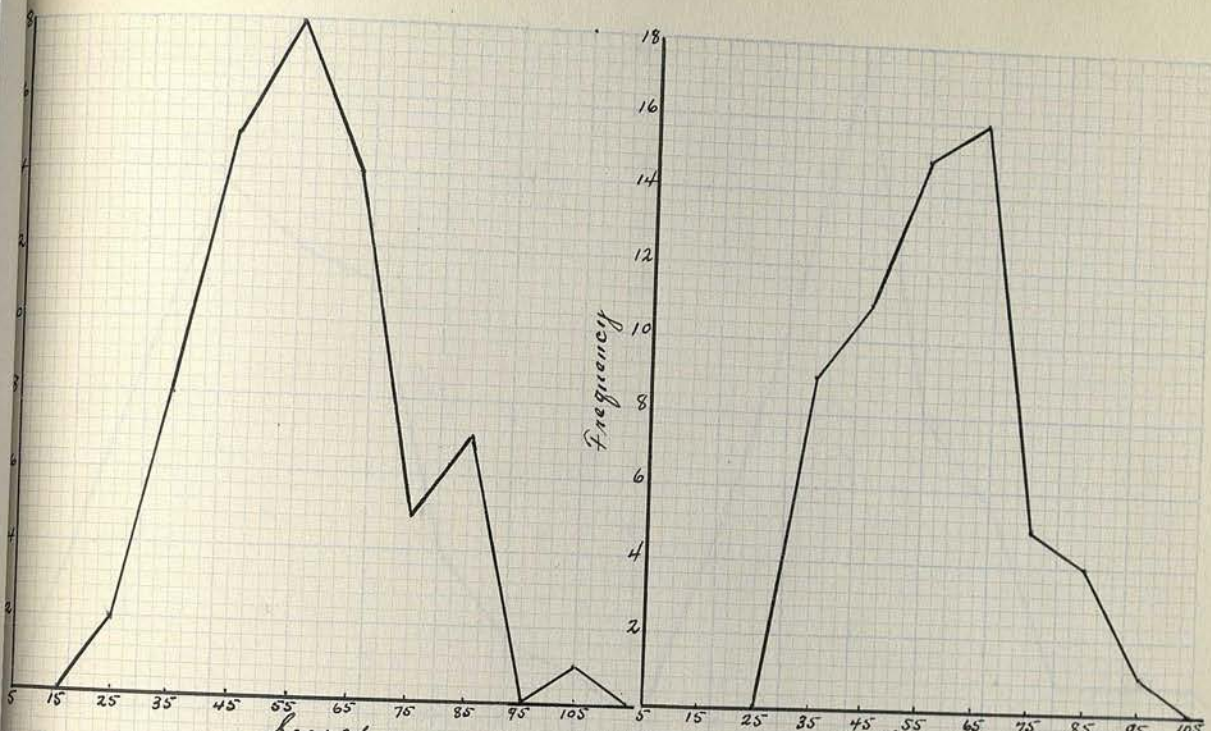
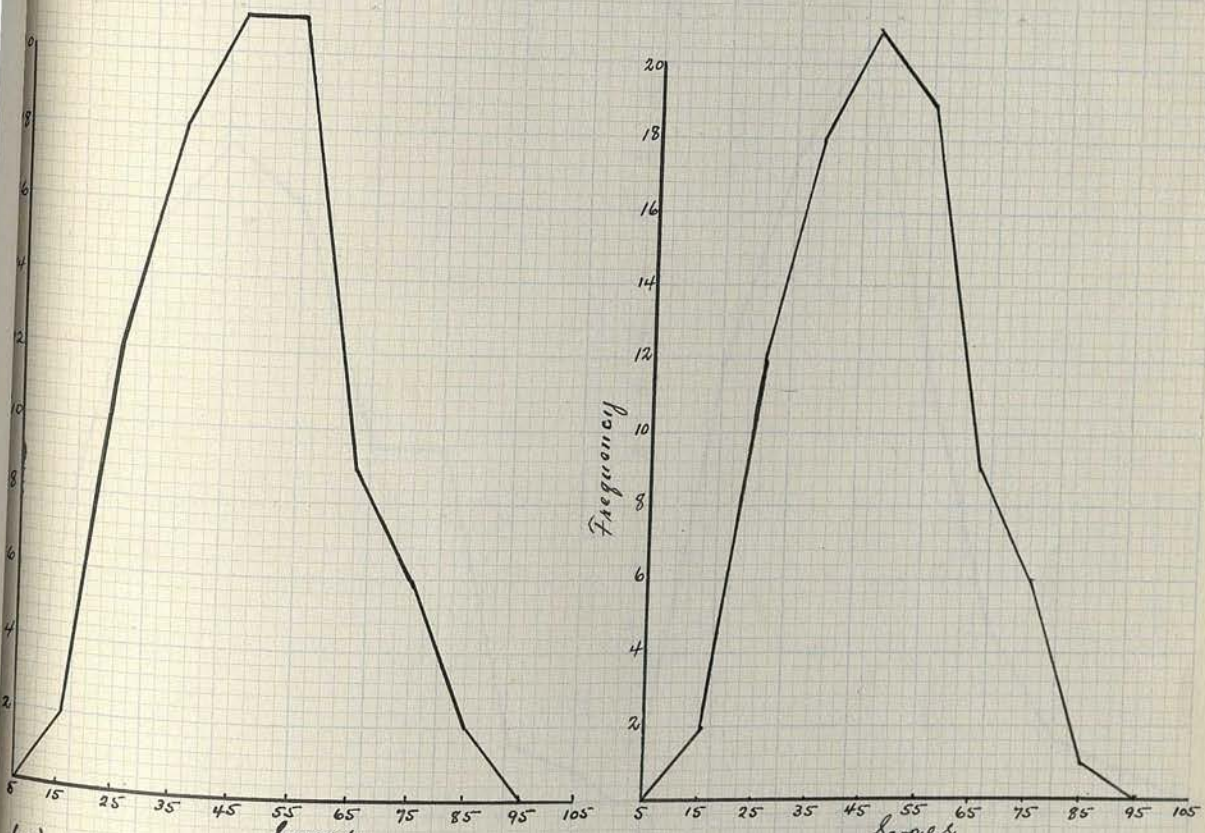


Fig. 7. Distribution of Scores on the "Mathematics" Tests, "M<sub>1</sub>" (Tests XIII A, B, C)



(a) Boys II (n = 70)

(b) Girls II (n = 61)



(c) Boys I (n = 100)

(d) Girls I (n = 90)

Fig. 8. Distribution of Scores on the "Mathematics" Tests, "M<sub>2</sub>" (Tests XV A, C, D)

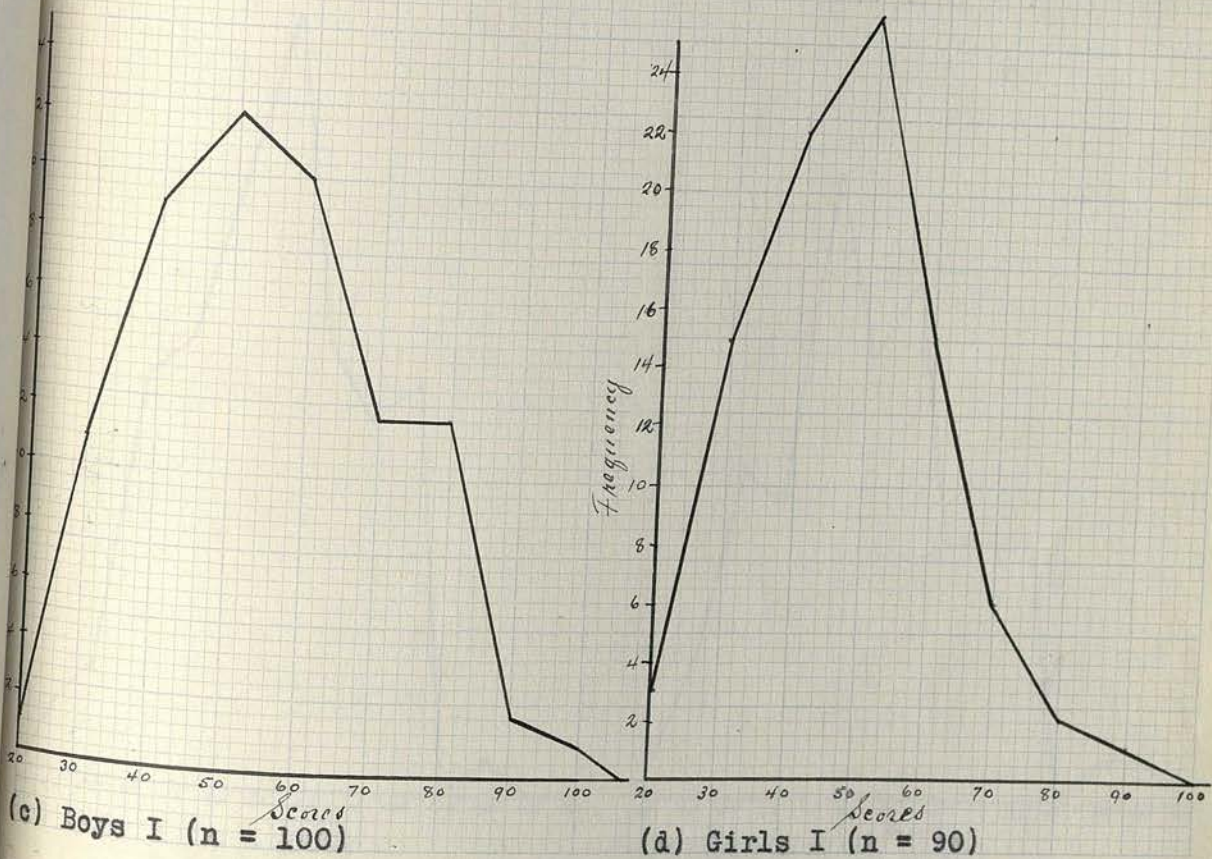
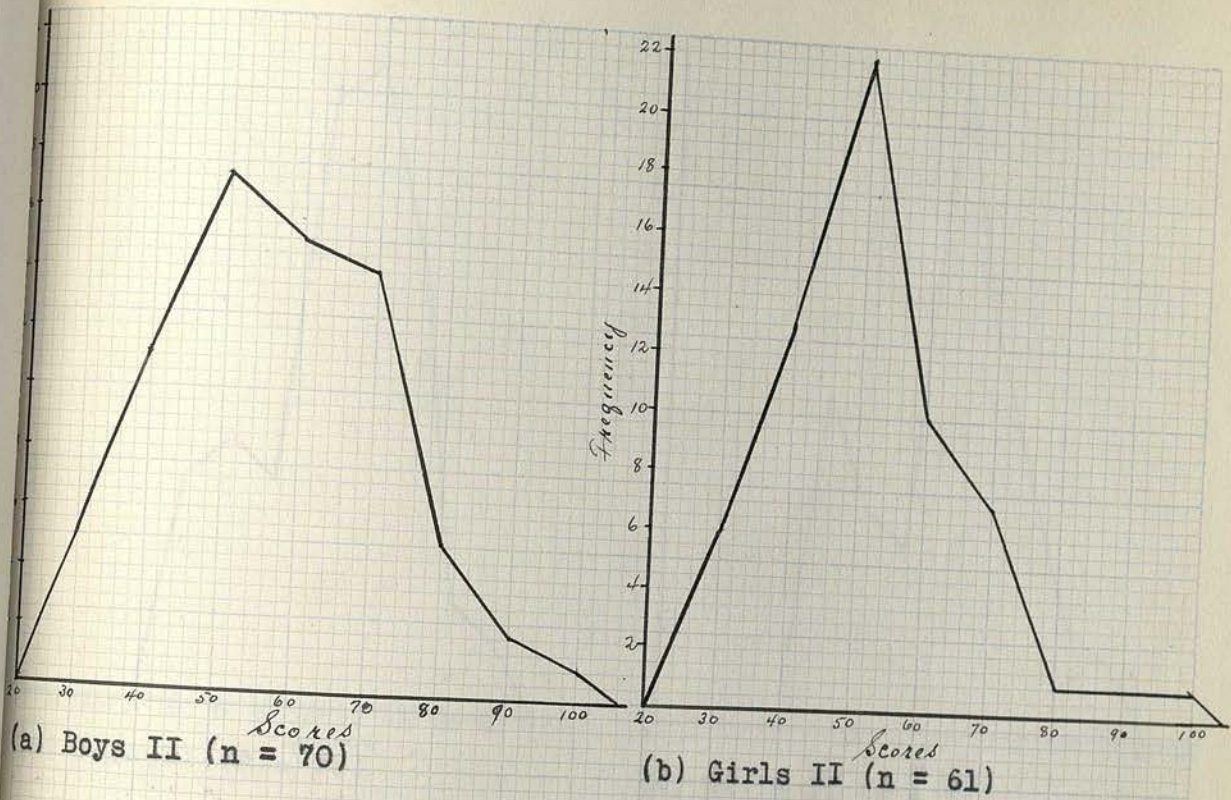
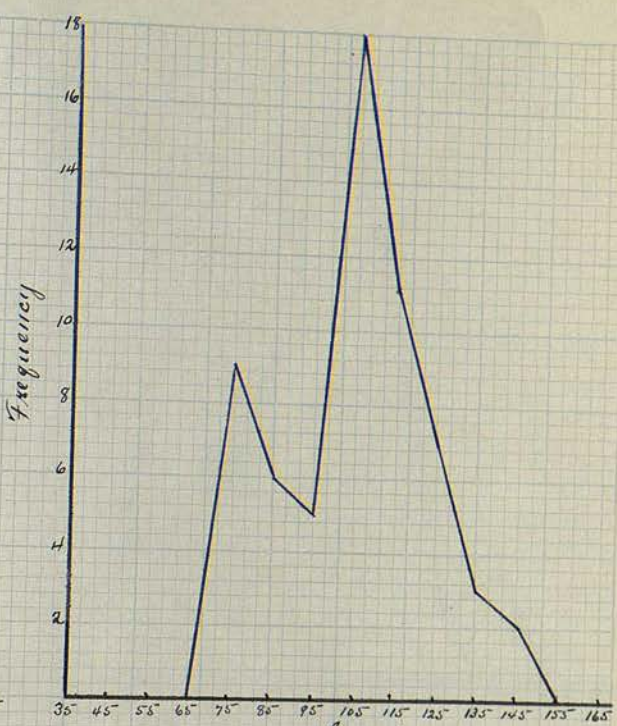
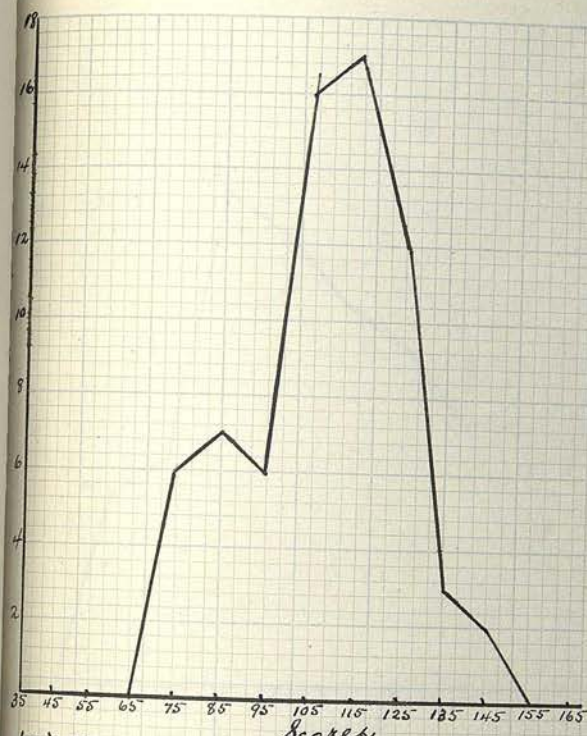
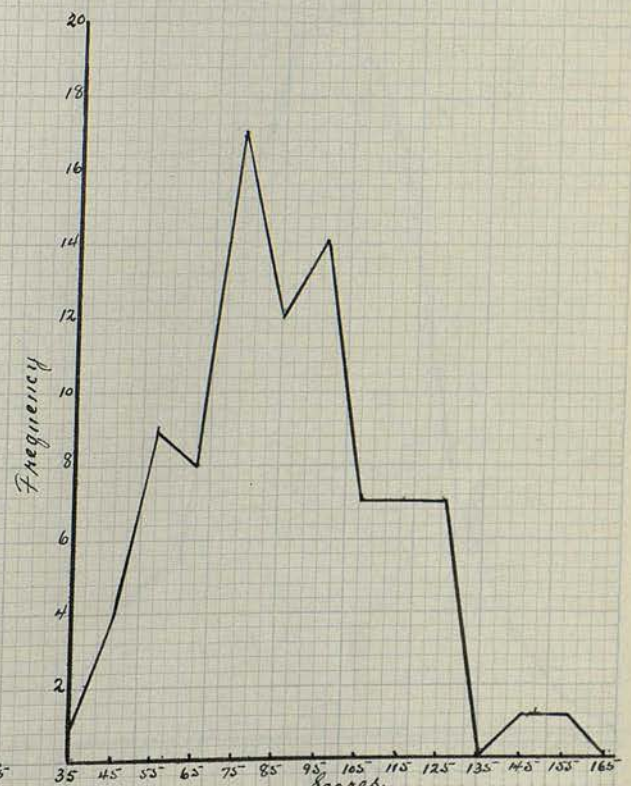
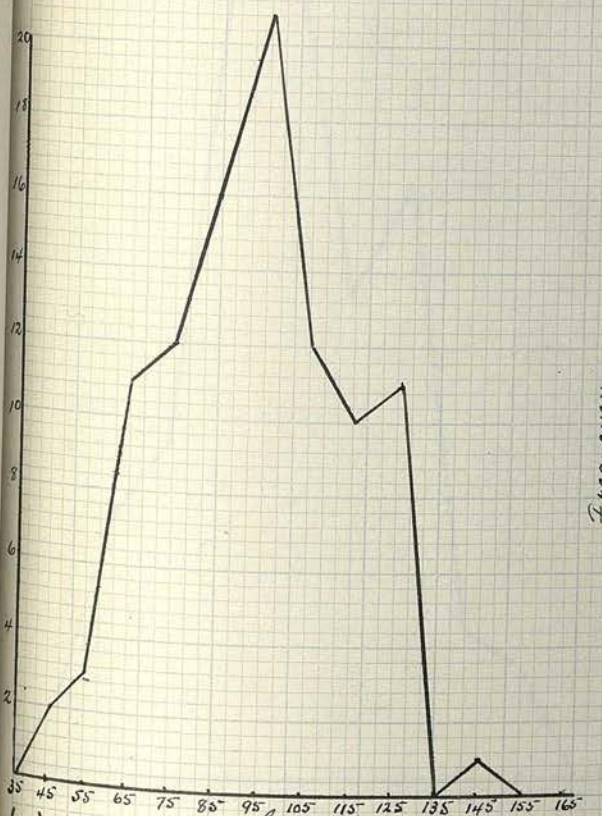


Fig. 9. Distribution of Scores on the "Form Perception" Tests, "FP<sub>1</sub>"  
(Tests XIX, XXI, XXII A)



(a) Boys II (n = 70)

(b) Girls II (n = 61)

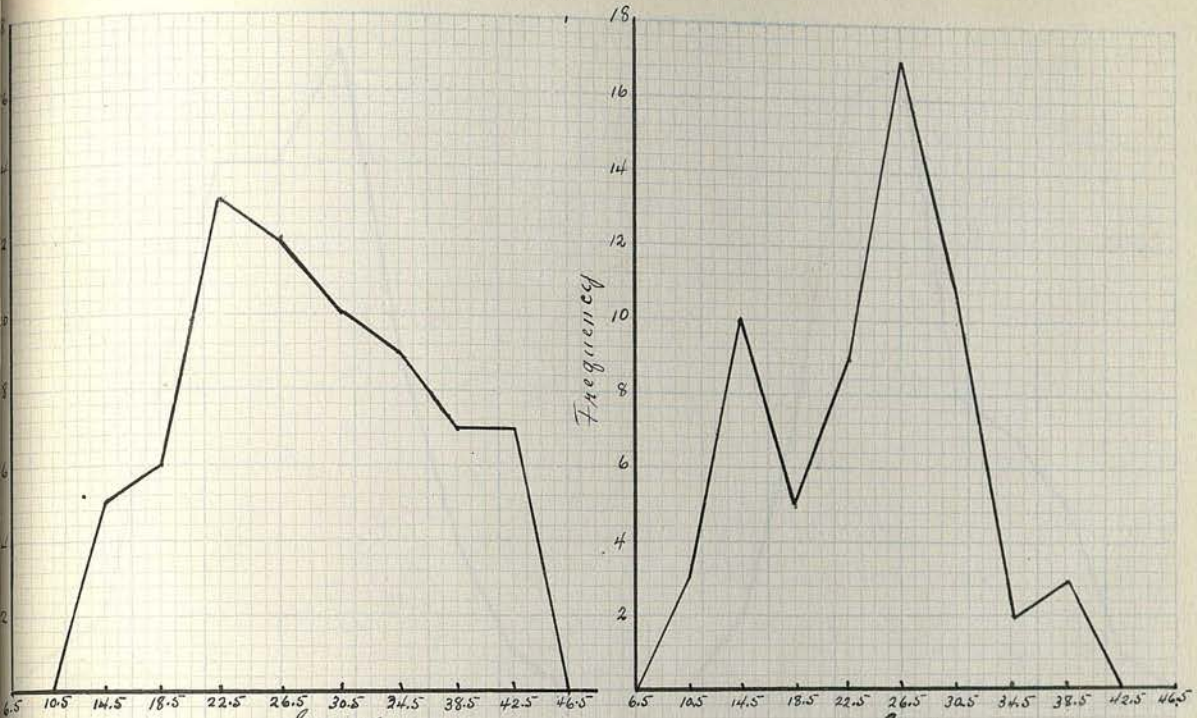


(c) Boys I (n = 100)

(d) Girls I (n = 90)

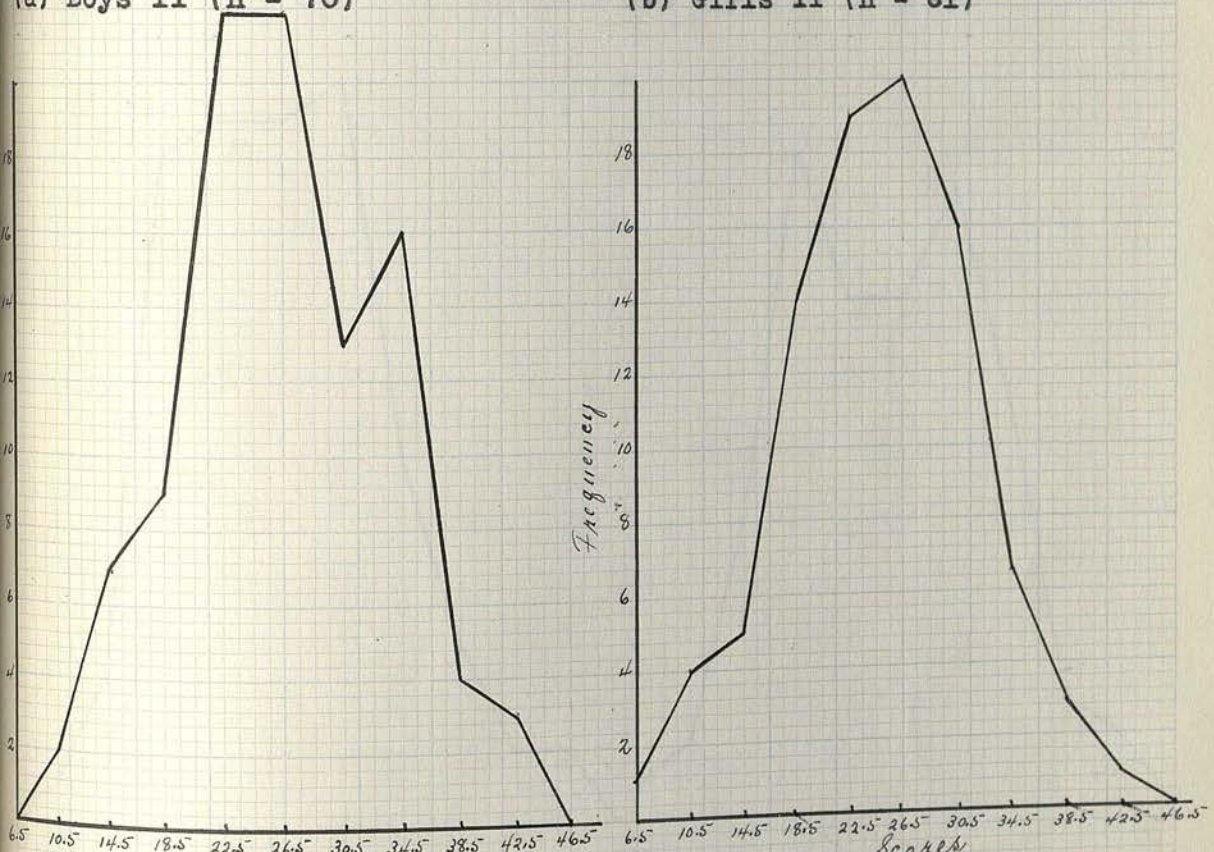
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Fig. 10. Distribution of Scores on the "Form Perception" Tests, "FP<sub>2</sub>" (Tests XVIII, XX)



(a) Boys II (n = 70)

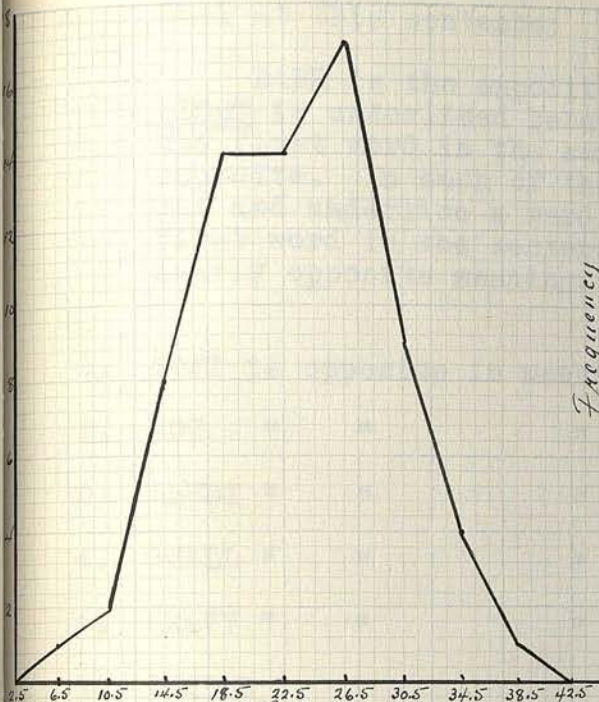
(b) Girls II (n = 61)



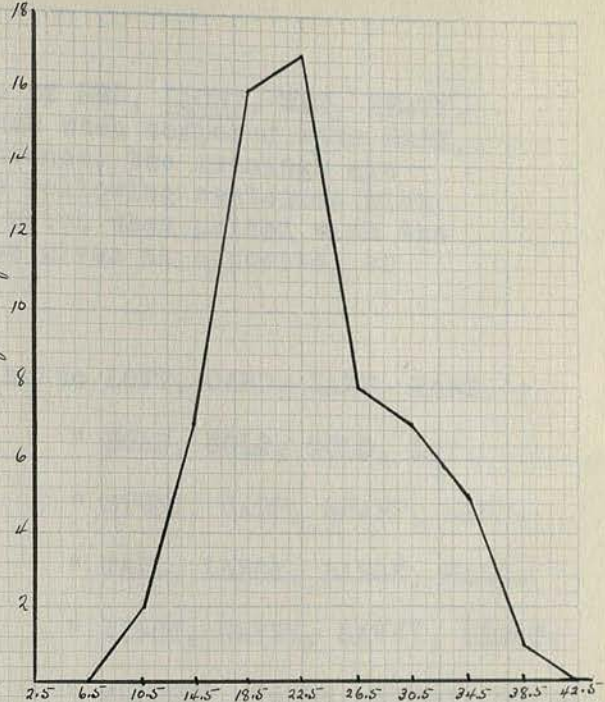
(c) Boys I (n = 100)

(d) Girls I (n = 90)

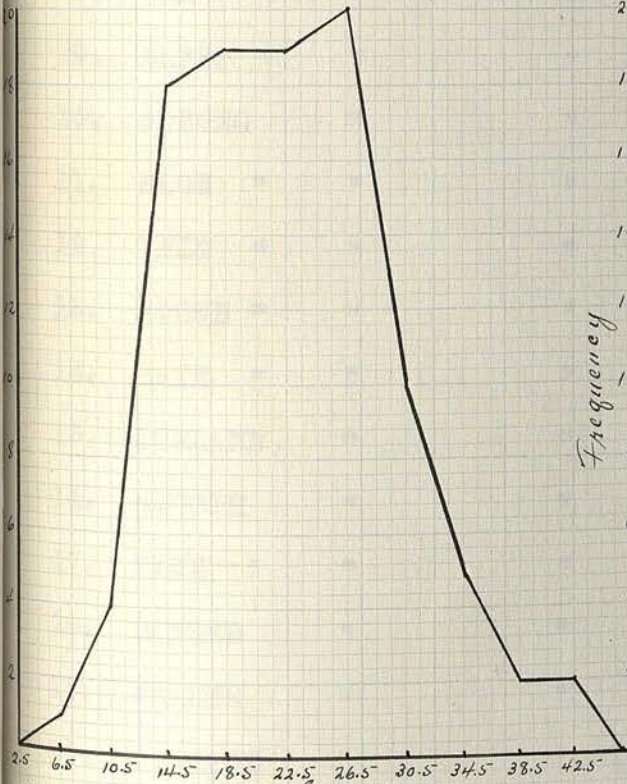
Fig. 11. Distribution of Scores on the "Form Perception" Tests, "fp<sub>1</sub>" (Test XIX A, B)



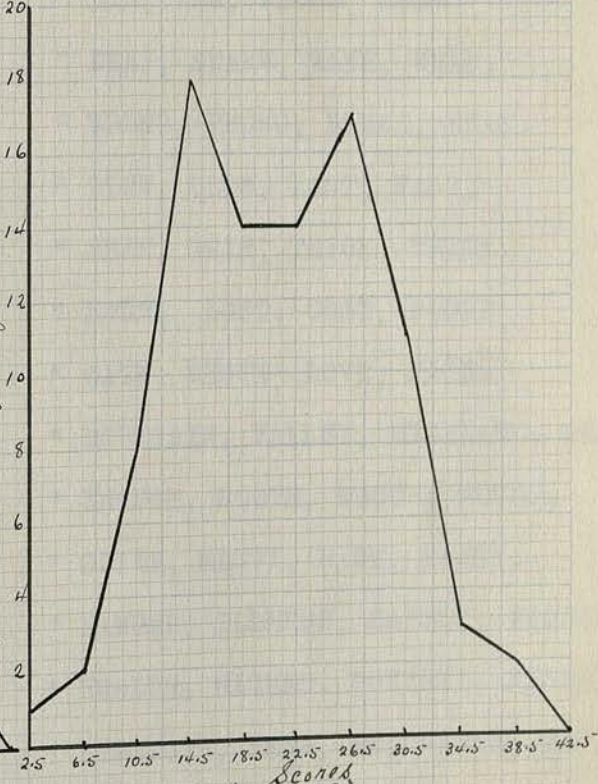
(a) Boys II (n = 70)



(b) Girls II (n = 61)



(c) Boys I (n = 100)



(d) Girls I (n = 90)

Fig. 12. Distribution of Scores on the "Form Perception" Tests, "fp<sub>2</sub>" (Test XX)

TEST 1 OPPOSITES.

Look at this sentence:

DARK is the opposite of RED, LIGHT, WET, HEAVY. LIGHT is underlined because when compared with DARK, the first word in the sentence, the meanings are opposite. In each of the following sentences pick out and underline a word which when paired with the first word in the sentence gives an opposite, or nearly opposite meaning.

1. SOFT is opposite in meaning to LOFT, CARD, LARD, HARD.
2. HOT " " " " BOLD, GOLD, GOLD, LOT.
3. BLUNT " " " " STUNT, CARP, SHARP, HARP.
4. SMALL " " " " TALL, LARGE, BARGE, HALL.
5. HEAVY " " " " TIGHT, NAVVY, SAVVY, LIGHT.
6. TENDER " " " " SLENDER, TOUGH, ROUGH, GENDER.
7. LESS " " " " MESS, MORE, SORE, TORE.
8. WIN " " " " BIN, TIN, WHOSE, LOSE.
9. SLEEP " " " " DEEP, STAKE, WAKE, WEEP.
10. STRONG " " " " WRONG, PRONG, BLEAK, WEAK.
11. SLOW " " " " BLOW, GLOW, LAST, FAST.
12. THIN " " " " SHIN, GRIN, THICK, TRICK.
13. FOUND " " " " HOUND, LOST, COST, POUND.
14. HATE " " " " GATE, SHOVE, LOVE, FATE.
15. LOWLAND " " " " MOUNTAIN, VALLEY, HIGHLAND, GLEN.
16. SMOOTH " " " " ENOUGH, SOOTH, TOOTH, ROUGH.
17. NICE " " " " SLICE, NASTY, RICE, PASTY.
18. DANGER " " " " MANGER, ILLNESS, SAFETY, WARNING.
19. WEALTH " " " " HEALTH, RICHES, POVERTY, MISERY.
20. COURAGE " " " " STRENGTH, FEAR, ENDURANCE, FATIGUE.
21. ACTIVE " " " " ALIVE, MASSIVE, THRIVE, PASSIVE.
22. FORGET " " " " NUGGET, BUDGET, REMEMBER, DECEMBER.
23. COMPLETE " " " " RECEIPT, SUSPENSE, COMMENCE, DEFEAT.

## OPPOSITES (continued)

24. ENTRANCE is opposite in meaning to EXIST, ENWRAP, EXIT, ENCASE.
25. MINUS " " " " SURPLUS, BUS, REBUS, PLUS.
26. RECENT " " " " DECENT, DEVOTE, REGENT, REMOTE.
27. MAXIMUM " " " " OPTIMUM, MINIMUM, PREMIUM,  
AQUARIUM.
28. EXPAND " " " " COMPACT, CONTACT, CONTRACT,  
EXTRACT.
29. AGONY " " " " AGONE, BLISS, BLISTER, AGAPE.
30. DIVIDE " " " " DIVISION, DECIDE, DECISION,  
MULTIPLY.
31. DEFECTIVE " " " " DETECTIVE, SUSPECT, PERFECT,  
INFECT.
32. ADVERSITY " " " " SUCCOUR, SUCCESS, ADVERSE,  
ADVERSARY.
33. REDUCE " " " " REDUCTION, INDUCE INDUCTION,  
INCREASE.
34. INCOMPETENT " " " " INCUMBENT, CAPACIOUS, CAPABLE,  
INDOLENT.
35. VILLAIN " " " " VILLEIN, NERO, ZERO, HERO.
36. WAX " " " " LAX, TAX, MANE, WANE.
37. TAUT " " " " LOSE, GOOSE, TEACH, LOOSE.
38. INNOCENT " " " " JURY, GUILLESS, GUILTY, JUDGE.
39. OPTIONAL " " " " COMPLETE, PERMISSION,  
CUMPULSORY, OFFICER.
40. OPPONENT " " " " OPPOSES, OPTION, SUPPORTER,  
SUPPORTS.
41. PURIFY " " " " PACIFY, DEFILE, DEFINE, REFINE.
42. ALTRUISTIC " " " " ALTRUIST, ALTERS, SELFISH,  
SHELLFISH.
43. STRANGE " " " " FAMILY, STRANGLES, FAMISHING,  
FAMILIAR.
44. VAGUE " " " " VOGUE, DEFINITE, PLAGUE,  
DEFENCE.
45. SCANTY " " " " SHANTY, SUFFICIENT, PROFUSE,  
DIFFUSE.
46. ENERGETIC " " " " SANGUINE, LANGUAGE, LANGUID,  
ACTIVE.
47. PERT " " " " INERT, DETOUR, PERTINENT,  
DEMURE.
48. ANY " " " " MANY, NONE, ONE, SEVERAL.
49. SUPERFLUOUS " " " " SUPERFINE, FLUENT, NECESSARY,  
EXTRA.
50. CELIBATE " " " " CELEBRATE, MARRED, MARRIED,  
CALIBRATE.
51. RECALCITRANT " " " " CALCULATED, OBESE, OBSTRUCTIVE,  
OBEDIENT.

## OPPOSITES (continued)

52.	APATHY	is	opposite	in	meaning	to	TELEPATHY, ENTHUSIASM, PATHETIC, ENFU ON.
53.	AGGRAVATE	"	"	"	"	"	AGGREGATE, ALIEVIATE, ALLUVIAL, PROVOKE.
54.	FERTILE	"	"	"	"	"	FERTILISE, FERRULE, STELLAR, STERILE.
55.	ACCELERATE	"	"	"	"	"	ACCUMULATE, MAGNIFY, MAGNETO, RETARD.
56.	RECTITUDE	"	"	"	"	"	LONGITUDE, TURPITUDE, LATITUDE, ATTITUDE.
57.	ANNUL	"	"	"	"	"	ANNAL, ANNOUNCE, RATIFY, RESTORE.
58.	AMBIGUOUS	"	"	"	"	"	EXIGUOUS, DECIDUOUS, VAGUE, CLEAR.
59.	ASPERITY	"	"	"	"	"	PROSPERITY, WILDNESS, MILDNESS, SINCERITY.
60.	METICULOUS	"	"	"	"	"	SCRUPULOUS, MIRACULOUS, FEARLESS, CARELESS.
61.	MAUDLIN	"	"	"	"	"	FOOLISH, SENSIBLE, CLEVER, ABSURD.
62.	CREDIT	"	"	"	"	"	DISCOUNT, EXCHANGE, DEBIT, BELIEVE.
63.	COMMAND	"	"	"	"	"	COMMANDEER, COMMUTE, ORDER, OBEY.
64.	CREATE	"	"	"	"	"	CREATION, CREMATION, DESTROY, DIVERT.
65.	LUGUBRIOUS	"	"	"	"	"	SALUBRIOUS, HILARIOUS, DUBIOUS, DEVICUS.
66.	DISUSE	"	"	"	"	"	ABUSE, PERUSE, ILL-USE, USE.
67.	PROLOGUE	"	"	"	"	"	PROLIX, DIALOGUE, EPILOGUE, COLLEAGUE.
68.	PREAMBLE	"	"	"	"	"	RAMBLE, ORATION, PREPARATION, PERORATION.
69.	CONCAVE	"	"	"	"	"	CONCORD, CONVICT, CONVEX, CONVEY.
70.	ASCETIC	"	"	"	"	"	ACETIC, DIETETIC, BON ACCORD, BON VIVANT.
71.	ABSTRUSE	"	"	"	"	"	ABSTRACT, PROFOUND, SIMPLE, DIFFUSE.
72.	EXTINCT	"	"	"	"	"	OLD-FASHIONED, EXTANT, DULL, EXTENT.
73.	PHLEGMATIC	"	"	"	"	"	FOREIGN, DELICATE, HOMERIC, CHOLERIC.
74.	SINCERE	"	"	"	"	"	SIMPLE, PRETENTIOUS, AMBITIOUS, SINGULAR.
75.	ADMIRING	"	"	"	"	"	ADMITTING, CONTEMPTUOUS, CONDEMNING, ENVYING.



24. HAZARDOUS	means the same or nearly the same as	HAPHAZARD DIFFICULT DANGEROUS HEINOUS.
25. RAVAGE	. . . . .	RAMPAGE PLUNDER SUNDER SAVAGE.
26. ABHOR	. . . . .	ABASE DECIDE VACUUM DETEST.
27. AUTHENTIC	. . . . .	WRITER ACKNOWLEDGE GENUINE ALLOW.
28. COMPETENT	. . . . .	CUMBERSOME CAPACIOUS CAPABLE IMPUDENT.
29. ANNUL	. . . . .	ANNAL CANCEL CHANCEL AISLE.
30. ALLUREMENT	. . . . .	INSURANCE CONFIDENCE ATTRACTION LOSS.
31. CULPABLE	. . . . .	CAPABLE GULLIBLE FALLIBLE BLAMEWORTHY
32. ANGUISH	. . . . .	LANGUISH DISTRESS DISTRRAINT REDRESS.
33. ADVERSARY	. . . . .	ADVERSITY OPPOSITE OPPONENT HOSTILE.
34. CONFISCATE	. . . . .	CONFUSE DEPUTE DEPRIVE CONTRIVE.
35. COMPETITION	. . . . .	LOTTERY INQUEST CONTEST PROTEST.
36. CORRUPT	. . . . .	UPRIGHT HONEST DEPRAVED GODLIKE.
37. OBSTINATE	. . . . .	OBSERVANT OBTAIN STUBBORN STUDIOUS.
38. FEASIBLE	. . . . .	FASHIONABLE PRACT- ICABLE FANCIFUL PLAIN
39. DECREPIT	. . . . .	UNTRUE BELIEF INFIRM INFORM.
40. ILLUSTRIOUS	. . . . .	BRIGHT PICTURED RESTORED RENOWNED.
41. FURTIVE	. . . . .	FESTIVE SHY SLY CONSPICUOUS.
42. DEplete	. . . . .	DEPLORE, INCREASE LESSEN DEDUCE.
43. RECOUP	. . . . .	RENOUNCE RECOMMENCE RECOMPENCE RELY.
44. CENSURE	. . . . .	EDIT ADVISE ADMONISH ABJURE.
45. VELOCITY	. . . . .	FEROCITY HASTE SPEED FLIGHT.
46. DOCILE	. . . . .	PUERILE INFANTILE GENTLE PLACID.
47. ASUNDER	. . . . .	ASIDE ALOFT APART AGAIN.
48. RECANT	. . . . .	DECANT WITHDRAW ADMIT RETURN.
49. HEINOUS	. . . . .	PLEASANT PEACEFUL FORCEFUL HATEFUL.
50. ADHERENT	. . . . .	ZEALOT FOLLOWER ADVISER OPPONENT.
51. AVARICE	. . . . .	GLUTTONY GREED VARIETY MISERY.
52. TRANSITORY	. . . . .	RAILWAY PASSENGER PASSING LASTING.
53. ABRIDGE	. . . . .	VIADUCT CROSS SHORTEN HILLY.

54.	RATIFY	means the same or nearly the same as	PURIFY PACIFY CONTRIVE CONFIRM.
55.	PAUCITY	. . . . .	CAPACITY QUANTITY LITTLE OVERWEIGHT.
56.	CAPRICE	. . . . .	DISCOUNT OVERCHARGE GRIM WHIM.
57.	ABJURE	. . . . .	CENSURE JUDGE DENY ADMIT
58.	CONSEQUENTIAL	. . . . .	SELFISH SELF-IMPORTANT SELF-DENIAL CONSECUTIVE
59.	PROTOTYPE	. . . . .	DUPLICATE ORIGINAL COPY PHOTOGRAPH.
60.	INFAMOUS	. . . . .	UNKNOWN UNTRIED WICKED WELL-KNOWN.
61.	HETEROGENEOUS	. . . . .	CLEVER MISCELLANEOUS HUGE GENEROUS.
62.	ARRAIGN	. . . . .	ARRANGE GOVERN CHARGE ACQUIT.
63.	PROFLIGATE	. . . . .	ABUNDANCE WASTEFUL GENEROUS PUNISH.
64.	MUTINOUS	. . . . .	MUNITION RENDITION REBELLIOUS LOYAL.
65.	ANIMOSITY	. . . . .	ADMIRATION REVERENCE LOVE HATE.
66.	CLEMENT	. . . . .	CLAIMANT CLAMANT CAUTIOUS KIND
67.	IRREFUTABLE	. . . . .	UNBREAKABLE UNHAPPY UNDENIABLE UNTRUE.
68.	PARADOXICAL	. . . . .	SELF-HELP SELF-CONSCIOUS SELF-SUFFICIENT SELF- CONTRADICTORY.
69.	INGENUOUS	. . . . .	INGENIOUS CLEVER FOOLISH SIMPLE.
70.	EULOGY	. . . . .	SOLILOQUY HARMONY PRAISE POEM.
71.	SUPINE	. . . . .	RAPACIOUS PRONE PROUD PRUDISH.
72.	SATIETY	. . . . .	SUFFICIENT DEPLETION REPLETION SAFETY.
73.	IMMUNE	. . . . .	LARGE GASSY FREE WARLIKE.
74.	CHOLERIC.	. . . . .	INFECTIOUS PASSIONATE CONTAGIOUS VOLUBLE.
75.	ADVENTITIOUS	. . . . .	RISKY ROMANTIC CASUAL CAUSAL.

22. SANITARY (CONCLUSION CONDITION ATTITUDE  
ARRANGEMENT)
23. TRIVIAL (OFFICE OFFENCE DEFENCE REWARD)
24. PLAIN (EVIDENCE WITNESS COUNSEL STATEMENT)
25. BUOYANT (VESSEL LIQUID SPIRIT VOICE)
26. FUTILE (ACHIEVEMENT ENDEAVOUR SUCCESS REGRET)
27. CHRONIC (TEMPER AILMENT WEATHER ARGUMENT)
28. PUNY (EFFORT ATTEMPT CONTEST ATTACK)
29. GRACEFUL (CONVERSATION MOVEMENT MANNER  
APPEARANCE)
30. CUNNING (METHOD DECISION STRATAGEM ADVICE)
31. AWKWARD (MOMENT TIME HOUR DAY)
32. UNHEALTH (COUNTRY CLIMATE WEATHER PERSON)
33. DELICIOUS (PLAY SITUATION FLAVOUR MUSIC)
34. ATTRACTIVE (OBJECT SUBJECT PERSON THING)
35. ROMANTIC (TALE HISTORY LETTER BOOK)
36. CONSUMMATE (BEAUTY SKILL IMPUDENCE COURAGE)
37. POPULOUS (TRAIN EXHIBITION SUBURB CINEMA)
38. PREHISTORIC (RAVINE MONSTER ICEBERG MONSOON)
39. OBSOLETE (CUSTOM MANNER HABIT RULE)
40. AFFECTIONATE (RELATIVE PARENT ONLOOKER LISTENER)
41. THOUGHTLESS (INFANCY YOUTH MANHOOD AGE)
42. METICULOUS (ENERGY ACCURACY NUMBER OBSTINACY)
43. LONELY (SINGLENESSE COMPANY ALOOFNESS ISOLATION)
44. UNRUFFLED (MIEN VOICE FACE CLOTHES)
45. PUNGENT (SMELL ODOUR AROMA PERFUME)
46. INFECTIOUS (SPEECH MANNER SPIRIT BELIEF)
47. HEINOUS (CRIME COMPLAINT PUNISHMENT THREAT)
48. HAZARDOUS (VOYAGE ADVENTURE ATTEMPT STORM)
49. EXTINCT (VOLCANO DODO MAMMOTH PHOENIX)
50. ABSTRUSE (OPINION ARGUMENT DECISION THEORY)

TEST III. WORD PAIRING.HANDSOME (TEASPOON MAN WOMAN MONKEY)USELESS (SEA POSTAGE LUMBER AEROPLANE)

In these examples one word has been underlined as being the most suitable, among those given, to use with the first word. Thus, we more often speak of a handsome man than of a handsome teaspoon. We do not say a handsome woman; We prefer to say a beautiful woman. Similarly we often speak of useless lumber but seldom of useless sea or useless postage.

Do the following in the same way:

1. GREEN (COW GRASS WOOD WATER)
2. ROSY (LIPS HANDS CHEEKS PEARS)
3. AUBURN (HAIR SUNSET LEAF PICTURE)
4. PURPLE (SUNRISE HEATHER PATHWAY PONY)
5. LAZY (HORSE POSTMAN HABIT RIVER)
6. UGLY (CHICKEN PUPPY BABY DUCKLING)
7. EVIL (ANGEL SPIRIT DRAGON GIANT)
8. STALE (MILK FIRE FOOD WATER)
9. CALM (POND RIVER SEA FLOOD)
10. RARE (ADVICE BEAUTY BURDEN PICTURE)
11. POLITE (TALK CONDUCT MANNER CHARACTER)
12. SILENT (BEHAVIOUR ACTION PRAYER SERMON)
13. OFFENSIVE (THOUGHT WISH NOISE SMELL)
14. GUSTY (CURRENT WIND HURRICANE BREEZE)
15. PIERCING (CALL YELL SHRIEK SHOUT)
16. VIOLENT (TOUCH BLOW SOUND SIGHT)
17. DISCORDANT (SONG SOUND NOTE CHOIR)
18. STRICT (ACCOUNT NOTICE IMPULSE SPEECH)
19. TASTY (MITE CAKE MORSEL LUMP)
20. REGULAR (THIEF SERVICE TIME-TABLE SERVANT)
21. WHOLESOME (WEATHER CLOTHING FOOD HOUSES)

TEST IV. DEFINITIONS.

Say in one or two words what the following objects are:

THIGH- upper part of the leg.

SHIN

SNAKE

BICYCLE

LARDER

ATTIC

CISTERN

RULER

TAP

HINGE

CORE

SHRUB

PANE

SHEARS

CRATE

STABLE

INN

GARAGE

BRAKE

TYRE

SIRLOIN

EMERALD

JESTER

PILOT

HAKE

SPONGE

CANISTER

PLUMBER

BAT ( 1 )

BAT ( 2 )

BAROMETER

CHALK

PECK

KNUCKLE

MESH

PLUMAGE

MATTRESS

CASTOR

POLLEN

PETAL

CEILING

ALUMINUM

KERNEL

THERMOMETER

ALLOY

AUDIENCE

LARYNX

GUILLOTINE

ASBESTOS

WORSTED

DYNAMO

OPTICIAN



11. The rotation of the <sup>earth</sup> moon on its <sup>hub</sup> axle causes <sup>night</sup> light and <sup>noon</sup> day.  
<sup>sun</sup> <sup>axis</sup> <sup>morning</sup> <sup>light</sup>
12. The habit of <sup>picking</sup> throwing stones is <sup>helpful</sup> deceitful because <sup>buildings</sup> persons may be  
<sup>finding</sup> <sup>dangerous</sup> <sup>chimneys</sup> hurt <sup>lost.</sup>
13. Cleanliness <sup>carelessness</sup>  
Dirt and darkness are enemies of <sup>disease</sup> spiders.  
Germs <sup>sunshine</sup> beetles.
14. Those who <sup>make</sup> drink a leak in a <sup>gas</sup> water pipe with a <sup>flash lamp</sup> lighted match will  
<sup>seek</sup> <sup>air</sup> <sup>watering</sup> can
- <sup>discover</sup> <sup>erosion</sup>  
<sup>probably</sup> <sup>recover</sup> an <sup>excursion.</sup>  
<sup>deceive</sup> <sup>explosion</sup>
15. Digging <sup>palatable</sup> <sup>restores</sup>  
Cooking food makes it more <sup>enjoyable</sup> and so <sup>hinders</sup> the  
Hunting <sup>comfortable</sup> <sup>aids</sup>
- <sup>congestion</sup> <sup>depart</sup> <sup>ears</sup>  
processess of <sup>digestion</sup> which <sup>end</sup> in the <sup>mouth.</sup>  
<sup>indigestion</sup> <sup>begin</sup> <sup>nose</sup>

Complete the following sentences to make the best sense by underlining one word in each set of three. For example:-

Water                      Copper  
Iron                      Wood                      are metals.  
Air                                      stone

1. James was of robust handsome build and robust healthy appearance, of healthy handsome

upright  
robust character and upright mind.  
energetic                      energetic

2. The student was so foolish delicate and pale ruddy that he requested invited athletic black consulted

his doctor about the condition expense of his carpet exercises. correction health

3. A pleasant paralysing terror kept him motoring running as that diminutive fulsome motionless gigantic form amusing

sounded  
sang nearer down the dimly brightly lighted passage.  
loomed                      cheerfully

4. One who deliberately accidentally misleads people is distrustful dishonest while if he incidentally deceitful

pretends                      forsake  
intends to possess worthy feelings which he lacks, he is  
decides                      deny

insufficient  
inappropriate  
insincere.

5. How often do people <sup>condemn</sup> praise in others the very <sup>virtues</sup> faults they <sup>profit</sup> serious
- are guilty of <sup>themselves</sup> perceiving.  
pardonning
6. The <sup>youngest</sup> kindest men have <sup>never</sup> sometimes a spark of kindness in them  
<sup>wickedest</sup> extinguished
- and the best have often a touch of <sup>heart</sup> selfishness.  
<sup>parent</sup> youth
7. Taking careful <sup>precautions</sup> instructions he fired at the <sup>covey</sup> platoon as it  
<sup>aim</sup> herd
- passed over the meadow and was highly <sup>incensed</sup> delighted when the  
<sup>through</sup> amused
- <sup>charge</sup> attendants <sup>shells</sup>  
<sup>rise of several</sup> birds showed that his words had taken effect.  
<sup>scarecrows</sup> shots
8. If we <sup>endeavour</sup> attend to any things at the <sup>right</sup> same time we  
<sup>neglect</sup> several <sup>usual</sup>
- shall probably do some of them <sup>informally</sup> incorrectly.  
<sup>unwisely</sup>
9. The power to <sup>enjoy</sup> use tools like the <sup>joy</sup> envy of <sup>eating</sup> singing in a  
<sup>admire</sup> power <sup>thinking</sup>
- <sup>country</sup>  
rational manner is among the most important gifts that  
<sup>attitude</sup>
- <sup>man</sup> <sup>minerals</sup>  
distinguish woman from the lower <sup>vegetables</sup>  
<sup>animals</sup> animals.
10. Persons who <sup>are born</sup> live in solitude for the <sup>greater</sup> lesser part of their  
<sup>die</sup> plenty <sup>smaller</sup>
- <sup>days</sup> <sup>pleasant</sup> <sup>enjoy</sup> <sup>loneliness</sup>  
<sup>nights</sup> find it difficult to <sup>hate</sup> themselves in the <sup>happiness</sup>  
<sup>evenings</sup> <sup>easy</sup> <sup>despise</sup> <sup>company</sup>  
of others.

TEST VII. COMPREHENSION.

Read the following stories quickly and carefully and then answer the questions at the end.

1. A donkey once said to a fox "How I wish I could run as fast as the horse". The fox replied "You could if you tried harder and talked less."

ANSWERS.

- How many animals are mentioned? . . . . .
- Which animal did not speak? . . . . .
- Which animal talked too much? . . . . .
- Which animal made the most sensible remark? . . . . .

2. Jim had too much faith in Uncle Ned to worry about their being lost. After they had tramped a bit farther, Jim's legs began to tire and ache. Uncle Ned said again, "I think we are going round in a circle, Jim. When people get confused in the woods they usually do just that. We could find our way out if we came to an old road that we could follow". He climbed a tree but could see nothing but forest in all directions. The shadows began to deepen as it was growing late.

- What did Uncle Ned hope to find? . . . . .
- Did climbing a tree help him? . . . . .
- Why was he becoming anxious? . . . . .
- Why did not Jim worry? . . . . .

3. A sentinel, alarmed by the strange noise, fired a shot into the air as a warning to the garrison. Soon they hastened to the walls from which, by the dim light of a few flares, the damaged airship could be faintly seen. A powerful searchlight was directed upon it by the lieutenant but no sign of a pilot could be discovered in the wreckage.

- What had happened? . . . . .
- How did the garrison learn of it? . . . . .
- What alarmed him? . . . . .
- What did the lieutenant discover? . . . . .

4. An Irishman was accused of stealing pigs and several witnesses declared that they had seen him surrounded by pigs. To which the prisoner replied. "Truth is stranger than fiction, for was I not surrounded by my neighbours?"

Was the Irishman paying his neighbours  
 a compliment? . . . . .  
 What did he mean? . . . . .  
 Was he really a thief? . . . . .  
 Did he tell the truth? . . . . .

5. Between the middle of the eighteenth century and the middle of the nineteenth century a great change took place in the main occupations of the people, a change known as the Industrial Revolution. Instead of being engaged mainly in agriculture, the people became occupied in manufactures and flocked from the country to the towns. The invention of machinery greatly increased the production of manufactured goods and added to our wealth.

What happened to the population of the towns? . . . . .  
 What suffered from lack of labour? . . . . .  
 How were people in towns employed? . . . . .  
 What helped to make their work increase? . . . . .  
 When did all this happen? . . . . .

6. The melancholy days are come, the saddest of the year  
 Of wailing winds, and naked woods, and meadows brown and sere.  
 Heaped in the hollows of the grove, the autumn leaves lie dead  
 They rustle to the eddying gust and to the rabbits' tread.  
 The robin and the wren are flown and from the shrubs the jay  
 And from the wood-top calls the crow through all the gloomy day.

What time of the year is it? . . . . .  
 What are the poet's feelings? . . . . .  
 What sights cause them? . . . . .  
 What sounds strengthen them? . . . . .  
 What does he miss? . . . . .

7. Many opinions have been given on the value of life. Some call it good, others call it bad. It would be more correct to say that it is mediocre; for on the one hand, our happiness is never as great as we should like, and on the other hand, our misfortunes are never as great as our enemies would wish for us. It is this mediocrity of life which prevents it from being radically unjust.

Opinion as to the value of life is .....?  
 The chief characteristic of life is its .....?  
 Because of this it displays little .....?  
 For the .....hoped for by our .....are  
 balanced by the .....desired by ourselves.

8. Tests such as we are now making are of value both for the advancement of science and for the information of the person who is tested. It

is important for science to learn how people differ and on what factors these differences depend. If we can separate the influence of heredity from the influence of environment, we may be able to apply our knowledge so as to guide human development. We may thus in some cases correct defects and develop abilities which we might otherwise neglect.

The cause of science can be helped by finding out .....  
.....;.....?  
Human development may be guided by discovering .....  
.....  
The individuals assisted are .....?  
They are helped in .....ways, viz., .....  
.....?

TEST VIII. was not printed in time to be used in the battery.

TEST IX. was eliminated because of unsatisfactory distribution of score.

TEST X. ANALOGIES.

Look at this sentence:-

GOOD is to BAD as white is to clean, black, wicked, red. The words GOOD and BAD are opposite in meaning, and so are black and white. The word Black has been underlined to show that it is related to white in the same way that BAD is related to GOOD. In the next example a similar thing has been done, but this time the words are not opposite in meaning.

BAKER is to BREAD as tailor is to Tailoress, cake, man, clothes. The relation between the tailor and the clothes is the same as that between the BAKER and the BREAD. He is the maker.

Do these in the same way. In each line underline one word only.

1. COAT is to WEAR as bread is to water, eat, starve, cook.
2. WATER .. DRINK cake .. bread, coffee, eat pie.
3. LEAD .. HEAVY cork .. bottle, weight, light, float.
4. FIRE .. HOT ice .. water, solid, ice-cream, cold.
5. TIGER .. HAIR Trout .. fish, water, scale, swims.
6. SHOE .. FOOT hat .. coat, nose, head, collar.
7. HORSE .. HARNESS soldier.. sword, gun, uniform, clothes.
8. MAN .. HOUSE bird .. fly, insect, worm, nest.
9. MOUSE .. SMALL giant .. monster, large, queer, small.
10. HORSE .. NEIGHING donkey.. kicking, sobbing, braying, jumping.
11. FUR .. BEAR feathers. man, down, camel, chicken.
12. EAR .. HEAR eye .. know, head, see, light.
13. GUN .. SHOOTS knife .. run, cuts, hat, bird.
14. PICTURE. SEE sound .. noise, music, hear, bark.
15. DAY .. LIGHT night .. shadows, dark, black, moon.
16. RED .. BLOOD green .. colour, grass, spring, fresh.
17. FOOD .. HUNGER water .. drink, clear, thirst, pure.
18. CART .. LAND boat .. horse, water, oar, sail.
19. LEATHER. SHOES brick .. mortar, house, saw, stone.
20. COURAGE. GOOD dishonesty punishment, honesty, cowardly, bad.

21. FRONT is to BACK as near is to by, yonder, far, next.
22. GO .. COME sell .. leave, buy, money, papers.
23. BOLD .. TIMID advance .. proceed, retreat, campaign,  
soldier.
24. AWAKE .. ASLEEP alive .. work, rest, dead, play.
25. PRETTY .. UGLY attract .. fine, nice, draw, repel.
26. LAUGH .. CRY joy .. sorrow, happiness, smile,  
marriage.
27. ABOVE .. BELOW top .. spin, bottom, surface, side.
28. ESTABLISH. ABOLISH begin .. slavery, wrong, abolition, end.
29. BEGINNING. END birth .. baby, mother, age, death.
30. ABIDE .. DEPART stay .. over, home, play, leave.
31. WORK .. REST day .. labour, night, sleep, wake.
32. DISMAL .. CHEERFUL dark .. sad, stars, night, bright.
33. QUARREL .. AGREE enemy .. friend, disagree, agreeable,  
foe.
34. ANCIENT .. MODERN remote .. rapid, improved, recent, new.
35. THRIFT .. EXTRAVAGANCE wisdom economy, riches, folly, praise.
36. HONESTY .. STRAIGHT dishonesty wrong, illegal, crime, crooked.
37. TRANSIENT. PERMANENT candle .. lamp, flame, sun, fire.
38. OBTUSE .. ACUTE asset .. assent, liable, liability, angle
39. APPROVE .. VETO allow .. alter, provide, cover, prohibit.
40. MONOTONY.. VARIETY expulsion. provision, retention,  
prevention, entrance.
41. PURSE .. MONEY grate .. iron, fender, gold, coal.
42. GAS .. PIPE electricity light, switch, wire, cigar.
43. MUSCLE .. MOTION mind .. sight, thought, school. beauty.
44. TALK .. TOLD speak .. song, spoke, speaking, sang.
45. WASH .. FACE sweep .. table, floor, sofa, bed.
46. POISON .. DEATH food .. eat, bird, life, bad.
47. WINGS .. FLIGHT hands .. talks, sounds, crafts, fights.
48. GRANARY .. WHEAT library .. librarian, papers, books, pens.
49. COLD .. ICE heat .. warm, air, coat, radiator.
50. DEATH .. SILENCE thunder .. lightning, terror, noise, fumes.

In each example underline three words that represent objects of the same class, for instance:- doll, ring, flower, top, drum, shoe. You will notice that doll, top and drum are all toys. That is why they are underlined. Do these in the same way:-

1. coat, foot, hat, gloves, soap, chair.
2. cotton, oats, oaks, wheat, bananas, barley.
3. satin, silk, wallpaper, matting, calico, linoleum.
4. meat, bread, fish, potatoes, poultry, milk.
5. gold, coal, copper, aluminium, paraffin, treacle.
6. beef, mutton, dog, egg, pork, mushroom.
7. red, white, black, diamond, yellow, blue.
9. shed, house, cottage, mansion, warehouse, church.
10. church, station, chapel, market, cathedral, dock.
11. thorn, apple, leaf, jam, pear, plum.
12. circle, parallelogram, square, quadrilateral, arc, axle.
13. pond, lake, ocean, river, canal, lock.
14. doctor, patient, lawyer, client, minister, flock.
15. workman, employer, union, carpenter, bricklayer, plumber.
16. piano, violin, violincello, viola, clarinet, trombone.
17. oak, ash, beech, holly, mistletoe, palm.
18. councillor, member, alderman, visitor, provost, policeman.
19. chicken, eagle, linnet, owl, dove, hawk.
20. fly, oar, swim, propeller, scale, fin.
21. wage, fee, money, salary, wealth, letacy.
22. poverty, honesty, beauty, diligence, courage, conceit.
23. seizing, playing, snatching, grabbing, giving, receiving.
24. joy, sadness, surprise, grief, woe, disgust.
25. carefulness, waste, forethought, negligence, thrift, prodigality

Now in the following examples underline one of the five words

which come last in each line to show that it belongs to the same class as the three words which come first in the line.

For example:-

hat, collar, glove	.....	hand, cane, <u>shoe</u> , head, house.
rose, daisy, violet	.....	bush, red, plant, bed, <u>pansy</u> .
desk, bed, chair	.....	book, table, floor, pencil, coat.

In the third example the first three words are all names of pieces of furniture. The only word among the last five which is a piece of furniture is table. Underline it. Now go on to these:-

26. plum, apricot, apple ..... tree, seed, peach, juice, ripe
27. cup, plate, saucer ..... fork, table, eat, bowl, spoon.
28. horse, pigeon, beetle ..... stall, saddle, eat, goat, chirp
29. boat, horse, train ..... sail, row, motorcycle, move,  
track.
30. pan, bowl, basket ..... pail, handle, knife, fork, spoon
31. snake, cow, sparrow ..... tree, doll, pig, feather, skin.
32. ship, bicycle, carriage..... sail, motorcar, wheel, ocean,  
harness.
33. axe, knife, shears ..... hammer, razor, hoe, rake, fork.
34. nut, turnip, potato .....shell, tree, bush, milk, apple.
35. pig, cat, donkey ..... fish, cart, woman, dog, hen.
36. class-room, pencil, arithmetic. water, circle, desk, spot.
37. parsnips, beetroots, potatoes.. custard, carrots, cherries, cheese
38. iron, silver, brass..... poker, gold, shilling, shovel.
39. tram, train, bicycle..... bus, boiler, crane, wheel.
40. water, milk, tea..... lemonade, porridge, soup, treacle.
41. signal, engine, carriage..... pavement, ticket, platform, guard.
42. table, chair, picture ..... hook, hammer, hose-pipe,  
hearthrug.
43. book, newspaper, magazine..... light, truth, amusement, letter.
44. shop, stall, emporium ..... stable, bazaar, bank, station.
45. penny, half crown, pound-note . invoice, receipt, cheque,  
counterfoil.
- 46-50.(These are similar).

TEST XIII. A. NUMBER SERIES.

2 4 6 8 10 12 (14) (16)  
 27 24 21 18 15 12 ( ) ( ).

In the first row of figures above, the numbers are increasing by two each time and the next two numbers that should come after 12 are 14 and 16, so these numbers (14) and (16) have been written in the brackets.

In the second row the numbers are decreasing by three at a time so the numbers that should come next are 9 and 6. Put these numbers in the brackets at the right of that row.

In each row below try to find out how the numbers are made up, then in the two brackets at the right write the two numbers that should come next. (the space at the left may be used for figuring.)

1. 1 3 5 7 9 11 ( ) ( )
2. 5 10 15 20 25 30 ( ) ( )
3. 16 14 12 10 8 6 ( ) ( )
4. 5 9 13 17 21 18 ( ) ( )
5. 33 30 27 24 21 18 ( ) ( )
6. 2 2 4 4 6 6 ( ) ( )
7. 3 3 3 6 6 6 9 ( ) ( )
8. 2 3 5 8 12 17 ( ) ( )
9. 37 29 22 16 11 7 ( ) ( )
10. 2 4 8 16 32 64 ( ) ( )
11. 8 4 2 1  $\frac{1}{2}$   $\frac{1}{4}$  ( ) ( )
12. 40 36 30 26 20 16 ( ) ( )
13. 5 5 8 8 11 11 ( ) ( )
14. 3 4 6 9 13 18 ( ) ( )
15.  $\frac{1}{256}$   $\frac{1}{128}$   $\frac{1}{64}$   $\frac{1}{32}$   $\frac{1}{16}$   $\frac{1}{8}$  ( ) ( )
16. 41 38 35 32 29 26 ( ) ( )
17. 21 23 25 32 34 36 43 ( ) ( )
18. 240 120 60 30 15  $\frac{15}{2}$  ( ) ( )
19. 47 51 56 62 69 77 ( ) ( )
20. 4 6 9 10 12 15 16 ( ) ( )

21.	3	4	7	5	6	11	7	8	( )	( )
22.	4	9	16	25	36	49			( )	( )
23.	81	27	9	3	1	$\frac{1}{3}$			( )	( )
24.	6	9	12	9	6	6	9	12	( )	( )
25.	5	6	12	10	11	22	15	16	( )	( )
26.	4	3	5	4	6	5	7		( )	( )
27.	120	91	66	45	28	15			( )	( )
28.	5	3	10	6	15	9	20		( )	( )
29.	3	2	6	4	9	8	12		( )	( )
30.	1	4	8	11	22	25	50		( )	( )

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TEST XIII. B. NUMBER SERIES.

In each set of five numbers on the right underline TWO numbers that suitably continue the series started by the four numbers on the left.

Samples.

30 40 50 60 .....65 70 75 80 85.  
 2 4 6 8 .....9 16 12 7 10.

In the first sample the numbers are increasing by tens, 70 and 80 are underlined as they should come next after 60. In the second sample the numbers are increasing by two's therefore 10 and 12 are underlined.

In each row on the left try to find out how the numbers are made up, then underline Two of the five numbers on the right, that continue the series started on the left.

1.	17	19	21	23	.....	24	25	26	27	28
2.	22	20	18	16	.....	17	24	14	15	12
3.	15	20	25	30	.....	40	50	35	45	55
4.	7	1	15	19	.....	21	23	28	27	29
5.	21	18	15	12	.....	14	6	8	11	9
6.	5	5	7	7	.....	10	11	9	12	9
7.	2	3	5	8	.....	17	16	12	9	10
8.	35	27	20	14	.....	5	6	12	10	9
9.	64	32	16	8	.....	7	9	4	3	2

10.  $\frac{1}{32}$   $\frac{1}{16}$   $\frac{1}{8}$   $\frac{1}{4}$       4  $\frac{1}{2}$  1  $\frac{3}{4}$   $\frac{1}{3}$
11. 18 18 21 21      22 22 24 25 24
12. 4 5 7 10      12 13 14 16 19
13.  $\frac{1}{192}$   $\frac{1}{96}$   $\frac{1}{48}$   $\frac{1}{24}$        $\frac{1}{22}$   $\frac{1}{8}$  24  $\frac{1}{12}$   $\frac{1}{6}$
14. 5 8 12 17      22 34 23 30 29
15. 51 48 45 42      40 35 39 31 36
16. 243 81 27 9      1 7 13 3 17
17. 14 19 26 35      39 46 52 47 59
18. 1 4 9 16      25 35 32 27 26
19. 7 11 16 22      30 37 29 33 32
20.  $\frac{1}{9}$   $\frac{1}{3}$  1 3      6 9 12 24 27
21.  $13\frac{2}{3}$   $13\frac{1}{3}$  13  $12\frac{2}{3}$        $11\frac{2}{3}$  12 11  $12\frac{1}{2}$   $12\frac{1}{3}$
22. 66 55 44 33      30 15 22 13 11
23. 98 95 78 75      68 65 58 50 55
24. 81 49 25 16      8 7 9 5 4
25. 17 28 40 53      72 67 63 60 77

## TEST XIII. C.

## NUMBER SERIES (Middle Quantities)

Look at these five words:-

ounce, pound, ton, stone, hundredweight.

The word "STONE" is underlined to show that if the five quantities named were put in order of size, "Stone" would be the middle one. Now do the examples below by underlining the word which would be in the middle if the five were put in order of size or value.

foot	inch	mile	furlong	yard.
peck	quart	half-pint	bushel	pint
sixpence	half-crown	crown	florin	shilling.
half-crown	threepence	florin	crown	shilling.
acre	square foot	square yd.	square mile	square rod
pint	gallon	quart	bushel	peck
$\frac{1}{2}$ D	4D.	ls.	7d	$\frac{1}{2}$ d
£1	penny	crown	shilling	sovereign
square inch	fourteen	twenty	square yd.	square ft.
twenty-two	fourteen	twenty	sixteen	eighteen.

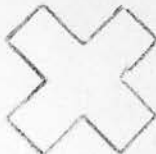
Now look at these numbers: 1 4 5 2 3.

The number three is underlined to show that it would be the middle number if the numbers were put in order of size.

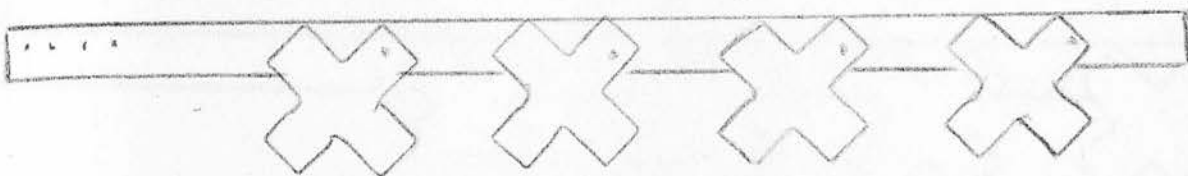
Underline the number that would be in the middle in each row if all the numbers in that row were put in order of size.

3	9	6	15	12
9	5	1	3	7
20	5	25	10	15
$7\frac{1}{2}$	9	$4\frac{1}{2}$	6	3
$\frac{1}{2}$	$\frac{1}{4}$	$\frac{5}{8}$	$\frac{1}{8}$	$\frac{3}{8}$
$\frac{3}{64}$	$\frac{3}{16}$	$\frac{3}{32}$	$\frac{3}{8}$	$\frac{3}{4}$
93	85	74	68	75
$\frac{1}{3}$	$\frac{1}{6}$	$\frac{1}{9}$	1	3
$\frac{1}{7}$	$\frac{3}{14}$	$\frac{5}{14}$	$\frac{6}{7}$	$\frac{2}{14}$
$\frac{1}{3}$	$\frac{1}{27}$	$\frac{1}{39}$	$\frac{1}{71}$	$\frac{1}{19}$

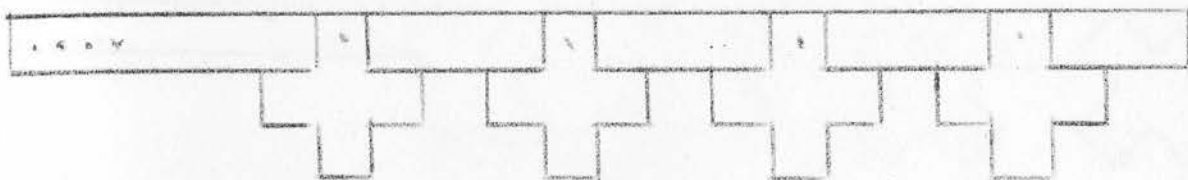
TEST XIV. NUMBER COMBINATIONS.

Here are drawings of some pieces of cardboard shaped like this  They are called rotators, because they can be rotated, that is, turned on an axis, like a wheel.

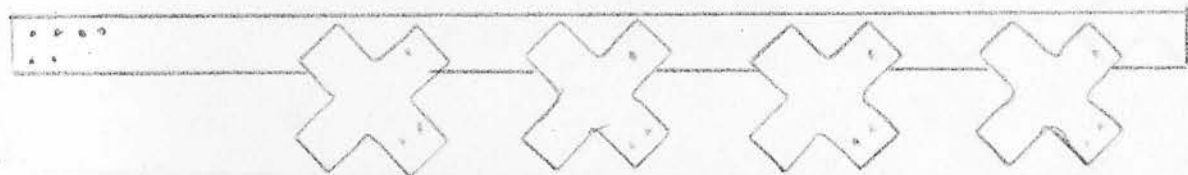
The following four rotators arranged as in this drawing below were given to a pupil. He was given the following instructions: "Turn the rotators so that one arm of each points upward and such that the sum of the dots on these four upward pointing arms equals the number of dots in the group at the extreme left".



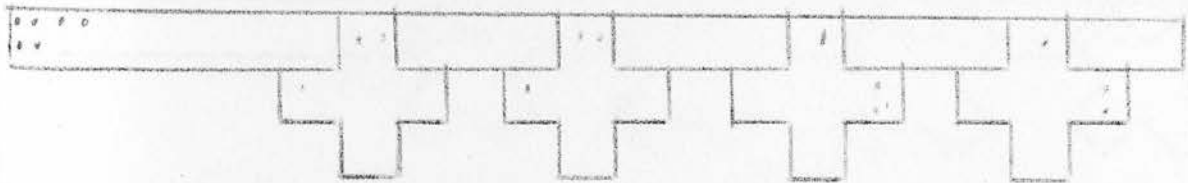
When correctly completed they looked like this drawing below:



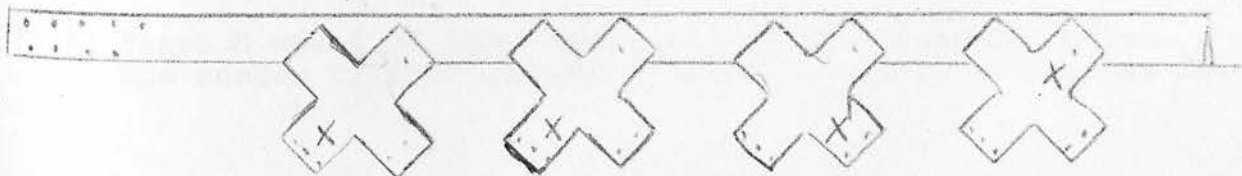
He was then given rotators like the following and told to do the same with them.



Here are 6 dots in the group at the left. The pupil saw that if he turned up two arms with 2 dots each and two arms with one dot each the total was 6, so he did it that way. He might also have had it correct by turning up 3 arms with 2 dots each and one arm with no dots, for the total then would be 6. When correctly completed, they looked like this drawing below:

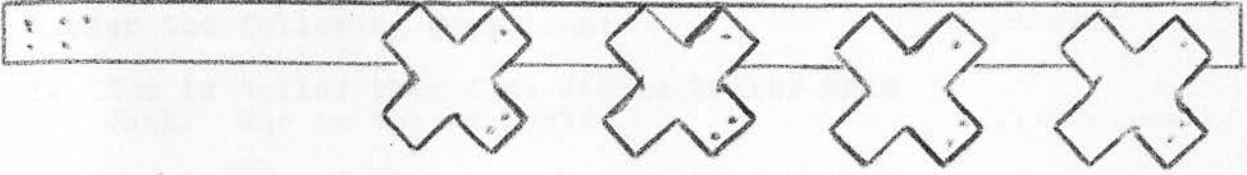


Note: Now imagine that you have the same task. On the following, put an X on each arm that you would have pointing up. Remember that you must, in imagination, turn the rotators so that the sum of the dots on the four upward pointing arms is equal to the number of dots in the group at the left. Here is one done for you:



## TEST XIV. Page 2.

1.



2.



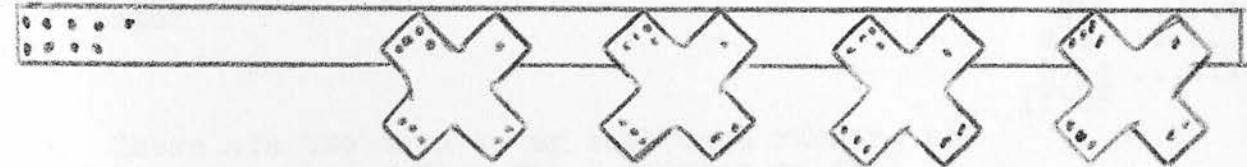
3.



4.



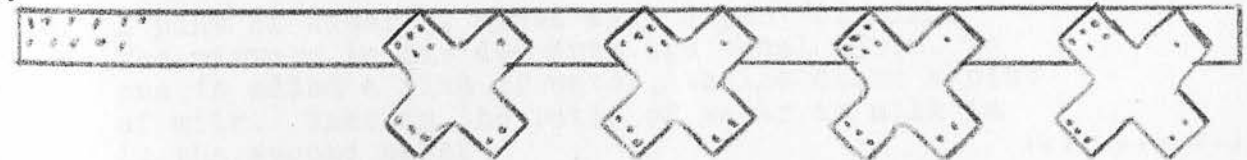
5.



6.



7.



Note: Pages 3 and 4 of this test continue in the same fashion.  
The number of dots gradually increases until it reaches 30.

Test 15 PROBLEMS Section A.

Answer the following questions:-

Answer

1. Tom is taller than Jim: Jim is taller than Jack. Who is the tallest? .....
2. Winnie runs faster than Mary; Annie runs slower than Mary. Who runs the slowest? .....
3. Henry lives nearer the school than Walter, but Walter lives farther away than William. Who lives nearest the school? .....
4. A man is 50 miles from home. He walks 22 miles the first day, 14 miles the second day. On the third day he gets a lift on a car for 11 miles. How far has he to walk to get home? .....
5. George has 5 more cows than Frank. Frank has three times as many as Henry. If Henry has 6 how many has George? .....
6. A fisherman starts one morning to travel up stream in a boat. Each day he rows 20 miles upstream. Each night his boat drifts 2 miles downstream. How many miles is he from his starting point on the morning of the third day? .....
7. What figures are missing from each line of this sum?  

263	.....
94	.....
<u>674</u>	.....
17985	
8. There are two taps to my bath each running at the same rate. It takes 8 minutes to fill it when both are running. How long will it take one tap alone to fill it? .....
9. What figures are missing from each line of this subtraction?  

16	.....
<u>917</u>	.....
6456	
10. A pint of water is mixed with a pint of milk. The mixture is divided into two equal parts. To one is added a pint of water, to the other a pint of milk. What is the ratio of water to milk in the second case? .....

Answer

11. A cherry is as big as two raspberries and a plum is as big as four cherries. Tom ate 20 raspberries and 6 cherries. John ate two raspberries and four plums. Charles ate 8 raspberries, 8 cherries and one plum. Who ate the most? .....
12. July 1st is on a Monday. My birthday is on the previous Wednesday. What is the date of my birthday? .....
13. I am six days younger than Harry and my birthday is on December 28th. This year Christmas falls on a Friday. On what day of the week is Harry's birthday? .....
14. The first odd number is 1, the second odd number is 3, the third odd number is 5. So that the fourth odd number will be  $(4 \times 2 - 1)$ , which equals 7. What is the 19th odd number? .....

Test 15 PROBLEMS Section B.

Answer the following questions:-

- 1 - 3. (These items were eliminated.)
4. Henry only sings when he is well. Sea voyages make him ill. Will he sing at the ship's concert? .....
5. All the boys in the school go to carpentry on Tuesday or Wednesday. All the girls go to cooking on Wednesday or Thursday. Yesterday both Tommy and Mary had their special lessons. What day will be the day after to-morrow be? .....
6. Janet dislikes beef but likes potatoes. Mary prefers cauliflowers to cabbage while Ann prefers boiled mutton and caper sauce to roast beef and Yorkshire pudding. Janet invited Mary and Ann to dinner. What eatables should she prepare? .....
7. Two boys were sent to deliver packages at every house in High St. One arrived before the other, delivered three packets on the shady side, and then crossed over to the sunny side. The second boy continued on the shady side and when he had finished crossed over to help the other. If the second boy delivered six packets on the sunny side, and if there were an equal number of houses on both sides of the street, which boy delivered most packages? .....
- How many more did he deliver? .....

Answer

8. In a large office Letters about money have to go to Mr. Smith or Mr. Jones. Letters about transport to Mr. Robinson or Mr. Smith. A letter arrives asking for the hire of a lorry and enclosing a cheque. To whom should it be sent? .....
9. To utter false notes is a crime. The school choir uttered many false notes. Therefore the members of the choir are criminals. Is this conclusion true or false? Why? .....
10. I don't like reading and I have no wireless set. The doctor has ordered a quiet evening indoors. Which of these shall I do? Read a book, listen to the wireless, play cards, whitewash the ceiling? .....
11. Lucy is Tom's only aunt and her only brother married a woman named Harriet. What relation is Tom to Harriet? .....
12. Where the climate is hot aloes and rubber do well; heather and grass will only grow where it is cold. Heather and rubber require moisture, grass and aloes will only grow in fairly dry districts. What plants would you expect to grow well in a hot, swampy, district? .....

TEST 15 PROBLEMS SECTION C.

Answer the following questions:-

Answers

- 1. C. is west of B. B. is west of A. In what direction from C. does A lie? .....
- 2. A boy made seventy-nine dots in a straight line, each dot one inch from the next. What was the distance between the first dot and the last? .....
- 3. I had a seat facing the engine and saw the sun setting through the carriage window on my left. In what direction was the train travelling? North, South, East or West? .....
- 4. I have come from the south and I want to go to Dalton-in-the Valley. I come to four cross roads. Straight ahead leads me to the sea-shore, while to the left there are uninhabited mountains. In what direction does Dalton lie? North South East or West? .....
- 5. My little hut has only one room, one door, and one window. At mid-day the sun shines straight through the window in the wall on the left. If you stand at the back wall and face the door in what direction are you looking? North South East or West? .....
- 6. A sign post stands at four cross roads running North South East and West, but an accident has caused the post to twist so that the East finger now points to the South. A traveller walks down the road now marked west. In what direction is he actually walking? .....
- 7. A boy took a square piece of paper and drew a straight line from the top left hand corner to the bottom right hand corner; then he drew another line from the top right hand corner to the bottom left hand corner. Then he cut the paper along the lines he had drawn. How many pieces were formed?.....

Draw a sketch of one of the pieces? Name it?

What size are the angles?

8. If 16 oranges are arranged on the ground in a compact square four oranges to each side, and then more oranges are piled on top to form a pyramid, (that is, a heap getting regularly less and less as it rises, until it ends in only one at the top).

How many oranges are in the second row of the pyramid? .....  
 How many oranges in the pyramid altogether? .....

9. Tom had eight small wooden cubes, each one inch long, one inch broad, and one inch deep. He glued them together to form one large cube, which he painted red all over. When it was dry he broke it up again into the eight small cubes.

How long was the large cube? .....  
 How broad was the large cube? .....  
 How deep was the large cube? .....  
 How many small cubes had paint on all six sides?.....  
 How many small cubes had paint on four of the six sides? .....  
 How many small cubes had paint on three of the six sides? .....  
 How many small cubes had paint on two opposite sides? .....  
 How many small cubes had no paint on at all? .....

10. Tom took twenty seven small one inch cubes and repeated the above process. In this case.

How tall was the large cube? .....  
 How many small cubes had paint on six sides? .....  
 How many small cubes had paint on three sides? .....  
 How many small cubes had paint on two sides? .....  
 How many small cubes had paint on one side? .....  
 How many small cubes had no paint on at all? .....

11. A clock stands on a mantelpiece with its back to the room, but the face can be seen reflected in a mirror which stands behind it, From where I am sitting I can only see the position of the hands, I cannot distinguish the figures. What is the actual time when the clock in the mirror seems to show

Eleven minutes past Seven? The correct time is .....  
 Twenty seven minutes to Two? " " " " .....  
 Eight forty-five P.M. " " " " .....  
 Six o'clock exactly? " " " " .....

TEST 15 PROBLEMS SECTION D

Answer the following questions:-

Answer

1. A typewriter has got out of order. If you press F it types 2, B types 3, M types 4 and C types 5. In what order would you press the letters to write 425453? .....

2. Two boys wrote to each other in a private code. The letters of the alphabet were numbered from 1 to 26. A being number 1, B number 2 and so on. Translate the following message:-

19, 20, 15, 16. - 6, 9, 18, 9, 14, 7 - 1, 20, -  
19, 21, 14, 19, 5, 20.

3. Write this message in the same code:-

TOM HAD A LARGE BLOCK OF WOOD

20, 15, 13.....

4. Find what code was used in the following case:-

Message: Are you in pain?

Code: bof zpv jo gbjo? The code is:-.....

5. Write this message in the code used in question 4.

see the little girl catch a butterfly.

6. A dressmaker used letters instead of figures in ticketing goods. A dress priced at £1:3:4 was marked C/M/E, a hat worth 7/6 was marked D/N and a coat worth 8/ - was marked B/Y. An assistant soon discovered that a simple sentence had been used as a key. Can you guess what it was? .....

7. Decipher the following code, by using the facts.  
(a) That few English words contain only one letter.  
(b) That the last letter of many words is e  
(c) That 3 stands for l, 4 for t, and 8 for s.

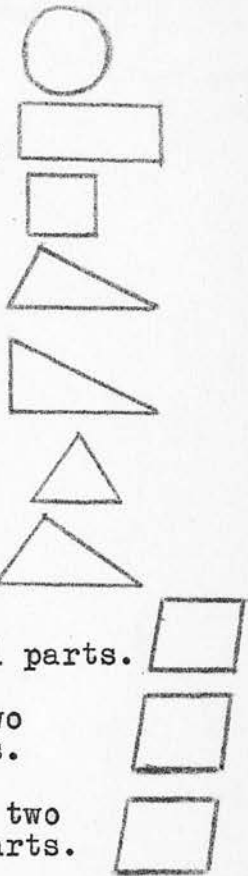
2 870 4574 2 078 7 324431 3741

.....



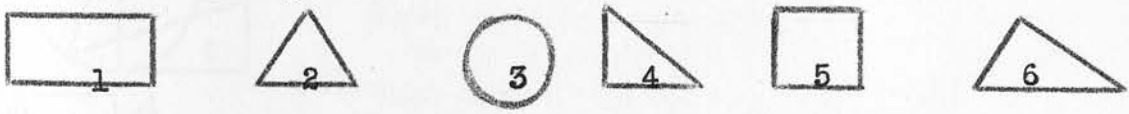
TEST XVII. FOLLOWING INSTRUCTIONS.

- A. 1. Here is a circle. Draw an X inside it.
2. Here is a rectangle. Divide it into two equal parts.
3. Here is a square. Divide it into two equal parts.
4. Here is a right-angled triangle (one square corner) Divide it into two equal parts.
5. Here is another right-angled triangle. Divide it into two equal parts.
6. Here is a triangle with all its sides equal. Divide it into two equal parts.
7. Here is another right-angled triangle. Put an X on its longest side.
8. Here is a different figure. Divide it into two equal parts.
9. Show another way of dividing the same figure into two equal parts.
10. Show still another way of dividing this figure into two equal parts.



In the following questions write all answers on the dotted line to the right.

Here are six geometric figures, a square, a circle, a rectangle, and three triangles. Each one has a number



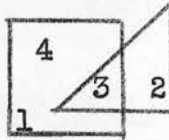
11. What is the number in the circle? .....
12. " " " " " " square? .....
13. " " " " " a right-angled triangle? .....
14. " " " " " another right-angled triangle? .....
15. " " " " " the other triangle  
(which has no right-angle)? .....

TEST XVII. FOLLOWING INSTRUCTIONS. (B and C.)

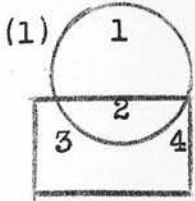
B.

In each of the following five questions, find the one number that is in the two overlapping figures. Write that number in the bracket at the right.

Sample



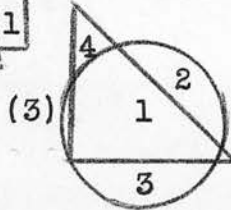
..... (3)



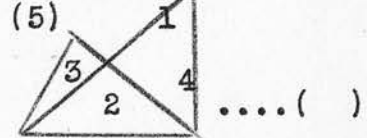
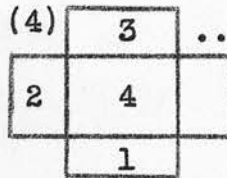
..... ( )



..... ( )

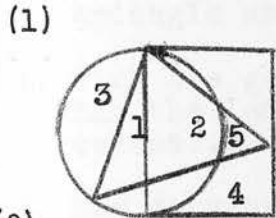


..... ( )

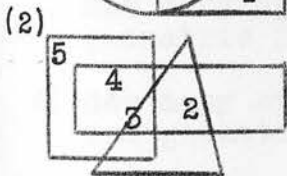


..... ( )

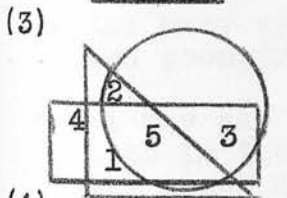
C. Each of the next five figures is made up of three overlapping figures. Answer the following questions:



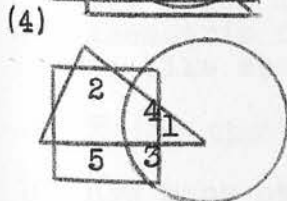
- (1) What number is in both the circle and the triangle but not in the rectangle?.....( )  
 What number is in the circle but not in the triangle?.....( )  
 What number is in all three figures, rectangle, circle and triangle?.....( )



- (2) What number is in both the triangle and rectangle, but not in the square?.....( )  
 What number is in both the triangle and square, but not in the rectangle?.....( )  
 What number is in all three figures?.....( )



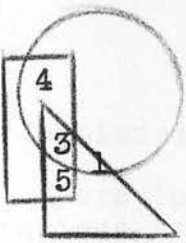
- (3) What number is in both the circle and rectangle, but not in the triangle?.....( )  
 What number is in both the circle and triangle, but not in the rectangle?.....( )  
 What number is in all three figures?.....( )



- (4) What number is in both the circle and triangle, but not in the square?.....( )  
 What number is in both the circle and square, but not in the triangle?.....( )  
 What number is in all three figures?.....( )

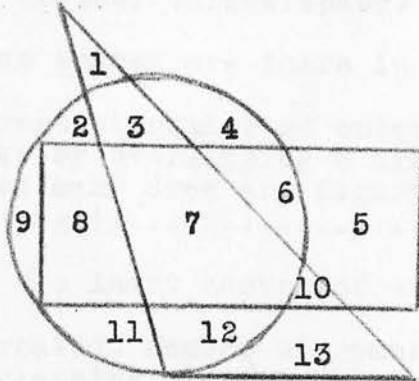
c. (Continued)

(5)



- (5) What number is in both the circle and rectangle, but not in the triangle?.....( )  
 What number is in both triangle and rectangle, but not in the circle?.....( )  
 What number is in all three figures?.....( )

TEST XVII. FOLLOWING INSTRUCTIONS. D



Answer the following questions about the above figure.

1. What is the smallest number that is in the triangle but not in the circle nor in the rectangle?.....( )
2. What is the largest number that is in the circle but not in the triangle nor in the rectangle?.....( )
3. Write the number that is in the lowest space that is in the triangle and in the circle but not in the rectangle.....( )
4. Find the geometrical (circle, triangle, or rectangle) that has the least number of spaces in it. Write that number of spaces.....( )
5. How many spaces are there each of which is in all three geometric figures?.....( )
6. How many spaces are there each of which is in one and only one geometric figure?.....( )
7. How many spaces are there each of which is in two and only two geometric figures?.....( )
8. We may say that space 12 is like space 3 because they are both in the circle and triangle but not in the rectangle. Any space is like another which is in exactly the same geometric figures. Write the number of the space which is like space 6.....( )
9. Write the number of the space which is like space 1.....( )
10. How many spaces are there like space 9?.....( )

## D. (Continued)

11. There is no other space like space 5, so we may call 5 unique (yuneek). Any space is unique which has no other space like it. Examine spaces 8, 9, 10, 11, 12, and 13 in order until you find another unique space. Write its number.....( )
12. How many unique spaces are there in the figure?.....( )
13. What is the greatest number of unique spaces which it is possible to make by overlapping a circle, triangle, and rectangle? (You may draw any figures you wish on empty spaces of this page).....( )
14. Also, what is the least number of unique spaces possible?..( )
15. What is the greatest number of spaces which it is possible to make by overlapping a circle, triangle, and rectangle?...( )

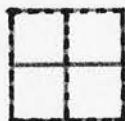
TEST XVIII A. JUDGMENT OF LENGTH.

The following drawings are made up of straight lines. The lengths of the lines can be judged by comparing them with the dotted square which is drawn above each group. Each drawing has a number.

In each group of drawings you are to find the drawing which has the longest total length of line, and the one which has the shortest total length of line. That is to say, find the drawing such that when the lines are added together end to end the total length is greater than that of any other drawing in the group. Write the number of the drawing in the space for longest. Then find the one which has the shortest total length and write its number in the space for shortest.

Arrange all the others in between so that the total lengths gradually get smaller. Start from the longest and arrange them in order down to the shortest.

This first group has been done for you.

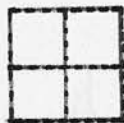


				The longest is number	..4.	
The next	or	2nd	"	"	"	..1.
"	"	"	3rd	"	"	..2.
"	"	"	4th (next shortest)			..3.
"	"	"	Shortest is	"	"	..5.

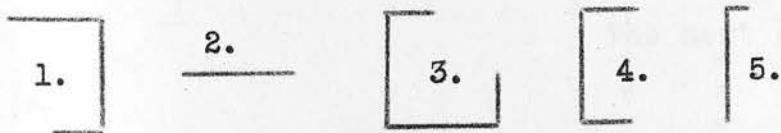


Do each of the following groups in the same way

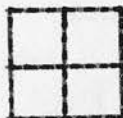
(1)



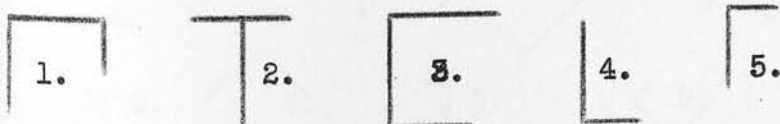
				The longest is number	.....	
The next	or	2nd	"	"	"	.....
"	"	"	3rd	"	"	.....
"	"	"	4th (next shortest)			.....
"	"	"	shortest is	number	.....	



(2)



				The longest is number	.....	
The next	or	2nd	"	"	"	.....
"	"	"	3rd	"	"	.....
"	"	"	4th (next shortest)			.....
"	"	"	shortest is	number	.....	



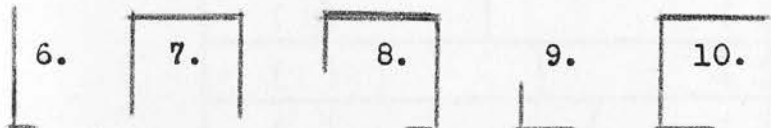
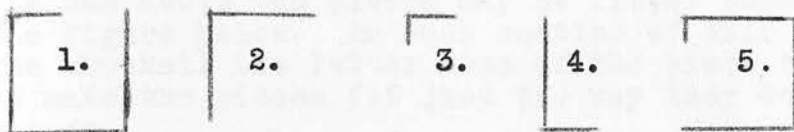
Continue in the same way with the longer groups on next page.

Test XVIII A continued.

(3)



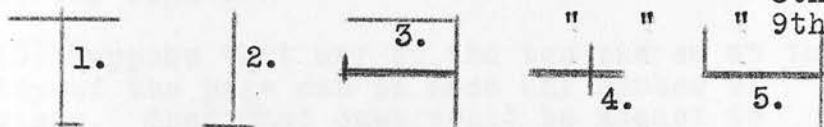
				The longest is number	.....
	The next	or	2nd	"	"
"	"	"	3rd	"	"
"	"	"	4th	"	"
"	"	"	5th	"	111..
"	"	"	6th	"	"
"	"	"	7th	"	"
"	"	"	8th	"	"
"	"	"	9th (next shortest is	"	"
"	"	"	shortest number is	"	"



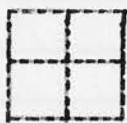
(4)



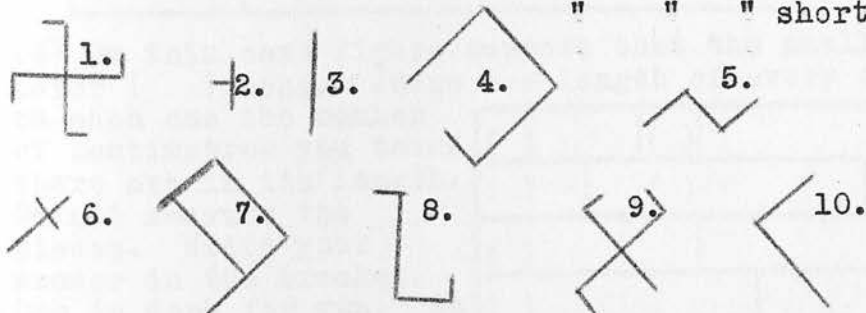
				The longest is number....
	The next	or	2nd	"
"	"	"	3rd	"
"	"	"	4th	"
"	"	"	5th	"
"	"	"	6th	"
"	"	"	7th	"
"	"	"	8th	"
"	"	"	9th (next shortest is	"
"	"	"	shortest number is	"



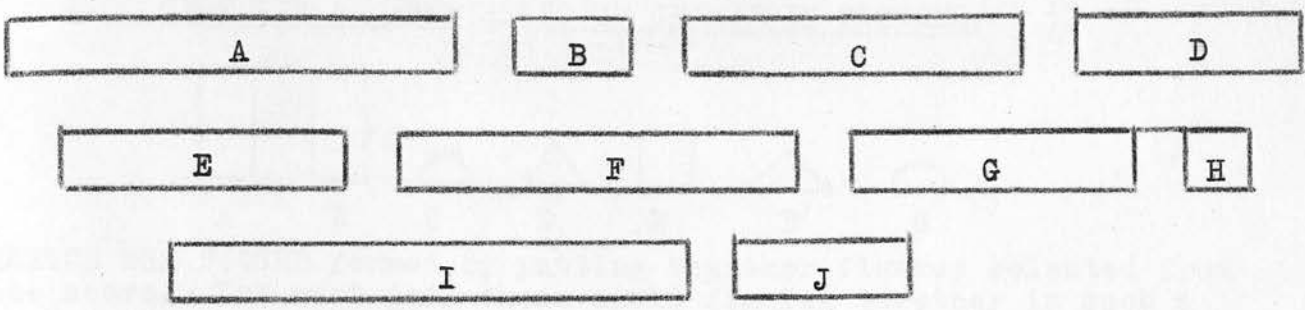
(5)



				The longest is number.....
	The next	or	2nd	"
"	"	"	3rd	"
"	"	"	4th	"
"	"	"	5th	"
"	"	"	6th	"
"	"	"	7th	"
"	"	"	8th	"
"	"	"	9th (next shortest is	"
"	"	"	shortest number is	"

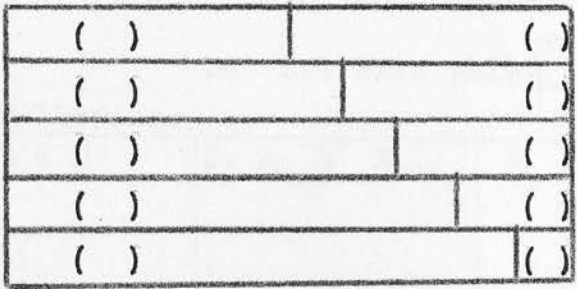


TEST XVIII B. JUDGMENT OF LENGTH.



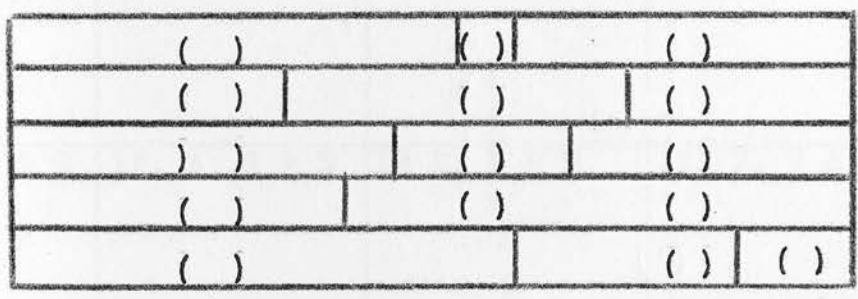
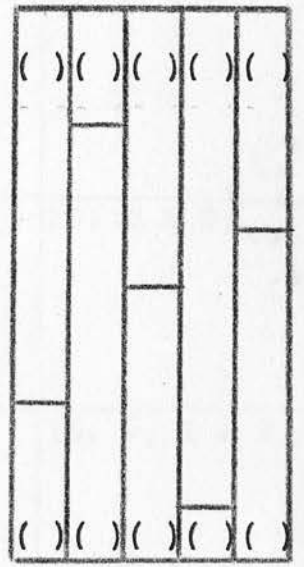
(1) The above ten pieces may be fitted together to look just like the figure below. In each section of this large figure write (inside the bracket) the letter name of the piece that would have to be used to make the pieces fit just the way they do here. Do not measure the pieces.

(1)

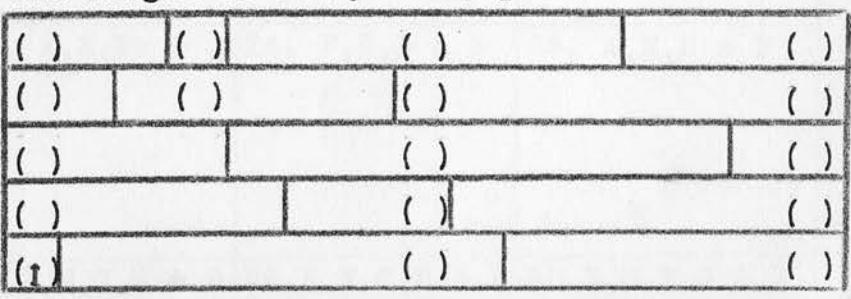


(2) Show how the same ten pieces would have to be arranged to look just like the figure at the right.

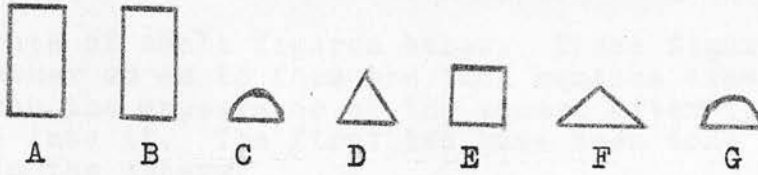
(3) Suppose that any of the ten pieces at the top of the page can be used any number of times. Show what ones would be needed to make a figure look just like the one below. Write in the name of the piece used for each section.



(4) On this next figure suppose that the smallest piece is one centimeter ( ) long. Judge the length of every other piece and write on each one the number of centimetres you think there are in its length. Do not measure the pieces. Write your answer in the bracket. One is done for you. Go ahead and do the rest.



TEST XIX A. SYNTHESIS OF GEOMETRIC FIGURES.



SKETCH THE FIGURE formed by putting together figures selected from the above. You must join these small figures together in such a way that equal sides fit together.

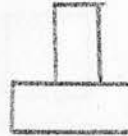
For example, A and B would look like this



or like this



but not like this

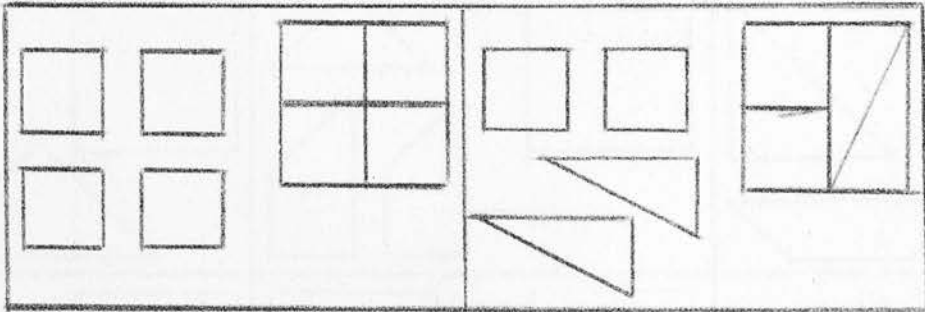


Now sketch the following:

1. A & B	2. B & D	3. A & E	4. C & E	5. D & G
6. E & F	7. C & G	8. A & F	9. F & G	10. D & F
11. B, C & D	12. B, E & G	13. C, D & G	14. F, E & B	15. C, E & F
16. F, C & G	17. A, G & D	18. B, F & D	19. F, E & G	20. D, E & B
21. A, D, C & E	22. E, F, B & G	23. C, E, F & G	24. F, G, E & D	25. A, E, D & F
26. D, E, F & C	27. B, D, F, E & G	28. F, E, C, D & G	29. B, F, C, D & E	30. E, C, B, G & E

TEST XIX B. SYNTHESIS OF GEOMETRIC FIGURES

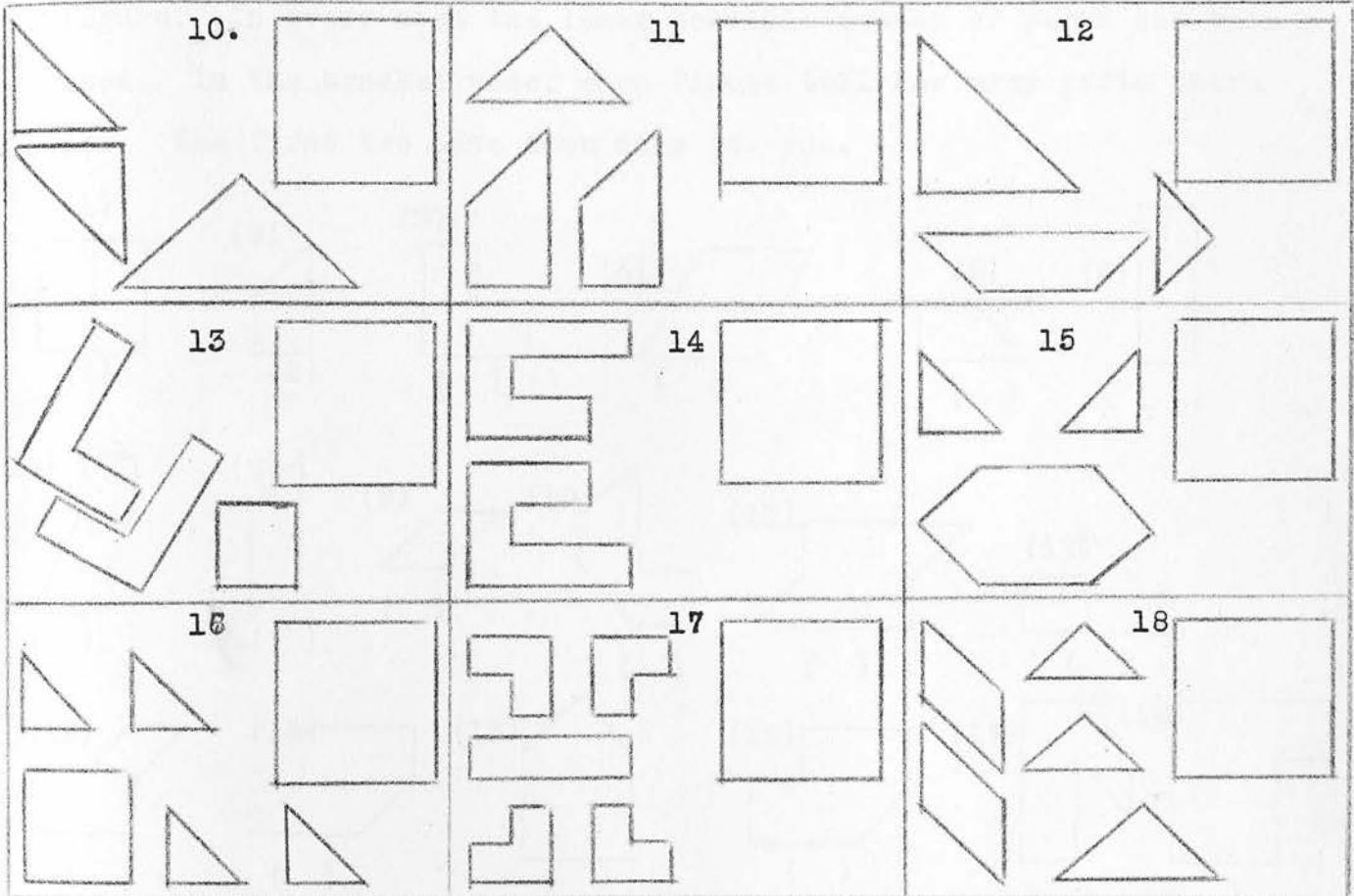
See the groups of small figures below. These figures may be fitted together so as to form the inch squares drawn beside them. Sketch the appearance of the square after the parts have been fitted into it. The first two have been done for you; go ahead and do the others.



<p>1.</p>	<p>2.</p>	<p>3.</p>
<p>4.</p>	<p>5.</p>	<p>6.</p>
<p>7.</p>	<p>8.</p>	<p>9.</p>

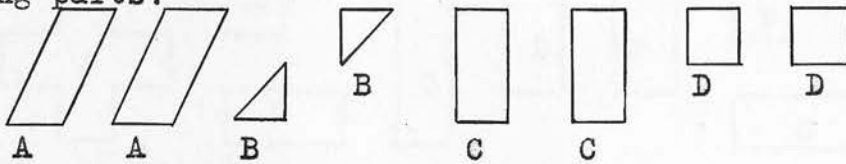
## TEST XIX B. Continued.

"Do the same with the following, but look very carefully; if any part needs to be turned over back to front before it can be made to fit, write the letter "T" on that part."



TEST XX. ANALYSIS OF GEOMETRIC FORMS

Some figures are given below which have been made up from the following parts:



Draw lines to show what parts have been used in making up each figure. In every case the least possible number of parts has been used. In the bracket under each figure tell how many parts there are. The first two have been done for you.

(1) (2)

(2) (2)

(3) ( )

(4) ( )

(5) ( )

(6) ( )

(7) ( )

(8) ( )

(9) ( )

(10) ( )

(11) ( )

(12) ( )

(13) ( )

(14) ( )

(15) ( )

(16) ( )

(17) ( )

(18) ( )

(19) ( )

(20) ( )

(21) ( )

(22) ( )

(23) ( )

(24) ( )

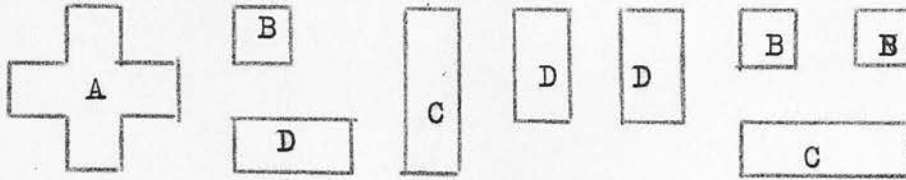
(25) ( )

(26) ( )

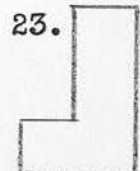
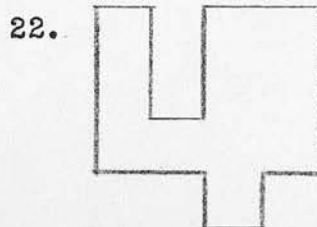
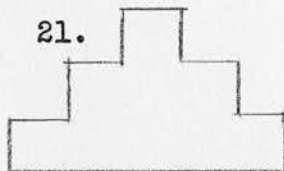
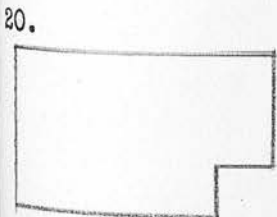
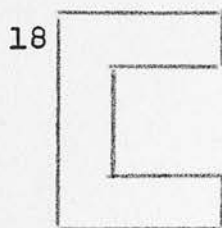
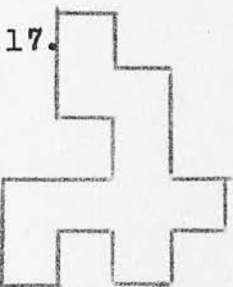
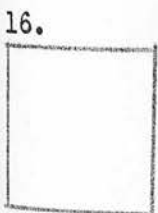
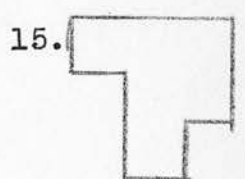
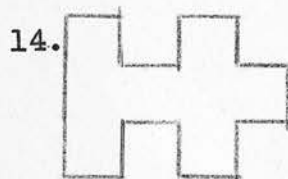
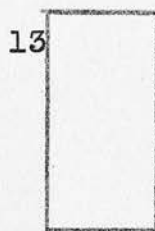
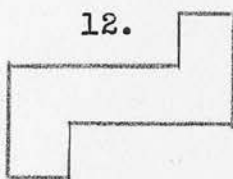
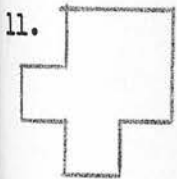
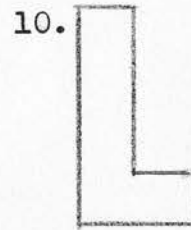
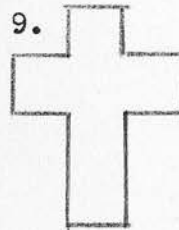
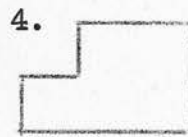
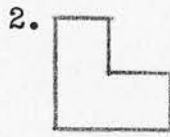
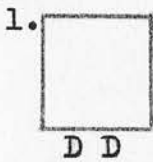
(27) ( )

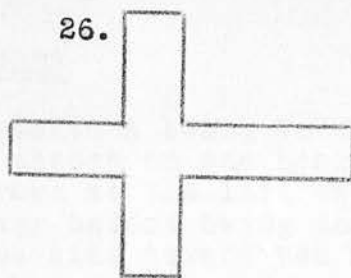
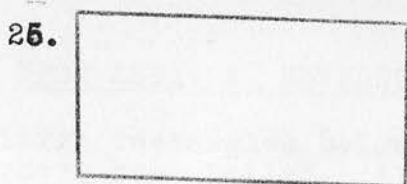
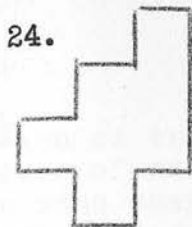
TEST XX. (Continued)

Some more figures are given below which have been made up of the following parts:



Do not draw any lines but under each figure write the names of the small parts that have been used in making that figure. No part is used more times than it is shown above, and in all cases the least possible number of parts have been used. When more than one piece of a particular size is used repeat the letter name for that piece. Be sure you have as few parts as possible for each figure. The first one is done for you. Go ahead and name the parts in the others.





TEST XXI. REVERSING LETTERS

- (a) Put a ring round the letters which would appear the same if turned upside down.

Sample.

F A L (B) C

A circle is put round B because it would look just the same if it were turned upside down. Never mind how these capital letters are usually made; look at them just as they are, and find as many as you can in each of the following rows that would look just the same when turned top to bottom.

R D J M B T Q E  
 W H G I L P X Y  
 C F D O A G B N E T K  
 Z E M I W S R H X J Ø  
 N B S A I Z D E W X T

- (b) Put a ring round the letters which would appear the same if turned over right to left or left to right. Thus (H). The letter H would have a ring round it for it looks just the same after it has been turned over as before. Imagine each letter turned over and put a circle round those that would still look the same.

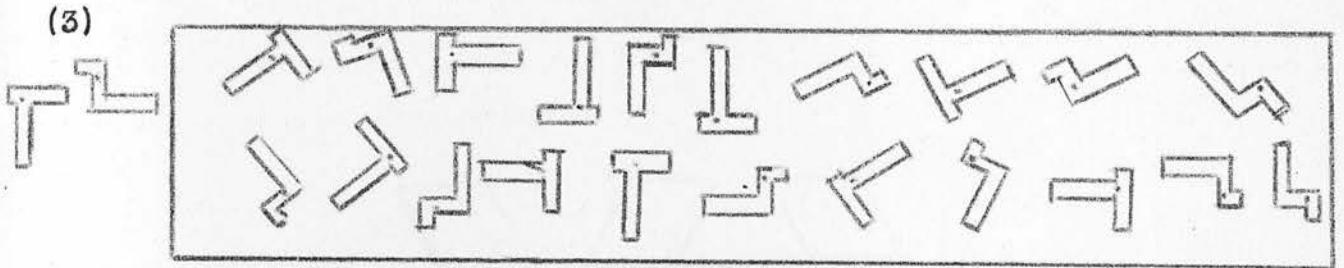
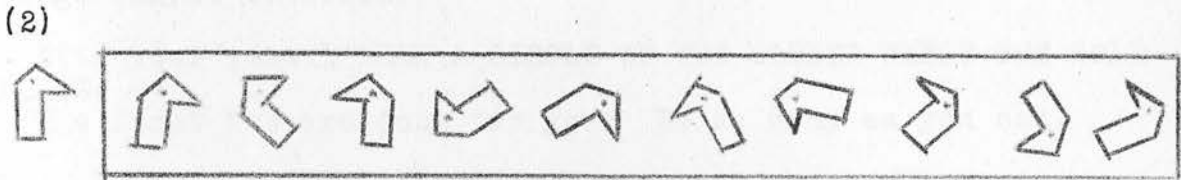
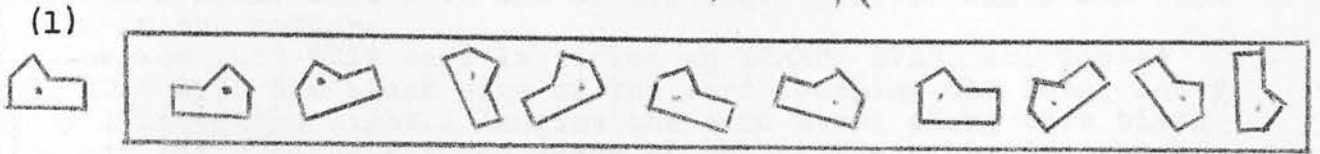
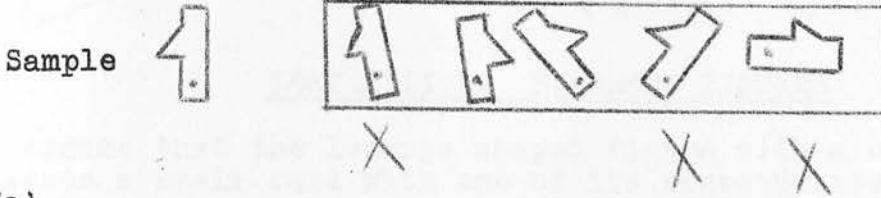
C D W I R J H K Y O S  
 M E Q T P X F A L W N  
 Z Q H M R G J Y O B X  
 K S A C W T R D N Y M

- (c) Now imagine each letter to be turned both upside down and left to right. Put a ring round the ones which would then appear the same as now.

B R S X F M Z T O N P

TEST XXII. A. REVERSED FIGURES

I. Each of the large rectangles below represents a board to which pieces of wood have been nailed. All the pieces on one board are the same shape as the piece (or pieces) drawn at the left of the board, but some pieces have been turned over before being nailed. Put an X below each piece that has the same side toward you as in the drawing at the left.

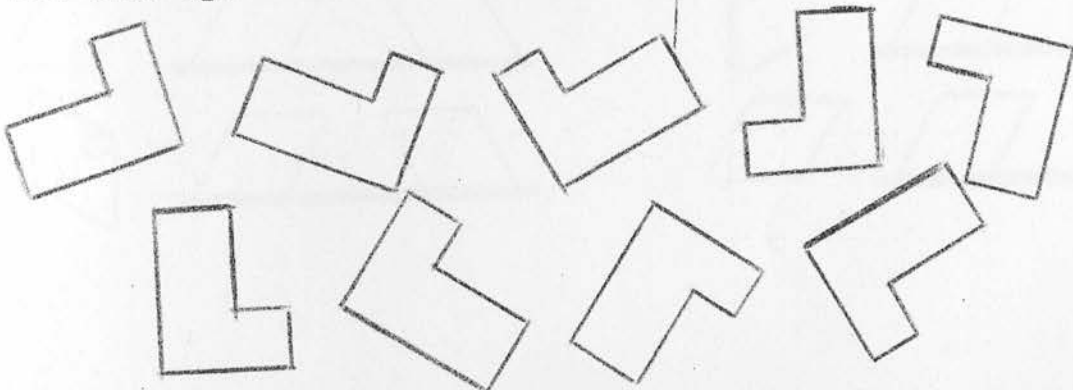


II.

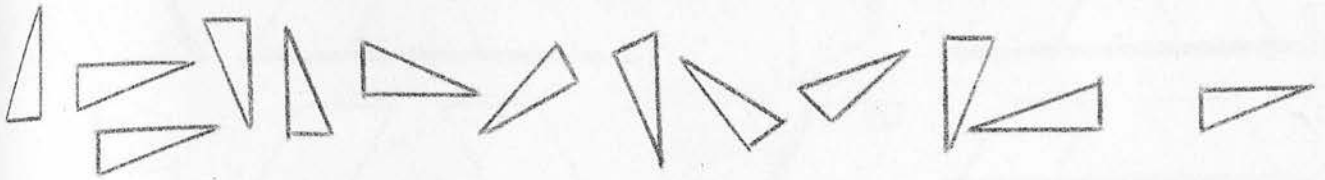


A piece of cardboard of the size and shape shown in the drawing is painted red on one side and green on the other. The drawing marked R shows what it looks like when it lies with the red side up, and the drawing marked G shows what it looks like when it is turned over so that the green side is up. This cardboard was placed on

this paper in the position shown below; sometimes with the red side up and sometimes with the green side up. Put an R in each piece that had the red side up.



III. Pieces of wood this shape and size have been painted red on the side facing you, and yellow on the underneath side. Mark with an R all the triangular pieces which will appear red.



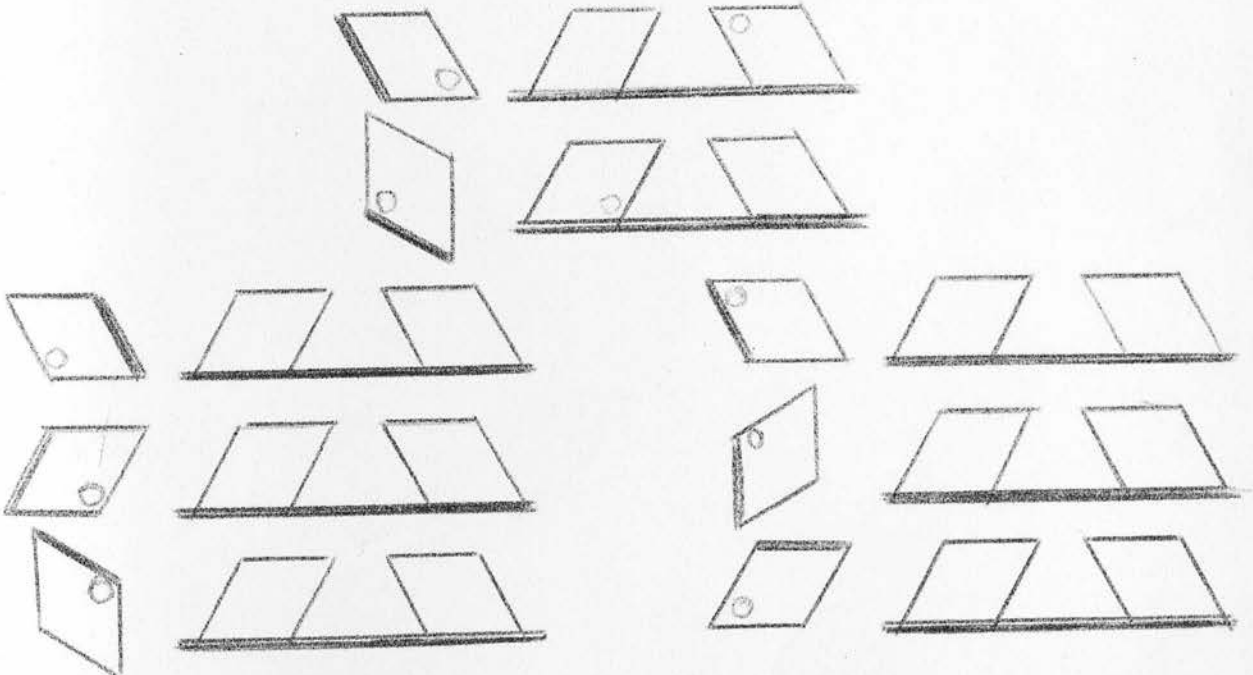
TEST XXII B. REVERSED FIGURES

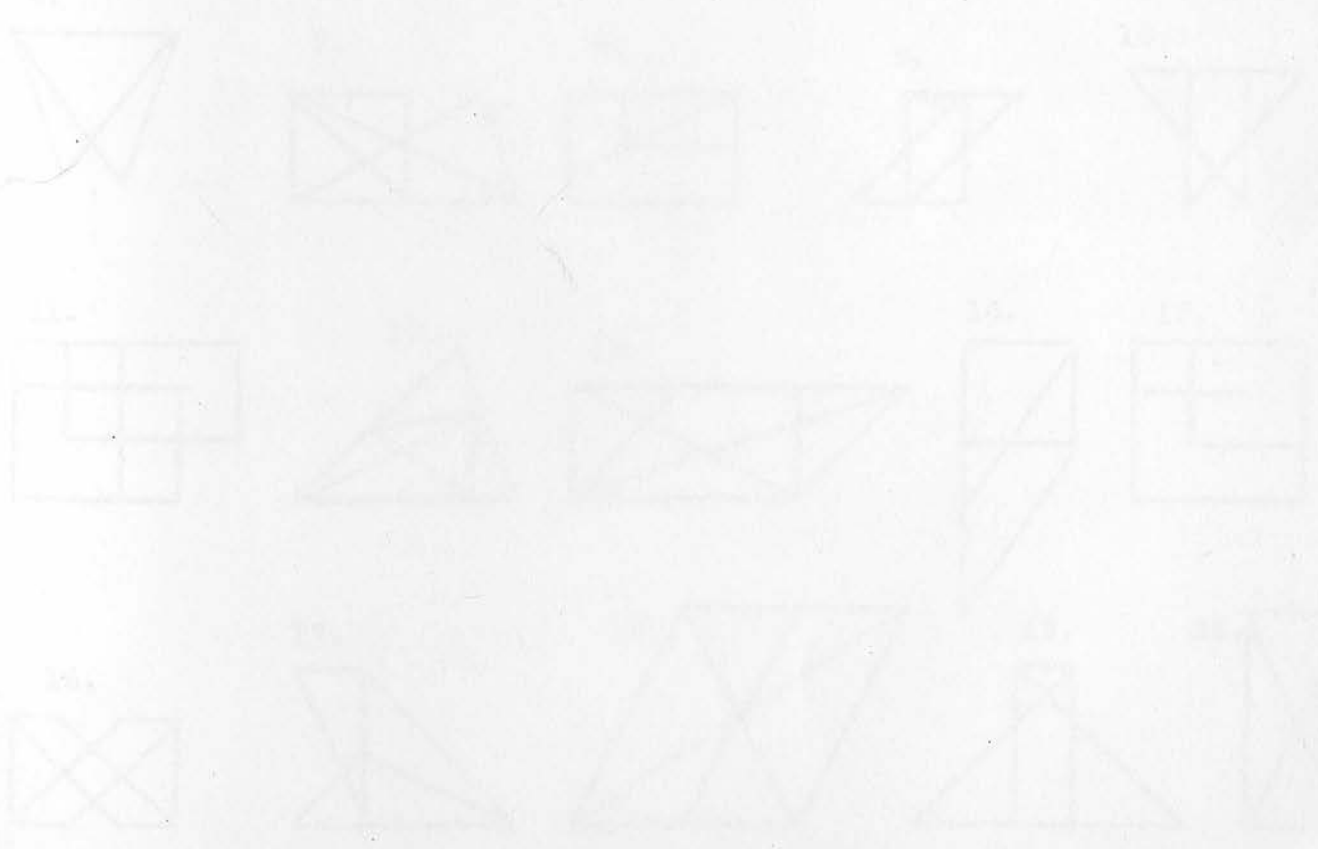
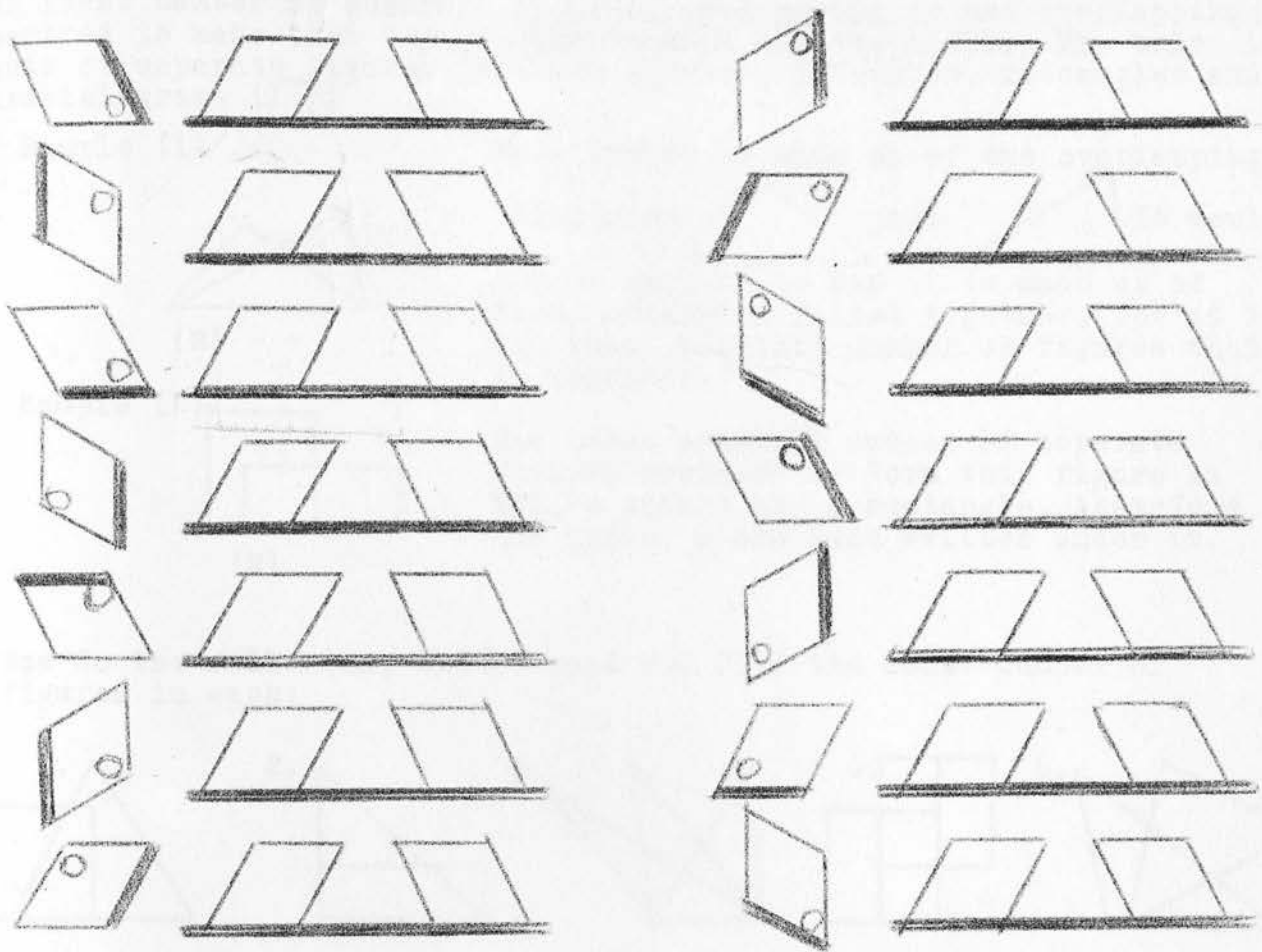
Assume that the lozenge shaped figure with a circle in it represents a small card with one of its edges printed black and with a hole in one corner.


Imagine that this card is picked up TURNED OVER, and placed FACE DOWN with the black edge of the card touching the long, heavy black line to the right. Imagine the card moved along this black line until its edges fit the edges of one or the other of the lozenge shaped outlines.

With your pencil DRAW A CIRCLE IN THE CORNER WHERE THE HOLE WILL BE.

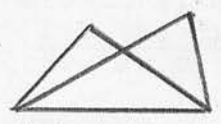
The first two are done for you. Do as many as you can.



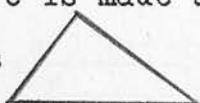
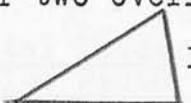


Write underneath each of the composite figures below what is the least number of separate figures, overlapping or not overlapping, required to make that figure, and to show all the lines. The only kinds of separate figures used are squares, triangles, rectangles and parallelograms ()

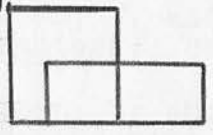
Sample (1)



(2)

This figure is made up of two overlapping triangles  and . It would not be correct to say it is made up of three triangles fitted together, for it is the least possible number of figures that is required.

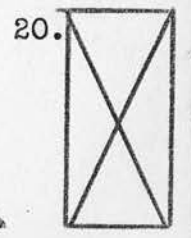
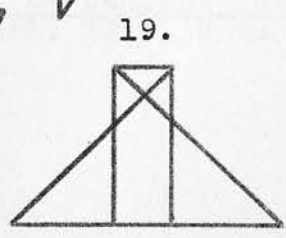
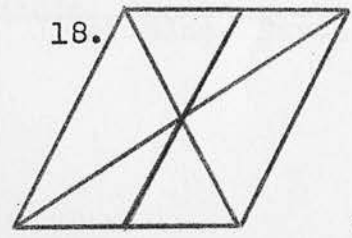
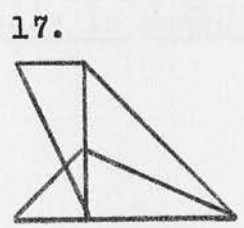
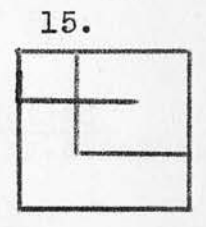
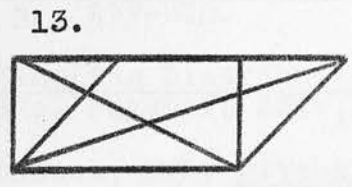
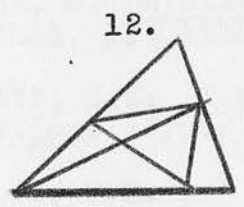
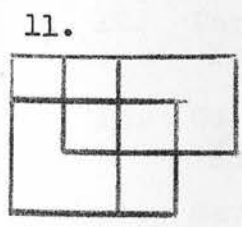
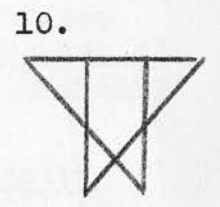
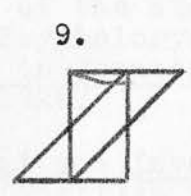
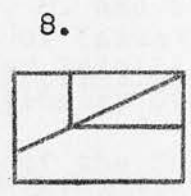
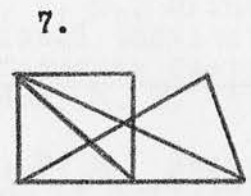
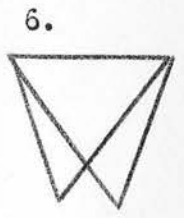
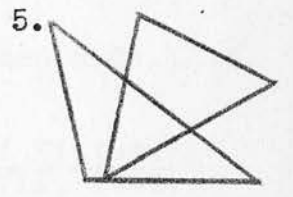
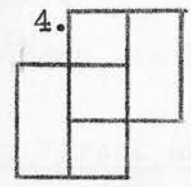
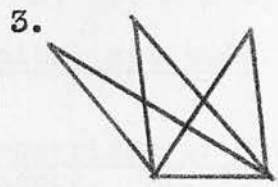
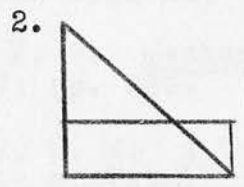
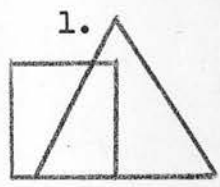
Sample (2)



(2)

The least possible number of separate figures required to form this figure is two, a square and a rectangle, therefore the number 2 has been written under it.

Now do the following, and be sure you find the least number of figures in each:



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