THE RELATIONSHIP BETWEEN THE READING COMPREHENSION
OF SHORT PARAGRAPHS AND LONG PASSAGES
OF SCIENCE TEXT-BOOK MATERIAL

by

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ABSTRACT

THE RELATIONSHIP BETWEEN THE READING COMPREHENSION OF SHORT PARAGRAPHS AND LONG PASSAGES OF SCIENCE TEXT-BOOK MATERIAL

This study attempts to establish whether or not the ability to comprehend long passages of text-book material is reflected in the usual reading comprehension test score. The skills which result in a high score on a standardized reading test may not be identical with those required in regular classroom reading.

A test was constructed to serve as a criterion of the ability to read a Grade 9 science text-book. The study was limited to the kind of reading which is done when the reader's purpose is total grasp of a fairly long passage of new and difficult material. Study skills were specifically excluded.

The Criterion Test, and Test 1 of the Stanford Advanced Reading Test, and Part III of the Cooperative Science Test for Grades 7, 8, and 9 were administered to 90 Science 10 students. This group was a representative sample of the Grade 9 population of the public schools of Vancouver, British Columbia. The intercorrelations of the test scores were computed.

For the sample used, the correlation between Stanford scores and Criterion scores was .58; between Stanford scores and Cooperative scores, .66; between Cooperative scores and
Criterion scores, .72.

The main inferences derived from these data were:

1. The size of the correlation coefficient (.72) between Cooperative scores and Criterion scores implies that the two tests measure groups of skills which are similar but not identical.

2. For most practical purposes, Part III of the Cooperative Science Test could be used to appraise the ability to read material from Science in Action, Book I.¹

3. The Stanford Test does not seem to be as good a measure of the ability to understand science text-book material as the Cooperative Test.

4. The correlations obtained suggest that the test scores are affected by content and length of passage, content being the more important factor.

It is possible that a better criterion would have resulted from having the students read one long passage directly from the text-book. Such a criterion would be more like a natural reading situation and less like a standardized test.

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Department of Education

The University of British Columbia,
Vancouver 8, Canada.

Date September 15, 1958
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CHAPTER I

INTRODUCTION

This study attempts to discover to what extent scores on a typical standardized reading comprehension test reflect the ability to understand long passages of science text-book material. A test to serve as a criterion of this ability was constructed. The correlation between scores on the criterion test and scores on a standardized test, was considered an indication of the validity of the standardized test for appraising the comprehension of long passages from a science text-book.

I. BACKGROUND OF THE STUDY

The investigation described in this thesis developed out of concern about the poor performance of a group of Grade 8 students on reading assignments based on their science text-book. Most of these students did fairly well in directed reading exercises when guided by factual questions. They did poorly, however, when required to interpret and apply what they read without specific help from the teacher.
In the elementary school, reading is a major part of the curriculum. In the secondary school, reading disappears as a subject in itself, but reading skills are applied to learning tasks in every field. Although extensive reading in a wide variety of source materials is preferable to intensive study of a single text-book, many students do no serious reading other than their text-books. If a text-book has been well-chosen, it contains the essential information and concepts for the course. Therefore, it is usually required reading, and assignments and examinations are often based on it. For these reasons, the student with limited comprehension of his text-books is under a severe handicap.

Since a student's progress in a subject is influenced by his ability to read the text-book, every teacher should have accurate data about his pupils' reading skills. A teacher can gain a general impression of his pupils' reading abilities by observation and informal questions. He can obtain further information from records. The most likely source of useful, reliable data would seem to be a standardized reading test. The use of any standardized test is justified only if it has educational value for the student and/or it provides useful information about the student. If the test is to
be of immediate practical use, it must have a direct bearing on the work being done in the classroom. The science teacher, for example, wishes to know how well his students can do the kind of reading that he assigns.

There are a number of good reading comprehension tests, but their suitability for estimating a student's performance in text-book reading has not been established. The skills involved in taking a standardized reading comprehension test seem rather different from those required for the understanding of a science text-book. The typical standardized test contains a collection of short, self-contained passages which are not related to each other or to the current classroom work. Text-book reading, on the other hand, usually calls for sustained application to a single topic, or to a group of closely related topics. It also calls for the ability to select and apply appropriate concepts from material recently studied. Furthermore, science text-books often require careful, detailed reading. Bond found that slow reading is a characteristic of high achievement(marks) in science.\(^1\) The comprehension of

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\(^1\)Bond, Eva, *Reading and Ninth-Grade Achievement* (New York: Teachers College, Columbia University, 1938), p. 58.
scientific material also requires the command of an extensive technical vocabulary and the ability to interpret symbols, charts, and diagrams.

The practice of dividing reading comprehension tests into sections according to the unit to be understood (the word, the sentence, the paragraph) suggests that measurable differences in these reading tasks exist. Few tests, however, attempt the appraisal of very long passages. Perhaps it is expedient to avoid the problems involved in such tests, but the assumption that any reading comprehension test can be used to estimate a student's ability to read lengthy passages should be confirmed or rejected on the basis of experimental evidence. A search of the literature did not reveal any studies on this particular topic.

II. STATEMENT OF THE PROBLEM

This study attempts to answer the following question:

What is the relationship between scores on a test of ability to understand long passages from a science text-book and scores on: (1) a general reading comprehension test, and (2) a test of ability to interpret scientific material?
III. DEFINITIONS

The following definitions help to clarify the problem.

General reading comprehension test. Reference is made here to a test which consists of short paragraphs chosen from many subject fields. Typically, it is designed for use over a wide range of reading levels.

Although the specialized test would seem to be more appropriate for scientific material than the general test, the latter is of interest because it is commonly used. Thus the relationship between general reading scores and reading competence in a particular field is useful information.

Text-book reading. In educational literature, the term reading is often used in a very broad sense to include all the intellectual skills which are applied when books are used. In this thesis, study skills (skimming, reviewing, summarizing, etc.) are specifically excluded. Text-book reading is restricted to the kind of reading done when the reader's purpose is the total grasp of new and rather difficult content. It includes the interpretation of illustrations. Rather difficult
content is specified because as Dolch states, we must admit "that assigned reading of middle grades and on through high school is 'hard' for most or at least many children". 2

Long passages. For the purpose of this study, a long reading passage is one which contains more than 500 words.

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CHAPTER II

REVIEW OF THE LITERATURE

Although the issue raised in this thesis has been virtually ignored in the literature on reading, much has been written on closely related problems. Since reading comprehension has not yet yielded to precise, unambiguous definition, a review of the research attempting to identify its components is pertinent.

I. FACTORS OF COMPREHENSION IN READING

The identification of the factors in reading comprehension has been approached in two ways. In the first technique, published tests are analyzed.\(^3\) Studies of this kind usually produce four or five factors, some of which may not be precisely defined. This type of analysis presupposes that the tests used include the most significant of the factors which make up reading comprehension.

In contrast, Davis began by postulating a large number of possible factors. From these he obtained nine independent factors.\(^4\) His analysis, however, was

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\(^4\) Davis, F. B., "Fundamental Factors of Comprehension in Reading," *Psychometrika*, IX (September, 1944), 185-197.
challenged by Thurstone, who maintained that in six of the nine tests, a single factor would account for the entire true variance. For the other three tests (word meaning, following the organization of a passage, recognition of literary devices) Thurstone found specific variances of .25, .22, .21 respectively.

Davis retreated from his original position by reducing his factors to five independent mental abilities which he describes as follows:

1. word knowledge.
2. ability to reason in reading.
3. ability to follow the organization of a passage...
4. ability to recognize literary devices...
5. tendency to focus attention on writer's explicit statements...(i.e. ability to find the answers to specific factual questions).

Davis' revised list is typical of the findings of research in this field, although no consistent pattern emerges beyond the confirmation of the first two factors. Johnson provides an excellent summary of the research dealing with the factors of reading comprehension.

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5. Thurstone, L. L., "Note on a Reanalysis of Davis' Reading Tests," *Psychometrika*, XI (September, 1946), 185-188.


II. READING IN CONTENT FIELDS

The need for distinguishing between general and special reading comprehension tests is suggested by the results of research concerning reading in content fields.

The consensus of expert opinion is that the content fields have specific reading problems. Socher reviews recent research in reading in the content fields and concludes that specific reading skills are needed in social studies, science, and arithmetic.

Typical of the minority opinion is Swenson's conclusion that the "only deviations from the striking concomitance of reading ability are found among different phases of reading skill (rate versus vocabulary and comprehension) rather than among reading materials (general-narrative material versus science-study material)."

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It is worth noting that an individual may read with unequal effectiveness in different fields although the readings seem to be equally difficult. Some of these variations can be explained in terms of experience and past and present interests. In the opinion of at least one investigator, the reader's experience far outweighs any other single factor as a determiner of the quality of understanding.\textsuperscript{12} Dolch believes that fluency of reading in a particular field results from two factors: first, a rapid recognition of the vocabulary, and secondly, familiarity with the characteristic thought patterns and the idioms of the field.\textsuperscript{13}

### III. VALIDITY OF GENERAL READING TESTS FOR SPECIFIC PURPOSES

**Testing higher levels of reading ability.** Strang has pointed out that an appraisal of reading ability based entirely on short test passages is not wholly satisfactory.


None of the standardized tests now available measures adequately the high levels of reading ability—the abilities to comprehend relationships in a long passage that calls for sustained attention, to organize content, to draw inferences, to grasp metaphors and shifts of meaning, and to apply what is read.\textsuperscript{14}

She also suggests that teacher-made tests based on textbook readings be used to obtain the data not available from published tests.\textsuperscript{15}

**Diagnosis of reading in a subject field.** In describing her diagnostic test of reading in social studies (high school and college), Conant strongly favours long passages for testing comprehension skills.\textsuperscript{16}

She considers the optimum length of passage for her purposes to be about 1,000 words.

**Reading for problem-solving in science.** Shores, an outspoken critic of general reading tests, developed a test for problem-solving in science (grades 4, 5, and 6). He provides data to show that his test is more valid


\textsuperscript{15}Ibid., p. 258.

for its special function than a general reading test.

In his words:

The suggestion is that ability to do the type of work-type reading required by problems in science, a reading skill which involves both reading and thinking critically about that which is read, is more independent of mental age than is general reading ability and is different in some degree from whatever is measured in tests of general verbal intelligence and general ability to read.\footnote{Shores, J. H., and Saupe, J. L., "Reading for Problem-Solving in Science," \textit{Journal of Educational Psychology}, XLIV (March, 1953), 149-158.}
CHAPTER III

EXPERIMENTAL DESIGN

Since no test appraising the understanding of long passages of science text-book material could be found, the Criterion Test was constructed for this purpose. Three tests were administered to a group of Science 10 students from Vancouver schools; (1) the Criterion Test, (2) a general reading comprehension test, and (3) a test of ability to interpret scientific material. The correlations among the distributions of scores indicate the relationships among the abilities measured by the tests. If the Criterion Test has high validity, then these correlations are good approximations of the relationships between the reading scores and the ability to understand long passages of science text-book material.

I. THE SPECIFIC PURPOSE OF THE CRITERION TEST

In order to minimize the interruption to the regular school program, the Criterion Test was designed so that it could be administered in a regular period. But the proposed length of the reading passages reduced the number of items which could be answered in a given time. It seemed advisable, therefore, to attempt to measure only
one aspect of text-book comprehension in the Criterion Test.

Vocabulary is undoubtedly of prime importance, but it is adequately measured in existing tests. Of other factors suggested, Davis' reasoning-in-reading seems most appropriate in this study dealing with the interpretation of scientific material. Each item of the Criterion Test is intended to contribute to the appraisal of this factor, although the items reflect to some extent other factors, particularly the ability to answer factual questions.

II. POPULATION

The experimental population consisted of all Science 10 students in the public schools of Vancouver, British Columbia. Science 10 (Grade 9 science) was chosen because there appears to be a significant increase in difficulty at this level which results partly from the amount of material to be mastered, and partly from the nature of the concepts presented in the course.

III. POPULATION SAMPLE

Because of the exploratory nature of the study, it was decided that a sample of about 100 pupils would adequately represent the specified population. However, such a sample could not be selected from a single school,
unless it was shown that there were no significant differences among Vancouver schools, teachers, and students. For ease of administration, the class was used as the unit of sampling. In order to be certain that a sample of the desired size and variability was obtained, the tests were given to a group of ten Science 10 classes, two from each of five schools. If analysis of variance indicated that all ten classes were derived from a common population, then several classes could be combined to form a sample of the desired size. On the other hand, if significant differences among the classes existed, then a random sample could be drawn from the total experimental group.

Since there is a high correlation between intelligence and reading comprehension, it is suggested that if a sample is representative of a population with respect to intelligence, it is likely also to be representative of that population with respect to reading comprehension. It would have been very difficult to obtain the IQ's for the Science 10 population, but the distribution of IQ's\textsuperscript{18} for the total Grade 9 population was available.\textsuperscript{19} The significance of

\textsuperscript{18}The Otis Self-Administering Test of Mental Ability, Intermediate Examination is given to all Vancouver pupils in their last year of elementary school.

\textsuperscript{19}These data would be slightly inaccurate because of changes in the population between time of IQ testing and time of the experiment.
the difference between means of Otis scores for sample and for the latter population was tested.

IV. EXPERIMENTAL MATERIALS

The Criterion Test. The construction of this self-administering test is described in Chapter V. The 38 objective items are based on four long passages chosen from Science in Action, Book I, the Science 10 text-book authorized for use in the schools of British Columbia. Pupils were allowed 48 minutes to complete the test.

The standardized tests. Part III (Comprehension and Interpretation) of the Cooperative Science Test for Grades 7, 8, and 9, Form Y was selected as the typical test of ability to interpret scientific material. Test I (Paragraph Meaning) of the Advanced Reading Test, Form JM, Stanford Achievement Test was selected as the typical general reading comprehension test. Both are 25-minute tests. There are 30 items in the former test, and 44 items in the latter.

V. TESTING PROGRAM

The three tests described above were administered to the experimental group of ten classes. The standard

class period in Vancouver secondary schools is 55 minutes. In order to complete the proposed testing program within two regular periods, special instructions were prepared which made it possible to give both the published tests in a single period (see Appendix B). The practicability of these instructions was tested before the final experiment was undertaken.

VI. STATISTICAL ANALYSIS

When it was established that the sample was representative of the total Grade 9 population, the Pearson product-moment correlation coefficients among the test scores were computed as indices of the relationships between the abilities measured by the published tests and the ability to read a science text-book.
CHAPTER IV

EXPERIMENTAL METHOD

This chapter contains a description of the experimental group, a report of the administration of the tests, and a discussion of the relationships between sample and population.

I. THE EXPERIMENTAL GROUP

The experimental group consisted of two Science 10 classes from each of the following secondary schools: Sir Winston Churchill, Gladstone, King Edward, Magee, and Templeton. As indicated below, the schools and their student bodies were distinctly different from one another.

Since reading ability is influenced by environment, an attempt was made in the selection of the schools to obtain the widest possible variety of environmental factors. Only a few of the possible factors are discussed below, but a group showing wide variations in these respects will probably show comparable variations in other factors bearing on reading ability.

Size of the schools. The enrollments in the chosen schools varied from slightly under 1,000 pupils to slightly over 2,000 pupils. In September, 1957, there were only three secondary schools in Vancouver (comprising about 4%
of the population of the secondary grades) which had enrollments much less than 1,000 pupils. Since these schools are expected to disappear completely within a few years, none was included in the experiment.

Grade range in the schools. Two of the schools were junior-senior high schools, two were senior high schools, and the other was a junior high school. The educational experience of Grade 7 and 8 students in secondary schools is quite different from the experience of their counterparts in elementary schools. The differences might be reflected in the scores on the reading tests.

Character of the student bodies. In the schools chosen for the experiment, there could be found students who were as well-to-do as any in Vancouver's public school system, and those who were as underprivileged as any. There were also wide variations in such factors as cultural background, parental occupation, racial origin, and home conditions.

Description of the classes. The sizes of the experimental classes ranged between 30 and 35 pupils, with about equal numbers of boys and girls. Each class was an unselected group of students, and was judged to be representative of its school.
II. TEST ADMINISTRATION

The tests were given in regular science periods by the classroom teacher during the last two weeks of September. The order in which the tests were given was varied so that any benefits due to a favoured position would be shared among all the tests. The selection of day and period was left to the discretion of the teachers of the experimental classes, but in every case, the two periods of testing occurred on different days.

Testing techniques which were familiar to the students were used, so that the form of the items might not be a source of confusion. All necessary instructions were given on the cover page. The parts were not separately timed, but the teacher announced when the students should begin each part. Each supervisor was provided with full directions for the administration of the three tests (see Appendix B).

III. RELATION OF SAMPLE TO POPULATION

Analysis of variance was applied to the criterion test scores to determine if all of the ten classes could be considered as representative samples of a common population. Since there was a significant difference in the class means of the Criterion Test scores, a sample of 100 was chosen from the total experimental group by means of a
table of random numbers. The scores of new Canadians (that is, students who had lived less than two years in an English-speaking country) and of students repeating Science 10 were excluded. There was no significant difference between the mean IQ of the revised sample and the mean IQ of the Grade 9 population.

The IQ's of the experimental group were taken from school records. Data for estimating the distribution of the IQ's for the total Grade 9 population were obtained from the Department of Research and Special Services, Vancouver School Board.
CHAPTER V

THE READING TESTS

This chapter describes the selection of the published tests, the construction, statistical analysis, and appraisal of the Criterion Test.

I. SELECTION OF THE PUBLISHED TESTS

As the first step in locating typical published tests, the reviews in the Buros' Mental Measurement Yearbooks were carefully studied. Specimen copies of the tests which seemed most suitable were then examined.

The General Reading Comprehension Test

The Stanford Paragraph Meaning Test was chosen as representative in form and content of standardized reading comprehension tests using short passages.

The Test of Ability to Interpret Scientific Material

Three tests of this type were studied:

Ability to Interpret Reading Materials in the Natural Sciences. 21 This test seems to be excellent for the upper high school grades. It is not appropriate

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21 Test 6 of the Iowa Tests of Educational Development for High School and College Freshmen.
in the present study because of its length and difficulty. Since it requires 60 minutes, it could not be given in a regular class period. The median score for Grade 9 pupils is only 24, somewhat less than 30% of the possible score of 81.

Reading Scales in Science (Grades 7 - 12). This test is of suitable length and difficulty. It requires 30 minutes for its administration. It has, however, a number of undesirable features. It consists of 12 short paragraphs and 73 items. There are nine items based on the 18 lines of reading in the first paragraph. The items are statements after which the student is instructed to place an "X" if the statement is in the paragraph, or can be derived from it. In other words, the test essentially consists of 73 true-false items with a heavy factual emphasis. Many of the passages contain concepts usually introduced before Grade 9.

Cooperative Science Test for Grades 7, 8, and 9. This test was chosen because of the following features:

1. It is specifically designed for Grades 7 to 9.
2. It contains material which is comparable to the content of Science 10 but not identical with it.

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*M. J. Van Wagenen, (Educational Test Bureau, 1938).*
3. It includes items on the interpretation of an illustration.

4. It attempts to go beyond the testing of facts. The 25-minute time limit on this test makes it possible to administer it and the Stanford test in one class period.

II. CONSTRUCTION OF THE CRITERION TEST

Specifications

The criterion test was designed to satisfy the following specifications:

1. that the test be valid and reliable,

2. that the reading selections be not less than 500 words,

3. that the passages include as many as possible of the special problems in interpretation of scientific material,

4. that the items stress interpretation rather than factual detail,

5. that the format of the test be as similar as possible to the format of the Science 10 text-book,

6. that the material in the test passages be new to the students,

7. that the test be a power rather than speed test.
8. that the directions be clear and establish the desired purpose.

9. that the test be self-administering.

Procedures

Selection of content. Six representative passages were chosen from the text-book. These passages included material which required interpretation of tables, formulas, and diagrams.

Preparation and editing of items. Items were constructed for each passage and the test materials were organized into two preliminary forms (A and B), each containing three parts (I, II, and III). Henceforth, a reading passage and the items based on it will be referred to as a part. The material for the preliminary forms was submitted to two experienced teachers of Science 10 for suggestions and criticism. Each part was administered to two grade 8 classes in order to detect ambiguities and difficulties not apparent to the adult critics. This pre-tryout also provided the first estimate of the times required to administer each part.

Administration of preliminary forms. Forms A and B were given to a sampling of students not in the local school. The sample was drawn from two Vancouver secondary
schools (Britannia and Sir Winston Churchill), and from Prince George Junior High School and Nelson Junior High School. The teachers supervising the preliminary experiment provided data regarding the time required for each part.

Preparation of revised form. From the six original parts, four parts were chosen. Items were revised or eliminated in the light of an item analysis, and a few new items were added. The revised form was submitted to two experts in educational testing for suggestions and criticism.

Try-out of revised form. The revised form was given to two classes in King Edward High School to provide data on the new and the revised items, and to serve as a final check on time limits and administration.

III. ANALYSIS OF THE PRELIMINARY FORMS

Item analysis. The item analysis of each preliminary form was based on a single school since it was found that the classes could not be considered as samples drawn from a common population. Each sample contained 100 papers. A worksheet was prepared to show in detail the response to each item for every paper in the sample. The item internal-consistency indices were computed from the follow-
ing formula:\textsuperscript{23}

\[ r = \frac{PQ-NW}{PQ} \]

where 

P = proportion of sample passing the item

Q = 1 - P

N = number of test papers in the sample

W = proportion of inconsistent responses

These statistics, together with the item difficulties (per cent passing), are given in Table VII and Table VIII in the Appendix.

Part I of Form A and Part I of Form B were discarded as the least suitable parts. Each item of the other parts was considered in terms of its difficulty and its correlation with the whole test. Part II of Form A was used as it appeared in the preliminary form, but most of the items in the other parts were revised in some way. The revisions did not usually involve major reconstruction. Typical


Essentially the Ferguson r is a correlation coefficient between the observed answer pattern and the "perfect" answer pattern. For an item of 40% difficulty, for example, the perfect answer pattern is achieved when the 40% obtaining the highest total scores is identical with the 40% passing the item. The coefficients derived from this formula are smaller than Flanagan r's. In the Department of Educational Research, Ontario College of Education, where the formula is regularly used, r's ranging from .25 to .50 are considered satisfactory, and an r $> .50$ is considered very good.
changes included the addition of a distractor, the re-wording of a non-functioning or a negatively-discriminating distractor, and improvement in the form of the item.

**Internal consistency.** The internal consistency of the preliminary forms was estimated from Kuder-Richardson formula #21:

\[ r_{tt} = \left( \frac{n}{n-1} \right) \left( \frac{\sigma^2_t - \bar{U} \rho}{\sigma^2_t} \right) \]

where \( r_{tt} \) = coefficient of reliability
\( n \) = number of items in the test
\( \sigma^2_t \) = total test variance
\( \rho \) = proportion of sample passing an item
\( q = 1 - p \)

For Form A, \( r = .81 \); for Form B, \( r = .80 \).

**IV. ANALYSIS OF THE REVISED FORM**

**Item analysis.** The item statistics are summarized in Table I. The items vary in difficulty from one which was passed by 17% of the sample to one which was passed by 85% of the sample. The item difficulties are approximately normally distributed around a mean difficulty of 53.5%.

<table>
<thead>
<tr>
<th>Part</th>
<th>Difficulty</th>
<th>Flanagan r</th>
<th>Difficulty</th>
<th>Flanagan r</th>
<th>Difficulty</th>
<th>Flanagan r</th>
<th>Difficulty</th>
<th>Flanagan r</th>
<th>Difficulty</th>
<th>Flanagan r</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a</td>
<td>b</td>
<td>c</td>
<td>d</td>
<td>e</td>
<td>f</td>
<td>g</td>
<td>h</td>
<td>i</td>
<td>j</td>
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<tr>
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<td>40</td>
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<td></td>
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<td>.54</td>
<td>.57</td>
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<td>.50</td>
<td></td>
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<td>II</td>
<td>40</td>
<td>44</td>
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<td>64</td>
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<td>28</td>
<td>73</td>
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<td>.57</td>
<td>.75</td>
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<tr>
<td>III</td>
<td>81</td>
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<td>.08</td>
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<td></td>
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<td>.63</td>
<td>.59</td>
<td>.42</td>
<td>.18</td>
<td>.54</td>
<td>.51</td>
</tr>
</tbody>
</table>

*aPer cent of sample passing the item.*
Flanagan r's are used to indicate the relationship of each item to the test as a whole. Out of a total of 38 items, 21 have r's ≥ .50. Only four items have r's < .30.

Internal consistency. The internal consistency of the revised form was .80 (Kuder-Richardson formula #21).

V. APPRAISAL OF THE CRITERION TEST

Validity. The validity of the Criterion Test is of crucial importance in this study. The best available indication of its validity is the extent to which it satisfies the specifications on page 24. In the author's opinion, the material in the Criterion Test is representative in kind and difficulty of science text-book material. Furthermore, nearly one-third of the items are based at least partly on the interpretation of illustrations of the type usually found in science text-books.

Reliability. Guilford states that for a homogeneous test an index of internal consistency comes closest to the basic idea of reliability (the ratio of true variance to total variance).25 That internal consistency is an

appropriate index of the reliability of the Criterion Test can be seen from size of the Flanagan r's listed in Table I. The Criterion Test \( r_{tt} \) probably underestimates the true coefficient of reliability since certain assumptions of the Kuder-Richardson formula are not realized.\(^{26}\) In particular, the item difficulties are not equal, nor are the item intercorrelations.

Any substantial increase in the internal consistency of a reading comprehension test beyond \( .80 \) is probably achieved at the expense of validity, since a valid measure of a complex group of skills requires a certain degree of heterogeneity in the items. In discussing this point Guilford says:

\[ \ldots \text{both reliability and validity cannot be maximal}\ldots \]

item-test correlations for well-constructed items range between \( .30 \) and \( .80 \). Items within these ranges of correlation should provide tests of satisfactory reliability and validity.\(^{26}\) There is probably better reason for going below these limits than above them in constructing items. To do so would err on the side of validity which, after all, is more important.\(^{27}\)

**Difficulty.** The test is of appropriate difficulty for the experimental group, since the scores are approximately normally distributed about a mean score of 20.13 (53\% of the possible score).


\(^{27}\) Ibid., p. 523.
From the discussion in the three preceding paragraphs, the Criterion Test appears to perform its function of appraising the ability to understand long passages of science text-book material.
CHAPTER VI

ANALYSIS OF THE DATA

I. HOMOGENEITY OF THE EXPERIMENTAL GROUP

The F-test was used to test the homogeneity of the experimental group. Only eight of the ten classes were used in this analysis since a total of 17 students in the other two classes had taken preliminary Form B. The computed F (2.52) indicated that the differences in the means were significant at the 5% level (F=2.05), but not at the 1% level (F=2.72). Since such a result suggested that there might be real differences among the classes, the sample was drawn at random from the total group. The summary of the analysis is given in Table II.

TABLE II

ANALYSIS OF VARIANCE FOR F-TEST OF HOMOGENEITY OF CLASSES TAKING REVISED FORM OF CRITERION TEST

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
</tr>
</thead>
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<tr>
<td>Between groups</td>
<td>653</td>
<td>7</td>
<td>93.3</td>
<td>2.52a</td>
</tr>
<tr>
<td>Within groups</td>
<td>8387</td>
<td>235</td>
<td>35.65</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>9040</td>
<td>242</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[ \text{F} = 2.72 \text{ required for significance at 1\% level.} \]
II. RELATION OF SAMPLE TO POPULATION

It will now be shown that the sample is representative, with respect to IQ, of a population which is similar to the Grade 9 population at the time of the experiment (September, 1957). The population referred to consisted of those students of the Grade 9 group who were attending Vancouver schools at the time the IQ's of the experimental group were obtained. The distributions of IQ's for the sample and for the population described above are shown in Table III. Inspection of this table reveals that both distributions are approximately normal. The hypothesis that there is no significant difference in the means was tested.

\[
\text{Critical ratio} = \frac{M_s - M_p}{\sigma_m} = \frac{M_s - M_p}{\sigma \sqrt{N-1}}
\]

\[
= \frac{108.89 - 108.09}{12.09/\sqrt{89}} = \frac{.8}{.28} = .62
\]

A ratio larger than .62 would occur by chance in 54 cases out of 100. For this reason the sample was considered to be representative, with respect to IQ, of the population described above.

The experimental population, however, consisted of students enrolled in Science 10.\textsuperscript{28} The majority of these

\textsuperscript{28}The population was restricted to Science 10 pupils in deference to the wishes of the Vancouver School Board.
### TABLE III

FREQUENCY DISTRIBUTIONS OF IQ'S FOR GRADE 9 POPULATION OF VANCOUVER SCHOOLS AND FOR RANDOM SAMPLE FROM EXPERIMENTAL GROUP

<table>
<thead>
<tr>
<th>IQ</th>
<th>Population&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Sample&lt;sup&gt;c&lt;/sup&gt;</th>
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<tbody>
<tr>
<td></td>
<td>n = 3874</td>
<td>n = 90</td>
</tr>
<tr>
<td></td>
<td>per cent</td>
<td>per cent</td>
</tr>
<tr>
<td>80 - 84</td>
<td>2.5</td>
<td>2.2</td>
</tr>
<tr>
<td>85 - 89</td>
<td>4.3</td>
<td>4.4</td>
</tr>
<tr>
<td>90 - 94</td>
<td>7.6</td>
<td>4.4</td>
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<td>95 - 99</td>
<td>10.5</td>
<td>5.6</td>
</tr>
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<td>100 - 104</td>
<td>13.8</td>
<td>16.7</td>
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<td>105 - 109</td>
<td>14.4</td>
<td>20.0</td>
</tr>
<tr>
<td>110 - 114</td>
<td>15.9</td>
<td>17.8</td>
</tr>
<tr>
<td>115 - 119</td>
<td>12.9</td>
<td>8.9</td>
</tr>
<tr>
<td>120 - 124</td>
<td>9.8</td>
<td>11.1</td>
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<tr>
<td>125 - 129</td>
<td>5.2</td>
<td>5.6</td>
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<tr>
<td>130 - 134</td>
<td>2.2</td>
<td>3.3</td>
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<tr>
<td>135 - 139</td>
<td>.6</td>
<td>-</td>
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<tr>
<td>140 - 144</td>
<td>.2</td>
<td>-</td>
</tr>
<tr>
<td>145 - 149</td>
<td>.1</td>
<td>-</td>
</tr>
<tr>
<td>150 - 154</td>
<td>.05</td>
<td>-</td>
</tr>
</tbody>
</table>

**Mean**
- **Population**: 108.09
- **Sample**: 108.89

**Standard Deviation**
- **Population**: 12.09
- **Sample**: 11.37

<sup>a</sup>Score on the Otis Self-Administering Test of Mental Ability, Intermediate Examination.

<sup>b</sup>All students in Vancouver schools who would be normally in Grade 9 at the time of the experiment.

<sup>c</sup>Selected at random from two Science 10 classes in each of five Vancouver Secondary schools.
students were taking university program. It is likely, therefore, that the mean IQ of the Science 10 population was slightly higher than the mean IQ of the whole Grade 9 population. However, it is not likely that the difference was so great that the sample could not be considered representative of the Science 10 population.

III. CORRELATIONS AMONG DISTRIBUTIONS OF TEST SCORES

**Raw correlations.** The randomly-selected sample was used to compute the Pearson product-moment correlation coefficients. Ten of the original 100 papers were discarded because of incomplete data. The raw coefficients obtained were:

- Standard-Criterion \( .58 \).
- Cooperative-Criterion \( .72 \).
- Stanford-Cooperative \( .66 \).

The scores are given in Table V in the Appendix.

**Correlations corrected for attenuation.** Since the object of the study is to determine the relationship between scores on a reading test and the ability to read a text-book, allowance should be made for the imperfect reliability of the Criterion Test. Applying the correction for attenuation in the criterion only, the correlation coefficient between Stanford scores and scores from a perfectly reliable criterion would be \( .65 \) for the sample. The corresponding Cooperative-criterion coefficient was \( .80 \).
CHAPTER VII

INTERPRETATION OF RESULTS

The thesis problem is answered by the correlation coefficients given in Chapter VI. The results apply only to the tests and population used in the study. The following inferences were derived from the statistical results.

1. The size of the correlation coefficient (.72) between scores on the Cooperative Test and on the Criterion Test implies that the two tests measure to a large extent the same group of skills. For most practical purposes, Part III (Comprehension and Interpretation) of the Cooperative Science Test could be used to appraise the ability to read material from Science in Action, Book I.

2. The correlation between the scores on the science reading tests is not high enough to say that the differences in the tests are negligible. The reading passages are comparable in difficulty and the items are similar in form and style. The most obvious difference, length of reading passage, may explain why the correlation was not higher.

3. There does not appear to be any significant difference among the correlations obtained in this study. There is, however, some basis for suggesting that the Stanford Test is not as good a measure of the ability to understand Science text-book material as the Cooperative Test ($r = .58$)
compared to \( r = .72 \). Furthermore, if the Cooperative Test really is more closely related to the Criterion Test than to the Stanford Test, this would imply that scientific content has more effect on reading test scores than length of passage.
CHAPTER VIII

EDUCATIONAL IMPLICATIONS

The findings of educational research are not confined to empirical results. In this chapter, certain implications of the study are discussed. The opinions expressed may be helpful to those interested in problems related to measuring the comprehension of text-book material. The suggestions for further research are problems which arise out of the present study.

How could the Criterion Test be improved?

The main weakness of the Criterion Test, which allegedly exemplifies text-book reading, is that it is more test than text-book. It is not free of the pressures which accompany formal tests. This fault might be largely overcome by having the students read one long selection directly from the text-book. Adequate introduction and orientation of the topic to be studied would then be possible.

A second criticism might be that the scores of the Criterion Test reflect in part the ability to interpret the items. Although this extraneous factor is difficult to eliminate in an item designed to test the understanding of the fine points, re-wording might clarify certain items.
Does the Criterion Test measure a higher level of understanding than the published tests used in the experiment?

The science reading tests were about equally difficult for the experimental group, but the Stanford Test was much easier. The mean scores of the three tests were 53%, 56%, and 75% respectively. However, the item statistics for the Criterion Test reveal that the items having the highest Flanagan r's test specific points. This might mean that the Criterion Test measures the ability to answer factual questions. On the other hand, even if the test does measure the ability to reason in reading, the factual items, because of their objectivity, could still correlate highly with the total score. This does not imply, however, that a test of reasoning-in-reading should be composed entirely of factual items.

As a test of complex comprehension skills, the Criterion Test does not seem to be appreciably superior to the published tests. A finer discrimination might be achieved if the test were designed for superior readers only.

To what extent do students in an average Grade 9 class understand what they read in their science text-book?

This problem is approached through a logical analysis of the items which were very difficult for the experimental
group. Consider the following item as a single example:

"Every compound has a definite chemical composition."

This means that
1. every pound of water (H₂O) has the same amount of oxygen in it.
2. when two substances combine chemically, they always form the same compound.
3. all compounds are made of chemical substances.
4. all compounds are made of the same substances.
5. compounds formed from the same substances have the same properties.

Only 27% of the group tested on this item answered it correctly. The Flanagan r was .13. Choices 2 and 5 are specifically contrary to ideas fully developed in the reading selection. Choices 3 and 4 do not include the concept of "definite composition". Therefore choice 1 is the only possible choice for a pupil who thoroughly understood what he read. Since this item is based on the key concept of the passage, it is apparent that the majority of the pupils did not master the ideas presented. The interpretation of the item should be a minor hazard to those who did understand the reading passage.

What is the relationship between science reading test scores and achievement in science?

Christmas science marks, Criterion Test scores, and Cooperative Test scores for two classes from one school are given in Table VI in the Appendix. These classes were taught by different teachers. The correlations between marks and Criterion Test scores for the two classes were .55 and .33.
The correlations between marks and Cooperative Test scores for the same classes were .48 and .34. There seems to be a closer relationship between marks and both sets of reading scores for one class, than between marks and one set of reading scores for the two classes. Possible inferences are that the class situation affected the relationship between reading skills and achievement, and that the science reading tests were not significantly different.

The relationship between reading skills and achievement in a school subject depends, among other things, on the amount and type of reading required of the students, on which skills are measured by the reading tests, and on how achievement is defined and measured. In the present case, the examination from which the Christmas marks were obtained emphasized knowledge of facts rather than application of knowledge. A close relationship between this type of achievement and reading comprehension would not be expected. The rather low correlations also indicate the existence of many other factors (interest, attitude, ambition, perseverance, etc.) which affect school marks. Guilford points out that in nature, correlations of zero or 1.00 are the rule between variables when isolated. The fact that we obtain anything else is because of the inextricable interplay of variables that we cannot measure in isolation.\(^{29}\)

What practical use can a classroom teacher make of Criterion Test scores?

1. Since the Criterion Test consists of typical readings from the text-book, a criterion score estimates a student's ability to learn from the text-book. Accurate estimates of the reading ability of the class and of the individual students will help the teacher to select appropriate methods. Good readers would profit from extensive supplementary reading. For a class of very able readers, lecturing should be reduced to a minimum. For a class of poor readers, time should be given to the direct teaching of reading skills.

2. A student's score on the Criterion Test is an estimate of his potential for understanding the concepts presented in Science 10. It can be used along with science marks for educational guidance.

3. The test's item statistics provide useful data regarding the difficulty of certain concepts. There is a very real danger that the expert is likely to underestimate the difficulty of the ideas in his subject. The poor results on the interpretation items presumably show the need for recognizing the difference between verbalization and genuine understanding. Students may be able to parrot the words of the text-book with very little comprehension.
SUGGESTIONS FOR FURTHER RESEARCH

1. How practical is the suggestion of having the students read one long passage directly from the text-book? Would several tests, each based on a single topic give consistent results?

2. What factors of the classroom situation affect the relationship between reading abilities and achievement in science? What is the relative importance of each?

3. Is there an optimum length of science reading assignment for Grade 9 students? How does it vary with the ability of the students?

4. What are the relationships between test scores and skill in text-book reading for other reading tests, other text-books, and other populations?
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<table>
<thead>
<tr>
<th></th>
<th>Cooperative Science Test, Form Y, Part III</th>
<th>Criterion Test</th>
<th>Stanford Reading Test, Advanced, Form J, Test I</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Testing time</strong></td>
<td>25 minutes</td>
<td>48 minutes</td>
<td>25 minutes</td>
</tr>
<tr>
<td><strong>Number of reading passages</strong></td>
<td>6</td>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td><strong>Longest passage</strong></td>
<td>224 words</td>
<td>725 words</td>
<td>96 words</td>
</tr>
<tr>
<td><strong>Content</strong></td>
<td>3 parts contain material similar to content of Grade 8 science (B.C. program), but not specifically taught in Science 8</td>
<td>excerpts from prescribed text for Grade 9 science</td>
<td>wide sampling of general reading and reading in special fields — 5 paragraphs could be classed as &quot;scientific&quot;</td>
</tr>
<tr>
<td></td>
<td>2 parts contain material similar to content of Grade 9 science, but not specifically tested in the criterion test</td>
<td></td>
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<td><strong>Illustrations</strong></td>
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<td></td>
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<td>8 points for drawing station model of weather map</td>
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<td>7-9</td>
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<td>Cooperative Science Test, Form Y, Part III (30 points)</td>
<td>Criterion Test (38 points)</td>
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<sup>a</sup>Otis Self-Administering Test of Mental Ability, Intermediate Examination.
### TABLE VI

CHRISTMAS SCIENCE MARKS, CRITERION TEST SCORES, AND COOPERATIVE TEST SCORES FOR TWO SCIENCE 10 CLASSES, KING EDWARD HIGH SCHOOL

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Mean 98.25 20.18 18.04 81.20 18.91 15.59
TABLE VII
ITEM DIFFICULTIES AND FERGUSON r's FOR PRELIMINARY FORM A OF THE CRITERION TEST, BASED ON A RANDOM SAMPLE OF 100 PAPERS

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aPer cent of sample passing the item.
bCalculated from formula on page 27.
## TABLE VIII

ITEM DIFFICULTIES AND FERGUSON r's FOR PRELIMINARY FORM B OF THE CRITERION TEST, 
BASED ON A RANDOM SAMPLE OF 100 PAPERS

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*a* Per cent of sample passing the item.  

*b* Calculated from formula on page 27.
APPENDIX B

I. DIRECTIONS FOR ADMINISTERING THE STANDARDIZED TESTS.

The tests to be given are:
1. Test 1 of the Stanford Achievement Test i.e. Paragraph Meaning
2. Part III of the Cooperative Science Test i.e. Comprehension and Interpretation

The working time of each test is 25 minutes. These instructions were prepared so that both tests could be given in a single 55-minute period. If the tests are given in a single period, the examiner must be thoroughly familiar with the directions and very efficient in carrying them out.

Distribute the Stanford tests and the answer sheets.

"You will be given two tests this period. The second test will be distributed while you are working on the first. Do not open the second test until you are told to do so. Do not put any marks on either test booklet. You are provided with an answer sheet. Write your name and division on the answer sheet now. Unfold the test so that pages 2, 3, and 4 face upward. Read the sample at the top of page 2... The correct answer to #51 is "brother" so put a "2" on the answer sheet after #51. Similarly, since "up" is the answer to #52, put a "7" after #52. You are to do only Test 1 - Paragraph Meaning. Are there any questions... Begin"

Record starting time. Check to see that all pupils are using the answer sheets and are answering by number. Pass quietly around the room distributing the Co-op test. Watch for pupils opening the second test before they are told to do so. At the end of 25 minutes, "Stop! Fold your booklets, place to one side with the cover page up. Turn to page 11 of the other test... Notice that the choices in question 1 are all marked 1-. When writing your answer on the answer sheet, use only the second part of the number. Do not put any marks in the test booklet. You are to do only part III of this test. Any questions?... Begin"

Arrange the answer sheets alphabetically.
The test is designed to measure a student's ability to read science textbook material. The working time for the complete test is 48 minutes. Preliminary experiments indicate that the average student has ample time to attempt every item. However, to avoid having some pupils waste too much time on difficult questions, the supervisor will announce when the students should begin each part.

The scores will be meaningful only if the test is carefully administered according to instructions. Some students will be tempted to look at a neighbour's paper. An alert examiner can reduce this source of error to a minimum.

As booklets are being distributed, instruct students to fill in the information requested on the cover page and warn them to wait for further instructions. Allow about one minute after last student receives his paper. Then read directions on cover page aloud.

"Are there any questions?" .... "Begin reading."

Record exact time and complete Time Record below. Each step of arithmetic should be double-checked. Make the announcements at the appropriate times.

The examiner is requested not to answer any question concerning the test after the pupils begin reading.

Time Record

<table>
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<tr>
<th>Date</th>
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<tbody>
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hr. min. -Start of test Number of pupils

+10 min.

"Begin Part II now if you have not yet started it."

+11 min.

"Begin Part III now if you have not yet started it."

+14 min.

"Begin Part IV now if you have not yet started it."

+13 min.

hr. min. -"Stop working!... Have you completed the cover page information?" Collect booklets at once.

-48 min.

hr. min. -(should check with starting time)

Arrange papers alphabetically. Please return all material, i.e. completed tests, unused tests, directions for administering.
I. SCIENCE READING TEST FOR GRADE IX

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD TO DO SO!

Name ........................................ School ........................................
Are you taking Science 10 this year? ............ Boy or Girl ..............
Father's occupation ............................... Age ..........................
Yrs.  Hos.

Directions:

Fill in the information asked for above. Wait for further instructions.

This is a test of your ability to understand the kinds of material that you would find in a science text-book. You have been chosen to take part in this experiment along with Grade 9 pupils from other Vancouver schools.

Since this is not a speed test, most of you will have more than enough time to try all the questions. To make sure that you do not spend too much time on any part, your supervisor will announce when you should be starting each part. However, it is not necessary to wait for these announcements.

There are four parts to the test. Read each selection carefully and then answer the questions which follow the selection. You may refer back to the passage if you wish.

Work right through to the end of the test. When you finish, go back and try again the questions you missed.

Most of the questions are in the multiple-choice form and you are asked to put the number of the best answer in the space provided. If you are not sure of the answer to a question, write down the number of the choice which seems most likely.

No questions will be permitted after the test begins.
Part I

SYNOPTIC OBSERVATIONS

A synopsis of weather conditions is made four times each day at all weather stations in Canada. These SYNOPTIC OBSERVATIONS are taken at times which correspond to 4:30 a.m., 10:30 a.m., 4:30 p.m., and 10:30 p.m. in the Pacific time zone. Information is forwarded from each centre concerning air pressure, highest and lowest temperatures, direction and speed of wind, humidity, clouds, visibility, and amount of rainfall or snowfall. These reports are sent as quickly as possible from the observation stations by radio, telephone, or telegraph, whichever is the most convenient. Eventually, the synoptic observations are compiled for the preparation of a weather map. Now we shall see how the forecaster is able to put all the facts sent from an individual observation centre into a tiny space about the size of a ten-cent piece.

MAKING THE WEATHER MAP

At the forecast office, the teletype service brings in synoptic observations at a rate of one report every 10 seconds. The observer now becomes a "plotter" and begins to assemble the details of a WEATHER MAP -- a summation of weather conditions as reported from several hundred weather stations. The type of weather map used in Canadian forecast centres is about 30 inches square and printed with the bare outline of the principal rivers, lakes, and mountain ranges of North America together with large portions of the Atlantic and Pacific Ocean.

---

Station circle symbols

(a) Sky cover by clouds 25%
(b) Barometric pressure 1020.9 millibars
(c) Type of low cloud (cumulus)
(d) Dew point in degrees Fahrenheit
(e) West wind, 25 miles per hour
(f) Temperature in degrees Fahrenheit

Each weather observation station is indicated on the weather map by a circle -- the station circle, as it is called at the forecast centre. The plotter assembles the information which he has received using certain symbols and numerals in definite positions inside and around the station circle. For instance, consider the simple scheme used on a weather map to indicate the direction and speed of the wind at a certain station. The direction from which the wind is blowing is shown by a line emerging from the circle. At the end of the line, one or more symbols are drawn to represent the wind velocity. Each whole barb or "feather" means 10 miles per hour; a half-barb means half that amount or 5 miles an hour; a solid "triangle" means 50 miles per hour. A combination of these symbols can be used to show any wind speed.
a. Which one of the following words could best be used instead of "synoptic"? (Put the number of the best answer in the space provided at the right.)

1. simultaneous  2. observed  3. summarizing  4. weather .....(a) 3

b. Use the "station circle" below to show exactly how the following data would be plotted on a weather map. Do not use any labels, letters, or symbols except those which would appear on the map.

- north wind, 15 miles per hour
- sky cover 50%, cumulus clouds
- dew point 40°F.
- temperature 75°F.
- barometer 1015.5 millibars

Go on to Part II
FORMULAS GIVE COMPOSITION OF COMPOUNDS

Every compound has a definite chemical composition. When we know what kinds of elements are present in a compound, its composition can be represented quite simply. Since elements can be shown by symbols, then compounds (which are made of elements joined chemically) can be shown by united groups of symbols called CHEMICAL FORMULAS. Consider table salt, a compound made up of two elements—sodium and chlorine: Na is the symbol for sodium, Cl is the symbol for chlorine. NaCl is the formula for sodium chloride (table salt). This formula shows that each bit of common salt which exists as a substance is made of 1 atom of sodium chemically united to 1 atom of chlorine. When we remember that each particle of a substance that can exist by itself is a molecule, then we will realize a formula is an arrangement of symbols standing for a molecule of a compound.

The formula of a compound tells the proportions of each element which have joined to make the chemical substance. When a molecule of a compound has more than one atom of an element in its composition, the actual number is shown by small SUBSCRIPTS—whole numbers written slightly below and immediately after the symbol for that element. Consider the formula HNO₃. It represents a compound called nitric acid and shows that each molecule of that particular acid is made of 1 atom of hydrogen, 1 atom of nitrogen, and 3 atoms of oxygen. Briefly then, a formula is an arrangement of symbols and subscripts and stands for a molecule of a particular compound.

ELEMENTS COMBINE IN SIMPLE PROPORTIONS

When two elements unite as a compound, that compound is not necessarily the only one which can be formed from them. Take the formation of carbon dioxide (CO₂) and carbon monoxide (CO) as an illustration: During burning, carbon usually joins with oxygen to form carbon dioxide (CO₂), a non-poisonous but suffocating gas. However, during a mine explosion or when a car engine is left running in a closed garage, often there is not enough oxygen present in the air to completely oxidize the carbon and deadly-poisonous carbon monoxide (CO) is formed. The distinction between these two compounds is in the proportions of the elements present in them—CO has 1 atom of oxygen to 1 atom of carbon, while CO₂ has 2 atoms of oxygen to 1 atom of carbon. This simple relationship is indicated by the names mono (one) oxide and di (two) oxide.

In 1804, John Dalton was able to make a generalization based on many similar relationships. He showed that whenever there are two or more compounds containing the same elements, the weights of the one element which are combined with a fixed weight of the other have such simple relationships as 2 to 1, or 3 to 1, or 3 to 2, and the like. Later, when he advanced the atomic theory, Dalton said that only whole atoms can unite with one another when compounds are formed.

Now we can understand why small whole numbers are used in the formulas for compounds and why we do not encounter such complicated arrangements of symbols and subscripts as C₁H₂ or H₂N₂O₅.
Put the number of the best answer to each question in the space provided at the right. Try each question. You may refer to the reading selection but do not waste too much time on any one question.

a. A chemical symbol is used to represent

1. an element  2. a proportion  3. a compound  4. a molecule
5. a formula ......................................................(a) 1

b. How many atoms are there in a molecule of \( \text{H}_2\text{SO}_4 \)? ............................................(b) 7

c. A subscript gives the number of

1. substances  2. molecules  3. atoms  4. elements
5. compounds ......................................................(c) 3

d. \( \text{H}_2\text{SO}_4 \) is a kind of chemical shorthand for sulphuric acid. The letters \( \text{H}, \text{S}, \) and \( \text{O} \) are

1. formulas  2. molecules  3. compounds  4. symbols
5. elements ......................................................(d) 4

e. How many atoms of sulphur (\( \text{S} \)) are there in a molecule of \( \text{H}_2\text{SO}_4 \)? .......(e) 1

f. \( \text{C}_2\text{O} \) is not used as a chemical formula because

1. carbon and oxygen do not join in this proportion
2. in an ordinary chemical change atoms do not divide
3. carbon-dioxide (\( \text{CO}_2 \)) and carbon-monoxide (\( \text{CO} \)) are the only compounds of carbon and oxygen
4. fractions are harder to work with than whole numbers ..............(f) 2

g. Suppose that the formulas given below represent actual substances.
Hydrogen (\( \text{H} \)) and oxygen (\( \text{O} \)) unite in the same proportion in \( \text{H}_2\text{O} \) as in

1. \( \text{H}_2\text{O}_2 \)  2. \( \text{H}_2\text{O}_2 \)  3. \( \text{H}_4\text{O}_2 \)  4. \( \text{H}_4 \)  5. \( \text{H}_2\text{O}_4 \) ............................................(g) 3

h. A compound is a combination of

1. symbols  2. chemicals  3. subscripts  4. formulas
5. elements ......................................................(h) 5

i. Element is to symbol as compound is to

1. proportion  4. molecule
2. formula  5. atom ...............................................(i) 2
3. subscript

j. \( \text{H}_2\text{O} \) is

1. an element  2. a formula  3. a mixture  4. an atom...(j) 2
Part III

ABSORPTION EXPLAINED

Plants take in water and dissolved minerals from the soil through the walls of their root-hairs. The membranes which line these cells have a special action with regard to substances passing through them. Water will pass through freely, dissolved salts less freely, and insoluble materials will not pass through at all.

A demonstration will show how water and certain dissolved substances pass through the walls of root-hairs. A solution of corn syrup (glucose) in water is held in an inverted thistle-tube by fastening a membrane of parchment paper or pig’s bladder over its mouth. The glucose represents the thick sap of plant cells and the membrane corresponds to the cell walls. After a time, you will notice that the liquid has risen in the stem of the thistle-tube. When you remember that water can move freely through the membrane, the rise indicated that more water had passed inward than had moved outward.

Perhaps you have used salt as a weed-killer along a walk or a driveway. Soon after the salt had been spread around, you noticed the weeds wilt and die. In this instance, it is apparent that more water passed outward through the cell walls towards the salty solution in the soil than passed inward to the plant.

In both cases, the direction of flow through the cell walls was from the dilute solution towards the more concentrated one. Such diffusion through a special kind of membrane is termed OSMOSIS. Osmosis plays an important part in the life of plants. Wilted flowers revive in water because water passes into their cells and extends them. When too much chemical fertilizer is placed beside a plant in the soil, it will wilt as water is taken from its cells.

Thus, under normal conditions, soil water diffuses through the walls of root-hairs and moves on into nearby root and stem cells. Finally, it reaches the plant leaf where water is one of the chemical substances needed during photosynthesis. The movement of liquids into plants is usually inward and continuous because most plants have special arrangements to get rid of any water not needed during food-making.

TRANSPIRATION -- WATER ELIMINATION PROCESS

Water is one of the raw materials necessary for the manufacture of food materials. In addition, it acts as a carrier for other raw materials, manufactured products, and wastes throughout the plant. Plants use more water than any other substance. The root system of an averaged-size tree raises an enormous quantity of water from the soil. A mature apple tree, for example, will lift 800 pounds of water out of the ground in a single day in the summer. A stalk of corn will raise almost 400 pounds of water during its growing season; while an acre of farm meadow will lift more than six tons of water during a warm July day.
Plants absorb more water through their roots than they require for photosynthesis. Only about 2% of the moisture taken into the plant goes into the food needed to build and nourish the plant. The remaining 98% of the moisture taken into the roots is passed off through the leaves as vapor. Stomata allow this water to pass off from the interior of the leaf into the air. This method of disposing of water is called **transpiration**.

Transpiration can be shown by placing the stem of a large shoot of a plant such as a geranium, through a hole in a piece of cardboard big enough to cover a drinking glass. The glass is filled with water and a second tumbler inverted over the leaf. In a short time, **dew** will appear on the inside of the upper glass—this represents moisture which has been evaporated into the air from the plants as transpired water.

Put the **number** of the best **answer** to each question in the space provided at the right. Try each question. You may refer to the reading selection but do not waste too much time on any one question.

---

**a.** Fig. 2 is a drawing of an experiment which shows that
1. sunlight provides energy for food-making in a plant
2. a plant absorbs more water through its roots than it requires for food-making
3. water rises by capillary action in the stems of plants
4. a dilute solution diffuses through cell walls into a concentrated solution
5. a concentrated solution diffuses through cell walls into a dilute solution ..................(a)  [2]

**b.** Elimination is related to transpiration as absorption is to
1. raw materials  4. osmosis
2. capillary action  5. diffusion ..........................(b)  [4]
3. photosynthesis

**c.** Salt can be used as a weed-killer because
1. it has little food value
2. it causes the loss of plant fluids
3. it is poisonous in large amounts
4. it stops osmosis
5. it clogs the plant's membranes ..........................(c)  [2]

**d.** A dilute solution is often
1. watery  2. saturated  3. salty  4. impure  5. thick ..... (d)  [1]

---
e. Osmosis is the process by which a plant
1. gets rid of excess water  4. makes its food
2. takes in carbon-dioxide  5. breathes  ..................... (e)  3
3. obtains certain raw materials

f. In the experiment shown in fig. 1, the water rises in the tube
because
1. air pressure holds up the water
2. capillary action draws up the water
3. the membrane is porous
4. the glucose solution is more dilute than the water
5. the water is more dilute than the glucose solution  ......................(f)  5

 g. On a warm July day, about how many mature apple trees would
absorb as much moisture as an acre of farm meadow?
1. five  2. ten  3. fifteen  4. twenty  5. none of these  ..........(g)  3

 h. A plant's needs are usually best supplied when the soil water is
1. pure  4. a concentrated solution
2. salty  5. a saturated solution  .....................(h)  3
3. a dilute solution

Go on to Part IV

PART IV

WORK

Many of us use the word "work" without understanding its real meaning. If you
push on some object and succeed in making it move, then — and only then — you have
done WORK. Thus if you lift a book, climb up stairs, or push on the pedals of your
bicycle, you are doing work. Or, as the scientists put it, whenever a force is
exerted and something is moved, then work has been done. This means that you could
exert all your strength in trying to budge a heavy piano, but unless it was actually
moved, a scientist would say that no work was done.

STATES OF ENERGY

Scientists define energy as the capacity for doing work. All energy is either
kinetic or potential. The energy of matter in motion is called kinetic; the energy
stored in matter is potential. Only kinetic energy can be put to immediate use;
potential energy must be changed in some way to the kinetic state before it can do
useful work.

POTENTIAL ENERGY -- ENERGY IN RESERVE

An object may have the ability to do work because of its position. A package
on the kitchen shelf has energy associated with it, as you may discover if it falls
on your head. As long as the package stays unmoved on the shelf, the term
POTENTIAL ENERGY may be used to describe the state of its energy -- the word
"potential" meaning stored or in reserve. A stone weighing 5 pounds and on the edge
of a 50-foot cliff has enough potential energy to do 250 foot-pounds of work because
of its position. Water stored behind a dam also has potential energy since it is in
position to do work when allowed to fall. Huge dams have been built in many parts
of the world to store run-off water when it is plentiful. These reservoirs hold it as potential energy which can easily be changed to kinetic energy as it is needed.

Bending, twisting, stretching, or compressing materials often gives them potential energy that can be used to do work. A stretched rubber band is an example; it can do work upon itself or on things it strikes when one end is suddenly released. A similar demonstration can be done with a clock spring. As you wind the clock mechanism, you give the spring a store of energy. This potential energy is gradually expended as the spring unwinds and turns wheels inside the clock. In a like manner, a bent bow has a reserve of energy; its sudden release causes an arrow to fly through the air. Compressed air provides yet another instance of energy being held in reserve. As the air is released from its container, it can be made to operate pneumatic hammers or drills.

Because of its chemical composition, a stick of dynamite has potential energy. On exploding, the compounds within the stick undergo chemical changes and its stored energy is released with great violence. Similarly, fuels such as wood, coal, oil and gasoline possess potential energy which can be released by burning them. The potential energy held in a material because of its composition is called chemical energy. Like fuels, the foods which we eat contain the necessary potential chemical energy to enable us to exert muscular force for movement and other useful work.

Scientists have found that all atoms have a kind of potential energy because of their internal structure. This atomic energy seems to be locked within each nucleus and in recent years, physicists have learned how to obtain its partial release from such atoms as thorium, uranium, and plutonium. Perhaps as more is learned about the forces within atoms, we shall be able to make a better use of this potential for the benefit of mankind.

Objects at rest may be capable of doing work because of their position or composition. However, the potential energy of such things as coiled springs, stores of water, foods or fuels, must be changed to the kinetic type before work can be accomplished.

**KINETIC ENERGY -- ENERGY OF MOTION**

The energy of motion is called kinetic energy. Kinetic energy can be described as the ability to do work because of its motion or the movement of its parts. A thrown baseball has kinetic energy because it can do work upon any object it might hit. Man uses various kinds of water-wheels and turbines to utilize the energy of running water and make it do work for him. Winds, circuits with electrical currents flowing in them, and falling hammers are other instances of things which possess kinetic energy -- they exert forces because they are in motion. This energy of motion is sometimes referred to as mechanical energy.

Put the number of the best answer to each question in the space provided at the right. Try each question. You may refer to the reading selection but do not waste too much time on any one question.

a. From what height in feet must a 4-pound weight drop to do 12 foot-pounds of work? ..............................................................(a) 3

b. A clock which has just been wound but is not going has
   1. no energy
   2. kinetic energy only
   3. potential energy only
   4. potential and kinetic energy
   5. mechanical energy .........................(b) 3
c. Which one of the following is an example of kinetic energy?
   1. a bent bow
   2. a river
   3. a truck parked on a hill
   4. a stick of dynamite
   5. none of these

   The correct answer is 3. a truck parked on a hill.

---

d. Work is being done when
   1. a person pushes against something
   2. an object moves
   3. a force is exerted
   4. a force causes motion
   5. an object has energy

   The correct answer is 4. a force causes motion.

---

e. A wood-pile contains
   1. chemical energy
   2. kinetic energy
   3. mechanical energy
   4. physical energy
   5. no energy

   The correct answer is 5. no energy.

---

f. Which one of the following is an example of potential energy?
   1. water flowing through a turbine
   2. a boy running down stairs
   3. a generator producing electricity
   4. a motor operating a fan
   5. none of these

   The correct answer is 2. a boy running down stairs.

---

g. Mechanical energy is also
   1. chemical energy
   2. atomic energy
   3. electrical energy
   4. potential energy
   5. none of these

   The correct answer is 5. none of these.

---

h. Which one of the following phrases describes a type of energy which is different from all of the others?
   1. stored energy
   2. energy due to position
   3. energy due to motion
   4. energy due to composition
   5. energy in reserve

   The correct answer is 4. energy due to composition.

---

i. An object at rest has
   1. both kinetic and potential energy
   2. neither kinetic nor potential energy
   3. no kinetic energy
   4. no potential energy
   5. no energy of any kind

   The correct answer is 3. no kinetic energy.

---

j. What kind of people have "capacity for doing work" from the scientific point of view?
   1. all people
   2. intelligent people
   3. people who like to work
   4. people who do not tire easily
   5. strong people

   The correct answer is 1. all people.

---

k. Which one of the following phrases does not belong with the others?
   1. chemical energy
   2. atomic energy
   3. mechanical energy
   4. potential energy
   5. electrical energy

   The correct answer is 3. mechanical energy.
Scoring Specifications for Part I (items b-i),
Science Reading Test for Grade IX

b. 1 point for north direction correctly shown.

c. 1 point for two barbs, the short one not more than three-quarters of the length of the longer.

acceptable  not acceptable

\[\text{\includegraphics[width=0.2\textwidth]{barbs}}\]

d. 1 point for any half of station circle cross-hatched or shaded.

not acceptable

\[\text{\includegraphics[width=0.2\textwidth]{shaded-circle}}\]

e. 1 point for correct symbol for cumulus cloud anywhere between the dotted lines.

Exception: When symbol was placed in 9 o'clock position and temperature and pressure figures also displaced by 90°, then 1 point for cumulus cloud but no credit for "positioning"—see (h) below.

\[\text{\includegraphics[width=0.2\textwidth]{cloud}}\]

f. 1 point for 40. No credit for 40°, 40°F, 40 degrees.

g. 1 point for 155. No credit for 155 millibars, 115, 15.5

h. 1 point for the three numerical quantities in the correct quadrants, or, if one symbol omitted, for two quantities in the correct quadrants.

\[\text{\includegraphics[width=0.2\textwidth]{quadrants}}\]

i. 1 point for not labelling the symbols in any way.
Exception: if station model is obviously not finished, no credit.
**TEST 2 Word Meaning**

<table>
<thead>
<tr>
<th>Word</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Clothing of any kind is called —</td>
<td>1. woolens 2. apparel 3. robes 4. draperies</td>
</tr>
<tr>
<td>2. Money wasted foolishly is —</td>
<td>5. proffered 6. severed 7. vandalized 8. squandered</td>
</tr>
<tr>
<td>3. If everybody agrees upon a plan, the agreement is —</td>
<td>1. unanimous 2. moderate 3. proportional 4. conscientious</td>
</tr>
<tr>
<td>4. An individual who insists upon doing things his way only is —</td>
<td>5. nimble 6. obstinate 7. kindly</td>
</tr>
<tr>
<td>5. When a man seeks a position with a certain firm, he becomes —</td>
<td>1. an applicant 2. a suitor 3. a petitioner 4. a contractor</td>
</tr>
<tr>
<td>6. A dramatic event in a story is called —</td>
<td>5. an epistle 6. a nucleus 7. a novelette 8. an episode</td>
</tr>
<tr>
<td>7. &quot;She has a good chance to recover&quot; means that improvement is —</td>
<td>1. certain 2. assured 3. impossible 4. probable</td>
</tr>
<tr>
<td>8. &quot;To draw on a blackboard, use a piece of —</td>
<td>5. pencil 6. straw 7. eraser 8. chalk</td>
</tr>
<tr>
<td>9. Anything a person elected to office should be —</td>
<td>5. confused 6. pitied 7. capable 8. noble</td>
</tr>
<tr>
<td>10. The &quot;crossing&quot; of two or more kinds of grain produces —</td>
<td>5. mongrels 6. hybrids 7. formulas 8. chaff</td>
</tr>
<tr>
<td>11. When a person repeatedly fails at something he wants to do, he may become —</td>
<td>5. buoyant 6. frustrated 7. fruitless 8. drenched</td>
</tr>
<tr>
<td>12. A beginner in some sport is —</td>
<td>5. a novice 6. a professional 7. a private 8. an assailant</td>
</tr>
<tr>
<td>13. A very exact measurement is —</td>
<td>1. absolute 2. concise</td>
</tr>
<tr>
<td>14. One who works hard is —</td>
<td>5. brazen 6. alluring 7. ancestral</td>
</tr>
<tr>
<td>15. A difficulty to be overcome is —</td>
<td>5. an obstacle 6. a miracle 7. a vehicle 8. a barnacle</td>
</tr>
<tr>
<td>16. A person over 21 years old is —</td>
<td>5. a graduate 6. an adult 7. a major 8. a patriot</td>
</tr>
<tr>
<td>17. Saving money for a &quot;rainy day&quot; is —</td>
<td>1. a token 2. a topic 3. a title 4. an article</td>
</tr>
<tr>
<td>18. Any statement about which there is question is —</td>
<td>5. a custom 6. a sacrifice 7. a duty 8. an opportunity</td>
</tr>
<tr>
<td>19. An individual who insists upon doing things his way only is —</td>
<td>5. an ordeal 6. an offense 7. a vigil 8. a seclusion</td>
</tr>
<tr>
<td>20. The kind of grain that comes after the frost in the summer is —</td>
<td>5. corn 6. wheat 7. barley 8. rye</td>
</tr>
<tr>
<td>21. The way an army executes its campaigns is called —</td>
<td>5. a custom 6. a sacrifice 7. a duty 8. an opportunity</td>
</tr>
<tr>
<td>22. Anything over 21 years old is —</td>
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<tr>
<td>23. The group of men who run a business are its —</td>
<td>5. managers 6. customers 7. salesmen 8. engineers</td>
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<td>24. A very exact measurement is —</td>
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<td>25. Mary Smith and John Doe are cousins if they have the same —</td>
<td>1. brother 2. sister 3. cousin 4. aunt</td>
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<td>26. The kind of grain that comes after the frost in the summer is —</td>
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<tr>
<td>27. Spotlessly clean clothes are —</td>
<td>5. chaste 6. immaculate 7. spotless</td>
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<td>30. Mary Smith and John Doe are cousins if they have the same —</td>
<td>1. brother 2. sister 3. cousin 4. aunt</td>
</tr>
<tr>
<td>31. Something you must do, such as paying taxes, is —</td>
<td>5. a custom 6. a sacrifice 7. a duty 8. an opportunity</td>
</tr>
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<td>5. buoyant 6. frustrated 7. fruitless 8. drenched</td>
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</table>

**DIRECTIONS:** In each exercise decide which of the four numbered words will complete the sentence best. Look at the number of this word. Mark the answer space at the right of the word you have chosen. **Study the samples.**
1. The children went to the circus. They saw elephants and monkeys and many other animals. There were many by the ring and lots of popcorn and peanuts. The children that wished a _1_ would come every day.

2-3. The gold used for jewelry is mixed with another metal, usually copper. Pure gold is very soft, and jewelry made of it would not wear well. Therefore, copper or some other metal is mixed with the gold to make _2_.

4. Insects that fly at night often mistake lights. It may be that they cannot tell the difference between the lights and an open fire. Sometimes these _3_ fly into a house and are killed.

5. I go to bed at seven o'clock. Bob stays up until eight. We _4_ in a thread stood for the things being written. Go on to the next page.

6. A few years ago most freight was carried by railroad track. _5_ of the 12-13 I-go-n-12-13 A long time ago the people of Peru did not know how to reach any point to which a _15_.

7. Most of the history of man might be written in terms of ocean currents. The warm Gulf Stream contributes so much heat to the northern waters that it prevents the Arctic Ocean from freezing so that if somehow it could be cut off, the region of the British Isles would be nearly uninhabitable. The mass of frigid arctic water helps bend the _18_.

8. The dog, first domesticated during the Old Stone Age, _19_. This substance is quite different from either iron or copper, but commonly called _20_. This substance is quite different from either the _21_ or the _22_, which combined to form it. 20-21. During the French and Indian War more than one hundred _23_. The colonists were supplied by the Indians on Deerfield, Massachusetts, and taken into the forest. Later, some were ransomed but many refused to return to _24_.

9. Architectural styles are the result of social, technical, and aesthetic standards. This illustrates the _30_. This substance is quite different from either the _31_ or the _32_, which combined to form it. 30-31. During the French and Indian War more than one hundred English colonists were captured by the Indians on Deerfield, Massachusetts, and taken into the forest. Later, some were ransomed but many refused to return to _32_.

10. Though the 

11. The dog, first domesticated during the Old Stone Age, 19. This substance is quite different from either iron or copper, but commonly called 20. This substance is quite different from either the 21 or the 22, which combined to form it. 20-21. During the French and Indian War more than one hundred English colonists were captured by the Indians on Deerfield, Massachusetts, and taken into the forest. Later, some were ransomed but many refused to return to 24.

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Please print:

Name .......................................................... Date ...........................................

Last Name .................................. First Name .......... Middle Name ...........

Grade or Class ........................................... Age ............. Date of Birth .................

Yrs. Mos.

School ...................................................... City .................................... Sex .......... M. or F.

Title of the science course you are now taking (for example: General Science) ...........................................

Teacher .....................................................

General Directions: Do not turn this page until the examiner tells you to do so. This examination consists of three parts and requires 80 minutes of working time. The directions for each part are printed at the beginning of the part. Read them carefully and proceed at once to answer the questions. DO NOT SPEND TOO MUCH TIME ON ANY ONE ITEM. ANSWER THE EASIER QUESTIONS FIRST; then return to the harder ones, if you have time. There is a time limit for each part. You are not expected to answer all the questions in any part in the time limit; but if you should, go on to the next part. If you have not finished a part when the time is up, stop work on that part and proceed at once to the next part. If you finish the last part before the time is up, you may go back and work on any part. No questions may be asked after the examination has begun.

You may answer questions even when you are not perfectly sure that your answers are correct, but you should avoid wild guessing, since wrong answers will result in a subtraction from the number of your correct answers.

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<th>Scaled Score</th>
<th>Percentile</th>
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<tr>
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<tr>
<td>II Terms and Concepts</td>
<td>15</td>
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<tr>
<td>III Comprehension and Interpretation</td>
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<td>Total</td>
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PART I
INFORMATIONAL BACKGROUND
(40 minutes)

Directions: Each of the questions or incomplete statements below is followed by five choices. Select the one that best completes the statement or answers the question, and put its number in the parentheses at the right.

1. A man watching the stars notices that stars which were just rising six hours ago are now directly overhead. This effect is caused by the
   1-1 rotation of the earth on its axis.
   1-2 vast speed of the stars in distant space.
   1-3 motion of the moon about the earth.
   1-4 turning of the stars around the sun as a center.
   1-5 ............................... 1( )

2. Discoveries that are announced by scientists are likely to be true because
   2-1 scientists are educated people.
   2-2 the discoveries are usually based on careful experiments.
   2-3 the discoveries are based on natural laws.
   2-4 scientists rarely make mistakes.
   2-5 scientists know what they are trying to discover.
   ............................... 2( )

3. It is believed that dinosaurs lost out in their struggle for existence chiefly because
   3-1 they were killed by man for food.
   3-2 man could not tame them.
   3-3 they were not adapted to changes that took place in the earth's surface and climate.
   3-4 they were not fitted to eat plant food.
   3-5 they had no brains.
   ............................... 3( )

4. Which of the following would tend to increase in number most rapidly if all owls in a locality were killed?
   4-1 Field mice
   4-2 Robins
   4-3 Groundhogs
   4-4 Wild ducks
   4-5 Quail
   ............................... 4( )

5. Which one of the following animals can most easily change his surroundings to fit his needs?
   5-1 A whale
   5-2 A gorilla
   5-3 An elephant
   5-4 A man
   5-5 A horse
   ............................... 5( )

6. The moon exerts a very important influence on
   6-1 the tides.
   6-2 changes in weather.
   6-3 crops.
   6-4 the relative lengths of day and night.
   6-5 climate.
   ............................... 6( )

7. The caloric rating of food refers specifically to the
   7-1 vitamin content.
   7-2 mineral content.
   7-3 heat energy released by burning the food.
   7-4 dry weight.
   7-5 amount of protoplasm it will build. ............................... 7( )

8. Most of the energy used by power plants at Niagara Falls is obtained from water by
   8-1 evaporating the water.
   8-2 distilling the water.
   8-3 changing the water chemically.
   8-4 making use of the force the water exerts in falling.
   8-5 taking electricity from the water. ............................... 8( )

9. Soft coal heated to a high temperature in the absence of air will yield
   9-1 coke.
   9-2 petroleum.
   9-3 marble.
   9-4 lime.
   9-5 sodium bicarbonate.
   ............................... 9( )

10. A blast furnace is used to
    10-1 extract aluminum from its ore.
    10-2 extract iron from its ore.
    10-3 extract gasoline from petroleum.
    10-4 produce natural gas.
    10-5 produce coal gas.
    ............................... 10( )

11. The planet which takes the longest time to revolve around the sun is
    11-1 the earth.
    11-2 Mercury.
    11-3 Venus.
    11-4 Mars.
    11-5 Pluto.
    ............................... 11( )

12. Through the entire atmosphere, as one gets farther away from the surface of the earth, the atmosphere
    12-1 becomes denser.
    12-2 becomes less dense.
    12-3 changes continuously in chemical composition.
    12-4 becomes bluer in color.
    12-5 increases steadily in temperature. ............................... 12( )

13. Fresh water will boil at about
    13-1 32° Fahrenheit.
    13-2 68° Fahrenheit.
    13-3 132° Fahrenheit.
    13-4 150° Fahrenheit.
    13-5 212° Fahrenheit. ............................... 13( )

Go on to the next page.
PART III

COMPREHENSION AND INTERPRETATION

(25 minutes)

Directions: This part consists of passages and tables. Following each selection are several items concerning it. Read the passage or examine the table carefully first; then decide which one of the choices given after each item best completes the statement or answers the question. If you cannot decide, you may go back to the selection. After you have decided on the answer to an item, put its number in the parentheses at the right as you did in Parts I and II.

<table>
<thead>
<tr>
<th>Disease</th>
<th>Means of Communication</th>
<th>Early Symptoms</th>
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<tbody>
<tr>
<td>Chicken Pox</td>
<td>Discharges from nose or throat of patient.</td>
<td>Rash.</td>
</tr>
<tr>
<td>Diphtheria</td>
<td>Nose or throat discharges; sometimes infected milk.</td>
<td>Begins like a cold.</td>
</tr>
<tr>
<td>Measles</td>
<td>Nose or throat discharges.</td>
<td>Begins like a cold. Reddish spots appear on the third day.</td>
</tr>
<tr>
<td>Mumps</td>
<td>Nose or throat discharges.</td>
<td>Pain in salivary glands.</td>
</tr>
<tr>
<td>Scarlet Fever</td>
<td>Discharges from nose, mouth, ears; infected milk.</td>
<td>Begins like a cold. In 24 hours evenly diffused bright red spots appear under skin.</td>
</tr>
<tr>
<td>Whooping Cough</td>
<td>Discharges from nose or mouth.</td>
<td>Cough worse at night. “Whooping” develops in about 2 weeks.</td>
</tr>
</tbody>
</table>

1. According to the table above, impure milk is most likely to carry germs of
   1-1 measles.
   1-2 mumps.
   1-3 scarlet fever.
   1-4 chicken pox.
   1-5 whooping cough. . . . . . . . . . . . . 1( )

2. Mary was sent home from school with what seemed like a cold accompanied by a rash. One would be justified in concluding that she probably had
   2-1 diphtheria.
   2-2 whooping cough.
   2-3 mumps.
   2-4 tuberculosis.
   2-5 some communicable disease; it is impossible to tell which one from the information given. . . . . . . . . . . . . 2( )

3. The diseases listed in the table, taken as a whole, are most likely to be spread by
   3-1 spoiled food.
   3-2 polluted water.
   3-3 air-borne germs.
   3-4 unpasteurized milk.
   3-5 household pets. . . . . . . . . . . . . 3( )

4. One of the most practicable ways to avoid getting these diseases is to
   4-1 stay away from crowds in poorly ventilated rooms.
   4-2 eliminate milk from one’s diet.
   4-3 boil all drinking water.
   4-4 pasteurize all milk.
   4-5 screen all windows and doors. . . . . . . 4( )

Go on to the next page.
In 1941 the United States shipped some 150,000 tons of water to Great Britain. This represents the water content (75 to 95%) of the fruits and vegetables that were transported during that year. Removal of this water by dehydration before shipping will make it possible for this tonnage to be used for the transportation of other materials.

Modern scientific dehydration preserves the flavor and some 90% of the vitamins of fresh food. In one process the fruits and vegetables are cooked, cooled, pulped, and then sprayed in a thin film on revolving drums, where heat drives off 96% of their water in from ten to twenty seconds. Steam rising rapidly from the food prevents oxidation, as when apples turn brown. The foods most successfully dried in this way are apples, bananas, peaches, peas, squash, and pumpkin; and in the dried state these foods will store well for years. When water is added and the food warmed up (it need not be cooked again), it is ready to be served.

5. The process described by the writer removes most of the water from the food by
   5-1 oxidation.
   5-2 preservation.
   5-3 evaporation.
   5-4 transportation.
   5-5 cooling.

6. The writer of the passage believes that
   6-1 many foods should be dehydrated before shipping.
   6-2 less food should be transported to Great Britain.
   6-3 dehydrated foods contain more vitamins than untreated foods.
   6-4 the transportation of other materials is more important than the transportation of food.
   6-5 dehydration of foods improves their flavor.

7. According to the passage, an important reason for drying foods before shipment is to
   7-1 increase the amount of water shipped to Great Britain.
   7-2 permit greater shipments of other materials.
   7-3 prevent apples from turning brown.
   7-4 conserve fuel by making it unnecessary to cook foods.
   7-5 make the foods more convenient to serve.

Go on to the next page.
When air masses are active, storms occur. To a meteorologist a storm does not necessarily mean rain or snow. It is merely an active field of combat where warm air has made a dent in the cold front. This forms a round or oval low-pressure storm area, anywhere from 300 to 2,000 miles in diameter, with the winds revolving around it counterclockwise and spiraling slowly towards the center.

Rains sometimes fall along the fronts in this “low” and are carried across the country by the prevailing westerly winds. Along the warm front, the onrushing warm air climbs over and pushes back the wedge of cold air, as is shown in Figure 1. As it rises, it cools and gives up its moisture. Clouds form as billions of tiny water droplets, only about 4 ten-thousandths of an inch across, condense out of the air, and cling to microscopic bits of dust. Then, as the droplets grow in size, they fall and we have rain—or if they freeze on the way down, we have sleet; or if they form crystals of ice while they are still in the cloud, we have snow.

Along the cold front, shown in Figure 2, changes are usually sharper. The warm air is pushed upward suddenly, and huge quantities of water, often thousands of tons, condense out of it to form towering thunderheads.

8. A storm may best be defined as
   8-1 a low-pressure area.
   8-2 a high-pressure area.
   8-3 an area in which the winds are revolving clockwise.
   8-4 an area in which the winds are spiraling out from the center.
   8-5 an area in which there are violent and destructive winds. 8( )

9. Rains usually move across the United States from
   9-1 east to west.
   9-2 west to east.
   9-3 north to south.
   9-4 south to north.
   9-5 southeast to northwest. 9( )

10. Which of the following characteristics of the warm air mass is responsible for its position as shown in Figure 1?
    10-1 Rapid motion
    10-2 Counterclockwise motion
    10-3 Large volume
    10-4 Light weight
    10-5 Relatively heavy weight 10( )

11. Sleet particles are most accurately described as
    11-1 frozen rain drops.
    11-2 large hailstones.
    11-3 frozen water vapor.
    11-4 small bits of dust.
    11-5 a kind of snow. 11( )

12. Rains are caused by
    12-1 cold fronts being pushed upward.
    12-2 cold fronts being pushed downward.
    12-3 warm fronts rising over cold fronts.
    12-4 warm fronts going under cold fronts.
    12-5 warm fronts mixing with cold fronts. 12( )

13. The center of every raindrop is
    13-1 a molecule of water.
    13-2 an atom of water.
    13-3 a tiny particle of ice.
    13-4 a tiny particle of dust.
    13-5 an electron. 13( )

14. A person who predicts weather on the basis of accurate information is technically called
    14-1 a weather forecaster.
    14-2 a geologist.
    14-3 a meteorologist.
    14-4 an anemometer.
    14-5 an astrologist. 14( )

15. What is the approximate diameter in inches of a water droplet in a cloud?
    15-1 .4
    15-2 .04
    15-3 .004
    15-4 .0004
    15-5 .00004. 15( )

Go on to the next page.
The work you do in walking is, for the greater part, work in lifting your body. To find how high you lift your body at each step, hold a piece of crayon touching the blackboard when you stand with your side to it. Walk along at your natural gait, keeping the arm rigid with the body. The crayon makes a rising and falling curved line. Find the number of inches from the average of the lowest points on the curve to the average of the highest points on the curve. This is the distance you lift your body at each step. Measure this distance in inches and change to a fraction of a foot. This number multiplied by your weight is the work you do at each step; multiply by the number of steps you take in walking from home to school to get the foot-pounds of work you do.

16. The work you do in taking one step is found by multiplying your weight by:
   - 16-1 12.
   - 16-2 your height.
   - 16-3 the distance, in feet, that your body is lifted in taking a step.
   - 16-4 the length, in feet, of the curved line in the experiment.
   - 16-5 the number of inches in one step.

19. Even without the use of the crayon and blackboard, one could calculate that the work done by a 200-pound man going up a step 9 inches high would be:
   - 19-1 150 foot-pounds.
   - 19-2 175 foot-pounds.
   - 19-3 200 foot-pounds.
   - 19-4 267 foot-pounds.
   - 19-5 1,500 foot-pounds.

17. In calculating the amount of work you do in walking from home to school by the method described above, it is not necessary to know:
   - 17-1 your weight.
   - 17-2 the distance you lift your body at each step.
   - 17-3 the number of inches in one foot.
   - 17-4 the number of steps from home to school.
   - 17-5 the speed with which you walk.

20. To make the change indicated in lines 12 and 13 of the passage, it is necessary to:
   - 20-1 multiply by your weight.
   - 20-2 multiply by the number of steps from home to school.
   - 20-3 multiply by 12.
   - 20-4 divide by 12.
   - 20-5 divide by your height.

18. This method for measuring the work you do in walking would be least accurate if you:
   - 18-1 weighed a great deal.
   - 18-2 were going uphill.
   - 18-3 walked in a straight line.
   - 18-4 walked in a circle.
   - 18-5 walked very slowly.

21. If your weight is 120 pounds, and the distance you lift your body at each step is one inch, how much work will you do in taking 1,000 steps?
   - 21-1 1,000 foot-pounds.
   - 21-2 1,200 foot-pounds.
   - 21-3 10,000 foot-pounds.
   - 21-4 12,000 foot-pounds.
   - 21-5 120,000 foot-pounds.

Go on to the next page.
Often the instinctive actions of insects seem so complicated that it is difficult to think of them as being purely mechanical reactions, as they are. The actions of a certain larva that is a parasite of one of the wild solitary bees illustrate this statement. Following their inherited instincts, these tiny larvae lie in wait for this certain kind of bee at the mouth of the underground tunnel in which she builds her nest. As she approaches, several of the larvae leap upon her back and bury themselves in her hair. Here they remain motionless while the bee, following her instincts, makes the necessary journeys to the flowers for materials with which to construct her cells and to store them with food for her young. But the instant she lays an egg in a cell, the egg somehow serves as a stimulus to the little parasites. Immediately they leap upon it, for it is the bee’s egg that they use for food. The bee seals the cell in her customary mechanical way—the only way that her inherited nerve structure permits. She has no way of knowing that her egg will be eaten, nor can she alter her behavior in the slightest degree.

22. The larva mentioned in the passage above is
   22-1 not harmful to bees in general.
   22-2 really of benefit to bees.
   22-3 harmful to many insects.
   22-4 a parasite.
   22-5 a nest-builder. . . . . . . . . 22( )

23. The food of the larvae consists of
   23-1 honey.
   23-2 part of a beehive.
   23-3 bees’ eggs.
   23-4 bees’ hair.
   23-5 parasites. . . . . . . . . . . 23( )

24. According to the writer, the actions of both the bee and the larva depend on
   24-1 past experience.
   24-2 the need for food.
   24-3 parental instruction.
   24-4 intelligent planning.
   24-5 inherited nerve structure. . . . . . 24( )

25. The author feels that
   25-1 some bees are very intelligent.
   25-2 seemingly intelligent behavior in insects is merely instinctive.
   25-3 parasites are among the most intelligent of insects.
   25-4 parasites as well as insects are important in pollinating flowers.
   25-5 domestic bees have more highly developed nerve structures than wild solitary bees. . . . . . 25( )

26. From the passage, one could justifiably conclude that
   26-1 most parasites eat bees’ eggs.
   26-2 this larva has a well-developed sense of smell.
   26-3 the disappearance of this kind of bee might also cause the disappearance of these larvae.
   26-4 the bees who know that their eggs are under attack can drive parasites away.
   26-5 this larva would be found in all beehives. . . . . . . . . . . . . 26( )

Go on to the next page.
The first stroke of the four-stroke cycle Diesel engine is the intake of a charge of fresh air. With the inlet valve open, the piston, moving downward, pumps in air to fill the cylinder. When the piston passes the bottom of its stroke, the inlet valve closes.

The second stroke compresses the air to between 500 and 600 pounds per square inch. When air is compressed, its temperature rises. In the Diesel engine the temperature of the compressed air may reach as high as 1,000 degrees Fahrenheit.

The fuel is injected into this hot air. Since the oil is in a fine, fog-like spray, it starts to burn immediately. The injector continues to spray fuel oil into the cylinder until all of the charge is injected. The pressure in the cylinder rises to between 800 and 850 pounds per square inch.

The third stroke is the power stroke. The hot gases expand and force the piston downward. The chemical energy of the fuel is converted into mechanical energy to move the piston.

The fourth stroke is the exhaust stroke. The exhaust valve opens and the piston, moving upward, forces the burned gases out to make room for a new charge of air.

27. The pressure which injects oil into a Diesel cylinder must be at least
   27-1 15 pounds per square inch.
   27-2 30 pounds per square inch.
   27-3 100 pounds per square inch.
   27-4 400 pounds per square inch.
   27-5 800 pounds per square inch. . . . 27( )

29. What causes the fuel to ignite in a Diesel cylinder?
   29-1 Hot fuel
   29-2 A spark
   29-3 Hot air
   29-4 Heat of friction
   29-5 A fuel pump . . . . . . . . . . . 29( )

28. Which of the following processes is most important during the third stroke of the piston?
   28-1 Chemical changes occur.
   28-2 Air is compressed.
   28-3 Heat is absorbed.
   28-4 Energy is stored.
   28-5 Energy is destroyed. . . . . . . . 28( )

30. In what position are the valves during the compression stroke?
   30-1 Both are open.
   30-2 Both are closed.
   30-3 The inlet valve is open and the exhaust valve is closed.
   30-4 The inlet valve is closed and the exhaust valve is open. . . . . . . . 30( )

If you finish this part before the time is up, you may go back and work on any part.

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Raw Score on Part III = Difference
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</table>
The relationship between Stanford Test scores and Criterion Test scores may vary with the ability of the group. To investigate this possibility, the correlations between these two sets of scores were computed separately for good and poor readers. From the total group writing the tests, the papers of students repeating Science 10 and those who had tried preliminary form B were discarded. Of the remaining group, the 65 pupils (25%) with the highest scores on the Stanford Test comprised the good readers. Since the range of ability had been greatly reduced, it was not surprising to find that the correlation coefficient dropped from .58 to .39. The corresponding coefficient for the poor readers, the group scoring in the bottom 25 per cent on the Stanford Test, was .21. Application of Fisher's z-transformation indicated that the difference between the correlations was not significant.

These data suggest that the Criterion Test calls for certain skills which are not included in general reading tests, but whether these skills should be included is a matter of opinion.

The scores are given in Table IX.
TABLE IX

STANFORD TEST SCORES AND CRITERION TEST SCORES
FOR GOOD AND POOR READERS

<table>
<thead>
<tr>
<th></th>
<th>Good Readers(^a)</th>
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\(^a\)The 65 pupils scoring in the top 25\% on the Stanford Test.

\(^b\)The 65 pupils scoring in the bottom 25\% on the Stanford Test.