AN INVESTIGATION OF THE NATURE OF COMPREHENSION GAINED THROUGH READING AND ITS RELATIONSHIP TO OTHER ASPECTS OF READING AND TO ACADEMIC ACHIEVEMENT

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Degree Doctor of Philosophy in the Graduate School of The Ohio State University

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1954

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ACKNOWLEDGMENT

The present study would not have been possible without the interest and participation of many individuals. The writer is indebted to the following individuals and groups for the various contributions which they made toward obtaining the results here reported.

To Professor Francis P. Robinson, the writer is most grateful for the help he gave in setting up the research design and for the supervision given in carrying the study up to its very last phases.

Professor John R. Kinzer acted as adviser and chairman while Professor Robinson was out of town. Professor Kinzer was most helpful in guiding the writer through the last steps of completing the dissertation and meeting the requirements of the graduate school. Professors Sidney L. Pressy, and Alvin Scodel served as members of the reading committee and made a number of helpful suggestions regarding the final draft.

To Professor Dorothy E. Moulton of the English Department, to Professor Waldo E. Steidtmann of the Biology Department, and to members of the staff of the Psychology Department at Bowling Green State University, many thanks are due for their help in getting the reading test materials prepared and administered.
Professor Robert M. Quinn was especially helpful in assisting the writer with some of the statistical computations.

Finally, appreciation is expressed to the students who participated in the study. Obviously, without them and their fine cooperation the study could not have been completed.
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CHAPTER 1

INTRODUCTION

I. The Importance of Reading in our Culture

A. Reading in General Life Activities

In this age when super-sonic travel, high speed linotype, and multiple-phased lithography make their contribution to the production and wide-spread distribution of the printed word in the form of newspapers, magazines and books, it would be difficult to find an activity which is more important to the ongoing behavior and adjustment of the individual than is linguistic communication in the form of reading.

Whether he be a pre-school child who has not learned to read, a school child just beginning to achieve reading skills of a basic nature, an adult with minimal or average formal education, or one of our highly trained professional or technical experts, his very existence in many ways depends solely upon his or someone's ability to read rapidly and accurately the ideas, meanings and concepts conveyed by the printed word.

Despite the fact that radio has become a well-established and essential form of communication and entertainment, and
notwithstanding the phenomenal way in which television has taken our nation by storm, one finds the managers of our already extensive library facilities constantly being forced to seek larger and larger areas for housing the ever-growing volume of printed materials being produced. Surveys of the use being made of library offerings show that the number of individuals patronizing these institutions in search of cultural and technical enlightenment is growing at a pace which is at least equal to the increasing volume of reading matter.

And who has failed to note the voluminous variety of magazines, manuals, and books on the counters and stands of the hundreds of news agencies, corner drug stores and super-markets scattered throughout our cities and towns? Without difficulty, one can find an article or series of articles relating to almost any phase of human activity. Many of the more popular hobby or interest areas have dozens of publications devoted to their cause. And practically all are put up in such attractive form, the over-sealess reader with ready cash may find his reading shelves becoming over-stocked.

Even this does not take into account the hundreds of thousands of copies of various publications which are sent directly into homes each week and month on yearly subscriptions. Truly, America is a reading nation, and rather than becoming obsolete, reading skill is continually taking on new and more essential roles in
our culture. Not only is it necessary that a person learn adequate reading skills in order to compete in our educational and economic systems, but position and standing of a social sort are enhanced if one is able to keep-up with a wider variety of activities and developments through reading.

Finally, in carrying the point to the ultimate, it can be said that man's mere existence and fundamental survival have come to depend to a great extent upon someone's (the individual's or the person's upon whom the individual can rely) ability to read, understand, and follow printed instructions and directions.

B. Reading in Our Schools

Since reading plays such an essential and ever-expanding role in the life of the American populace, and since experience and analysis have shown that good reading skill is seldom acquired by accident, the public schools of our land have given a central position to programs for the teaching of reading. Such is so much the case that teachers of all subjects at the elementary and high school levels have all been given some degree of responsibility for the teaching and improving of reading skills.
Although the college instructor, in general, has not had such responsibility forced upon him, college staffs and administrators have not failed to recognize the importance of reading skill to academic success at this higher level. It is at this level in the educational ladder that the student first encounters the demand for covering vast amounts of assigned reading materials rapidly and with understanding. Much of this reading must be done on the student’s own responsibility and the interested and highly motivated individual will even want to explore sources beyond those that are assigned. In the case of the well-rounded person who strives to maintain a talking acquaintance with fields outside his specialty and with current events, the reading load can reach mammoth proportions.

If the person’s slow reading brands him as a plodder, or if he, at best, does not rate higher than average in reading skill, he will be forced to forego many interesting and beneficial reading experiences and may be able to cover only a portion of the course assignments. Often, if he does manage to complete his assignments, the coverage will be desultory and lacking in effectiveness.

In other instances, where the student is conscientious but lacks adequate reading skills, he will not be satisfied with a job half done and will resort to using recreational hours and
sleeping time as study hours. Threatened by possibilities of failure he will become anxious and tense, such disturbance being made all the more vicious by the loss of sleep and the failure to gain relaxation through recreational activities. Thus, in some instances the individual may become ensnared in a tightening web of circumstances, and may find himself edging inexorably toward serious personal and social maladjustment.

Recognizing the dire ultimate consequences to which such developments occasionally accrue, colleges have endeavored to meet the situation in various ways. Provision is now being made for entrance testing programs of a more practical and more effective sort than was formerly the case. By means of such programs, counselors and deans who help the new student to set up his schedule of courses are afforded ratings on each individual. Capacity for college achievement and other factors are evaluated. Deficiencies, where identified, are allowed for or efforts are made to remove them.

A typical entrance testing program will include a test of intelligence or college aptitude, a reading or English-usage test, and occasionally a speech and hearing test. These are administered along with the traditional physical or medical exams. In addition to this, some of the more progressive and
pioneering institutions have been using devices whose purpose is to identify or screen-out those with potentiality for disabbling personal-social problems. The over-all concern is toward making each student a more efficient scholar and a more effective citizen.

On the basis of results from such testing programs, coupled with increasing demands for help on the part of students, and the recognition of a need for it on the part of teachers and advisors, another type of service is being provided. This relates to the establishment of diagnostic clinics and study-aid centers where the individual can be subjected to various tests and evaluating techniques, and where remedial devices and training facilities can be provided.

Since reading ability obviously is a highly important prerequisite to achievement in the academic field, the reading test has gained preferred status in most college entrance programs and in many diagnostic and remedial clinics. If the student, counselor or dean can be provided with early information regarding the adequacy of the student's capacity for academic achievement without going through the time-consuming and otherwise expensive procedure of the actual tryout, the benefit to be derived over an extended period and where great numbers of students are involved, can be tremendous. Not only will the student be able to embark upon his
educational endeavors with a higher level of confidence and security and thus be more effective in his efforts, but the adviser and instructor may also be able, on the basis of dependable advanced knowledge of the student's capacity, to direct his advisee to take courses that will advance him most rapidly towards his goal. Shortcuts and enriched programs are then likely to be more effective and the danger of lowering standards of training will be reduced to a minimum.

On the other hand, if the student's reading ability is shown to be inadequate, proper procedures can be followed in lining up his program of study so that he will use his particular level of ability to best advantage. In addition to this type of program planning, the student can be referred to the diagnostic and remedial clinic for further attention and guidance.

Thus, we see that the measurement of reading ability through the use of standardized tests can be a crucial event in the life of the student. It is important that the tests measure all the characteristics and components of reading skill that are shown to be related to academic achievement. The present study is particularly concerned with the measurement of certain aspects of the reading ability when used in college entrance testing programs.
II. The Measurement of Reading Ability at the College Level

Without denying the fact that reading ability and the accurate measurement of reading skills are highly important aspects of learning at all levels of the scholastic hierarchy, it is the intent of the present study to investigate reading ability in its fully-developed, adult form as found in college students. Furthermore, we would not deny recognition to the early methods of measuring reading skills which obtained a gross sample of the total reading performance. Such methods as the use of oral reading, or the use of silent reading and informal report on content materials, have played important roles in the evaluation of reading capacity and in some instances may still have valuable contributions to make. The main interest of the present study, however, is directed toward those attempts which sought to identify the various components by means of formal, standardized tests. It is hoped that a more accurate evaluation of these components will lead to a more adequate diagnosis of reading ability. Also, an assessment of the interrelationship of these components might show whether or not a broadly conceived measure of reading ability is actually being utilized.
A. The Development of Standardized College Reading Tests

A survey of the history of the development of formal tests for the evaluation of the components of reading ability in college students reveals three distinct phases or periods. In tracing the transition from the beginning stage to the present status of the standardized reading test we gain a clear picture of the evolutionary processes and changes through which these instruments have moved.

Stage one started early in the third decade of the present century (about 1920) and was characterized by an arm-chair, or subjective analysis of the reading process and the construction of devices to test and measure the traits and factors thus defined. The original form of the Iowa Silent Reading Test (34) attempted to get at the factors of reading ability as they were defined by the subjective judgments of a national committee. This committee's analysis of the reading process was used by Horn and McBroem in their attempt to construct tests for the measurement of such component skills as comprehension, speed, organization, and remembrance.

As practice and experience were gained in the use of these early testing devices, it became apparent that although they afforded measurements which were broader in scope and which involved less overlapping of function than the previous subjective
estimates of ability, they still failed to provide a complete and satisfactory picture of reading ability. Since the tests were still based on subjective judgments as to the nature of reading, disagreements arose as to just what factors were being evaluated and as to the importance and independence of the factors in the reading process. Also, there seemed to be facets of reading ability and skill which were still not being taken into account.

The demand for a more objective evaluation of the nature of the reading process upon which to base the construction of more adequate reading tests led to the second stage in the transition from early to present-day tests. This involved the application of correlational techniques to the problem. Through the use of this statistical method, workers succeeded in devising tests for the independent measurement of various aspects of the reading process. Where low correlations were found to exist between various sub-test scores, it was generally agreed that independent factors or aspects of reading ability were being sampled. The use of many such tests of low relationship was held to be the more accurate way of evaluating reading ability. The construction of the Gates Grade III to VIII Reading Test (25) was typical of this approach. This new method, however, did not take into account the overlapping, or interrelationship of the skills identified by the sub-tests used in tests by different authors, a
fact which led to much needless measurement and confusion.
For instance, Hall and Robinson (31) compared results on Gates' tests of 'entirely different' reading skills with each other and found that they correlated as highly as some tests by different authors which were supposed to be measuring identical skills.

As efforts were exerted to eliminate or clear up some of the undesirable effects of the correlational approach, the utilization of a relatively new statistical technique called factor analysis seemed to have promise. This introduced the third stage in the evolution of the standardized college reading test.

In the factor analysis approach, an objective as well as a refining method was afforded. Consequently, more weight and importance could confidently be attached to some aspects of the reading process, while others, though recognized as being operative, were considered to be less crucial to the over-all effectiveness of the skill or ability. For example, a number of investigators, Gans, (23) Langsam, (37) Pankaskie, (40) found such factors as reading rate, verbal facility, and comprehension accuracy to be independent and important aspects of reading ability.

Robinson and Hall (31) in their application of factor analysis to the problem identified five factors as being involved in the types of reading situations which they investigated. They called
these factors "attitude of comprehension accuracy, rate for inductive reading, verbal or word meaning, rate for unrelated facts, and chart-reading skill."

Subsequent efforts in test construction have been directed toward the objective and standardized measurement of the components which were revealed by factor analysis and which were identified as independent and important in the reading process.

B. The Inadequacy of Measurements of Comprehension in Reading

In the college reading tests which are generally used today, the method of measuring comprehension accuracy involves the asking of various types of test questions relating to the content material of a particular reading passage or of several passages. These questions have invariably been presented immediately after the reading of the passage.

In a few instances in research studies, delayed comprehension has been investigated by presenting test questions at varying intervals of time after the reading has been completed. No standardized reading test, however, has included this type of measure.

So far as the writer knows, there have been no attempts, in either standardized reading tests or reading research projects, to check comprehension accuracy or informational background for a particular field or body of knowledge prior to, as well as
following the reading of materials related to the particular field. Likewise, no report has been found of any attempt to determine the relationship between previous knowledge for reading materials and the immediate and delayed comprehension of facts and ideas presented in the materials read.

Further more, none of our findings reveal that comparisons have been made between the relationship of previous and immediate comprehension accuracy, and the other aspects of the reading process, namely, reading rate, vocabulary, and paragraph comprehension. Finally, we have found no reports dealing with the relationship between previous knowledge and immediate comprehension accuracy and how this relationship might affect college achievement and rating on intelligence tests.

It is not difficult to see that the factor of previous knowledge, its nature and extent, may have a very profound bearing on immediate comprehension accuracy and upon ratings on standardized reading tests. The character of previous knowledge, as well as the nature of delayed comprehension may both have an extremely important and essential relationship to intelligence and to college achievement. Nevertheless, modern reading tests make no provision for the evaluation of these seemingly highly important aspects of comprehension accuracy and reading ability.
III. The Problem

The present investigation, therefore, seeks, first, to obtain an accurate measure of previous knowledge for a specific field of knowledge and, second, to show the effect which such previous knowledge has on the comprehension of reading materials related to that field. This "effect" or this relationship will then be evaluated with respect to its influence on or relationship to some of the other components of reading ability, namely, reading rate, vocabulary, and paragraph comprehension. The attempt will also be made to determine what bearing this relationship between previous knowledge and comprehension has on college achievement and how it is related, if at all, to ratings on intelligence tests.

Technically, the problem might be stated in question form as follows: Can difference scores computed between comprehension-test ratings obtained before and after the reading of assigned materials, and the determination of the relationship of such difference scores to the other aspects of reading skill, to academic achievement and intelligence, add measurably to the understanding of the reading process?

Specifically, the effort will be made to establish the relationship of a different score (derived as stated above) to:
(1) reading rate; (2) vocabulary rating; (3) delayed comprehension; (4) paragraph comprehension; (5) academic achievement; and (6) rating on an intelligence test.

The primary objective of the study will be the more precise evaluation of gains in comprehension actually made at the time of reading and the demonstration of how such gains in comprehension relate to other recognized aspects of the reading process and to scholastic achievement and intelligence. The comprehension and knowledge which college students possess for selected reading materials and which they reveal on tests taken prior to the reading of the materials, and the comprehension shown by the same students on tests taken subsequent to the reading of the same materials will be statistically compared.

In the case of academic standing, the objective will be to find controllable variables which might enable us to predict with a higher degree of accuracy than heretofore possible the grades which a college student might be expected to make.

Finally, in regard to intelligence, it is an objective of this study to discover controllable variables which might permit college counselors and advisers to direct a student toward the more effective use of his intellectual capacities.
IV. Limitations

The subjects used in the present study will be college students enrolled in courses in the Psychology Department of Bowling Green State University. The population will include male and female students in about the proportion in which they appear in the general university population. The three colleges of Business Administration, Education, and Liberal Arts will be represented and the four class levels of freshmen, sophomores, juniors and seniors will be included. However, better than half of the group will be drawn from the sophomore and junior classes. About half of the group will be enrolled in the College of Education, and about one-third of the group will be enrolled in the College of Liberal Arts, with the remaining fifteen percent coming from the College of Business Administration.

The findings of the study will be applicable to students in other courses and to individuals in the general university population only to the extent that the students involved in the study are representative of these other groups.

V. The Value of The Study

Through the results obtained in this study, greater insight should be gained into the nature of reading skills and the factors
influencing the reading process. On the basis of this increased insight it should be possible to construct more valid and more reliable tests of reading ability. The results may also lead to a better understanding of the scores earned on college reading tests, and the more accurate interpretation and better utilization of the information thus afforded.

An additional outcome of the study might be the improvement of the services provided by college clinics and remedial programs through the provision of better tests and the improvement of means of interpreting test scores. In the same sense, college entrance testing programs stand to benefit.

Any improvement in the services offered by the university or college in these respects should ultimately lead to the improvement in the use of the student's learning capacity and to their higher achievement in college courses. Not only might there be better selection of courses to fit the capabilities of the student, but those students suffering from disabilities in reading skill will also have a better chance for getting their deficiency diagnosed and remedied. In general, any improvement in reading skill should eventually lead to higher learning capacity and higher academic standing.

Using the foregoing presentation as an introduction to the factors and forces which give rise to the present research, we
will now turn to Chapter 2 for a more detailed survey of background studies and investigations which appear to have some bearing on the problem and on the method used in dealing with the problem.
HISTORICAL BACKGROUND

The claim was made in Chapter One that previous knowledge is an important factor affecting gains made in comprehension during reading. Attention was also drawn to the fact that tests for the measurement of reading ability, although they usually include materials for the evaluation of comprehension, fail to take into account this factor of previous knowledge. Even though some test makers, such as Robinson and Hall (1951) have made an effort to minimize the effect of previous knowledge on reading test performance by the use of relatively unfamiliar material for the reading passages, no report has been found of any attempt to get a quantitative measure of this effect.

As a means of gaining a better understanding of what has been done regarding the measurement of comprehension, and in order to point out the tendency of reading tests to neglect the accurate evaluation of comprehension, a brief survey of the research involving this component will now be presented.

Secondly, since studies relating to human learning, particularly those having to do with retention and forgetting, have a bearing on any project dealing with the effect of previous knowledge on subsequent behavior, a review of the relevant literature from research in the psychology of human learning and forgetting is in order.
I. The Measurement of Reading Comprehension

No attempt will be made to give consideration to reading tests in general or to any particular reading test's method of measuring all the components of reading ability and skill. A number of authors have compiled lists of standardized reading tests with annotations giving good descriptions of their nature and provisions. The publications of Buros (12), Gray (27), McCulleugh (38), Strang (49), and Traxler (52), are noteworthy in this respect. It is our purpose, however, to show how these standardized tests deal with the question of comprehension and to point out inadequacies in their method of handling this phase of the measurement of reading.

Traxler, in his monograph (52) gives a detailed report on the results of his survey of twenty-four different reading tests. In this publication a tabulation is made of the various kinds of reading ability which these tests claim to measure. Among the other factors which the tests purported to be measuring, 14 of the 24 provided for the measurement of paragraph comprehension and five evaluate story comprehension. Other factors which might be considered closely related to comprehension and which were supposed to be measured by the tests were: central thought or main idea—evaluated by six of the 24; sentence meaning—claimed to be measured by six of the tests; and interpretation of meaning—by three.
Nowhere in this study by Traxler (52) or in any other survey where tests are listed and described, such as Buros' Mental Measurement Yearbooks (9), which lists all the commercially available reading tests published between 1938 and 1951, is there any indication of efforts to measure previous knowledge and its effects upon comprehension. A search through Psychological Abstracts for the past three years gives no indication of any attempt to evaluate this important background factor.

Studies have repeatedly indicated that the factor of comprehension in some form or another is essential to reading ability and in almost all cases care has been taken that it has been included for evaluation.

South (47) in his Index to Periodical Literature on Testing, 1921-36, lists nine references which dealt with comprehension and its evaluation during that period. None of these makes any reference to previous knowledge as a factor in comprehension or makes any attempt to evaluate it.

The study of Robinson and Hall (31) previously referred to in Chapter 1 summarizes the results of several studies and announces the isolation by factorial analysis of an "attitude of comprehension accuracy" as one of five essential components of reading ability.
Gans (23) investigation of critical reading comprehension in the intermediate grades, shows that there has been a very definite awareness of the importance of comprehension and even some concern for different classes or levels of comprehension. Her study indicates that the tests of that period were stressing the concept of "reading to comprehend and believe ideas," but neglecting the deeper aspects of comprehension involving the interpretation and application of materials read.

Langsam (37), along with the identification of other factors, tentatively identifies one as that of "seeing relationships." He concludes this after administering eight standardized tests (six on reading and two on intelligence) to 100 freshmen women at Hunter College and applying the factor analysis technique to the results. This "capacity to see relationships" came nearer than any of his other factors to being the same as the reading comprehension used in the present study.

Pankaskie (40), after running a factor analysis of eleven variables derived from three tests—The Iowa English Training Examination, The Iowa Mathematics Aptitude Test, and The Iowa Silent Reading Test—gave tentative identification to three factors which he believed to be essential to reading. These factors were speed of comprehension, vocabulary, and ability to
find answers to questions.

Davis (18), utilising the profile of the Cooperative Reading Comprehension Test, Form Q, and analyzing results with a factorial technique, obtained two new factors which he claimed were operative in reading. He called these "word knowledge" and "reasoning." The first would seem to have something in common with what we refer to as previous knowledge and the second would probably have a fairly close identification with comprehension. In a later study Davis points out that word knowledge accounted for much of the variance found in reading comprehension.

Two studies, one by Spitser (48) and another by Sherman (45) direct efforts particularly toward the evaluation of delayed comprehension. In this respect they relate to one phase of the present study. These two studies are of special import in that they recognize delayed comprehension as another measurable factor relating to reading ability. We will give more particular attention to them later on. It is sufficient here to note that both these studies, although they are concerned with the comprehension aspects of reading, fail to give any consideration to previous knowledge and its possible effects upon immediate ratings in comprehension.

It is evident, then, that many investigators have concerned themselves with comprehension in its various forms and have attempted
to get an objective measurement of this factor as it relates to reading ability. It is also evident that no investigator, so far as has been found, has noted the possible effects of previous knowledge on the capacity to comprehend, nor has anyone made any report of attempts to measure this effect.

II. Relevant Research from the Psychology of Human Learning and Forgetting

Since the literature in this broad field of the psychology of human learning and forgetting has been accumulating for many years and has reached voluminous proportions it would be irrelevant and impossible to attempt to cover all of it. It is appropriate, however, to point out several studies and findings in this area which have some definite and important bearing on the present problem and its treatment. For instance, no reference will be made to the traditional studies of human learning and forgetting which involve the use of non-sense syllables and other non-verbal materials which are so different from the meaningful reading passages used in typical college reading tests. Likewise, since we are concerned only with the measurement of reading comprehension in college students, only those studies dealing with this type of subject will be considered relevant.
Even though the use of non-sense syllables is in effect a way of controlling the factor of previous knowledge, it also eliminates meaning, an important variable which we must retain.

Regarding comprehension and previous knowledge, English (21) states that understanding is important to the learning process and is a prerequisite to learning. He continues:

There is warrant for making an even stronger statement, namely—that unless material is understood it is not learned at all, hence not retained. Each individual learner 'learns' only that which has meaning for him, and it is probable that he retains also only that which continues to have meaning for him. The statement highlights the individual of the learning process. It is the meaning for the individual which is prerequisite to learning, and that depends largely on his stage of development and his previous experiences.

All the studies and writings relating to the importance of "readiness" to learn, and to the importance of "previously solved" problems to the solving of new problems, show the awareness of investigators to the effects which previous experience, preparation, and set are likely to have on the learning and reactions of the individual in new situations.

Washburne (59) defines three kinds of readiness which are of significance in learning situations. One of these seems to refer to the type of experiential background with which our study
is concerned. He lists "physiological readiness," "readiness in mental development," and "readiness in experiential background" as essential to learning.

It can be said that comprehension will depend upon all three of these factors and there seems to be little necessity for pointing out the similarity between Washburne's "readiness in experiential background" and our "background of previous knowledge."

Research which relates to reading readiness is also to be found in considerable abundance. Harrison (33) gives a summary of research studies and experts' opinions on the kinds of experiential background having an influence on a growing "readiness to read." She covers the field up to 1936. Since that time there has been an increasing concern for evaluating "readiness" and for preparing the child before he is taught reading. The same attitude is taken for all the areas of academic training at the elementary level. Buros lists nine tests of reading readiness for the period 1940-47, two of which appear for the first time. For the 1947-51 period he lists seven tests for reading readiness, four of which are new. (11, 12)
Another possibility which has been pointed out by workers in the field of learning is that of detrimental effects arising out of an unfavorable experiential background. In other words previous knowledge might have an inhibiting influence on learning and might actually interfere with the process of comprehension.

The permanency with which learned materials are retained is generally considered to be an indication of how completely the content was actually mastered at the time of reading or hearing. This, according to the principle stated by English might times become a test of how much of the material was actually comprehended. It is on the basis of this assumption that a number of investigators have concerned themselves with delayed comprehension.

Dietze and Jones (19) attempted to determine the range and average extent of immediate and delayed factual materials for which a group of 2,789 pupils in grades 7 through 12 showed memory, after reading a short article a single time. These investigators computed the percent remembered, or that which actually "got across" in the one-time reading, and obtained the following scores: immediate memory, 90%; memory after an interval of one day, 76%; memory after a delay of fourteen days, 59%; after thirty days, 51.7%; and after one hundred days, 47.6%. The material in the short article was described as "interesting and highly factual." Memory was tested by multiple choice questions of the five-choice type.
Spitzer (48) had 3,605 sixth grade pupils respond to two tests of comprehension after reading two articles of about 600 words each. The results on one of the tests were used as a means of dividing his total group into eight experimental groups while the results from the second test were used for checking retention. By dividing his main group into eight equated sub-groups he was able to administer the second article and test to different groups at varying intervals from that immediately after the passage had been read to one involving a 63-day delay. He found that the groups which were tested immediately, and twenty-four hours after the reading forgot only 2% (remembered 98%) of the facts contained in the reading passage. The group which was not tested immediately, but only after the twenty-four hour delay following the reading, forgot 44% (remembered 56%) of the material tested for. This indicates a marked loss of memory for the materials after the one-day delay. But after a one-week delay, with no intervening testing, the loss was 67% (memory 33%). After a three-week interval the loss had risen to 83% (17% memory).

Other studies have been more definitely related to the present study in that they involved college students. On the basis of comprehension test scores, Warman (58) divided a total of 97 university students into four equated groups. They were then tested with multiple-choice and true-false questions at various
time intervals after the reading of a passage. Group A was tested immediately after the reading; group B's test was delayed for one day; group C's for seven days; and group D's for fourteen days. It was found that the mean score earned by each group on the comprehension tests administered at the respective intervals, yielded a typical curve of forgetting. The rapid loss of memory for materials, which was evident immediately after the completion of the reading, gradually slowed down as the time interval increased. The resulting score were significantly different by statistical check.

Sherman (145) in an investigation of delayed comprehension had 655 freshmen in university English classes read prose and non-prose materials and then answer questions over the Materials read. By means of two orders of presentation, he administered two forms of the comprehension test to two different groups, one containing 345 and the other 310 students. In this manner he obtained immediate comprehension ratings for each group on different but equivalent sets of questions. Delayed comprehension ratings were based on the opposite sets of questions. The delayed responses were made twenty-four hours after the reading of the materials.

The results of this study warranted the conclusion that delayed comprehension is a relatively independent aspect of reading and that the effect of delay is significant if measured as early
as twenty-four hours after the reading exercise.

Graham (26) in a study involving 163 students, mainly freshmen and sophomores, had the subjects read materials silently with the expectation of having to answer a factual quiz the following day. She used tests which had been constructed by Robinson and Hall (43) and which contained materials of equivalent difficulty. The first test was used to measure immediate comprehension, while the second checked delayed comprehension after an interval of twenty-four hours. The tests were alternated throughout the groups to gain a random sample. She found that with this meaningful material there was a significant loss of memory for facts over the period of one day.

In a study which attempted to evaluate reading comprehension by the use of two different types of test materials, English, Walborn, and Killian (22) had college students read a difficult prose passage and then respond to questions involving materials of a verbatim and non-verbatim sort. The results indicated that repetition of the reading assignment increased the retention for the verbatim but not the non-verbatim materials. It was also found that recognition for the two types of materials was better after an interval of twenty-four hours than it was immediately after the reading. The verbatim items, however, showed a typical forgetting curve thereafter, whereas the non-verbatim items showed
loss over periods extending up to seventy days. In some cases, over the longer delay period, there was even a statistically significant increase in recognition for the non-verbatim items.

From the studies which have been cited above, several conclusions regarding reading comprehension and the effect of previous knowledge upon immediate comprehension and delayed comprehension seem to be justified.

In the first place, comprehension is given one of the central positions relating to the components of reading ability and skill. This aspect of the reading process has been evaluated in many ways and under a wide variety of circumstances since the very beginning of standardized reading tests. Comprehension has been identified as a factor which plays a very prominent and essential role in learning and forgetting.

Secondly, the permanency of learning depends upon the depth and completeness of the comprehension for the materials to be learned. This gives delayed comprehension and its measurement a very important position in any study concerned with learning capacity and the mastery of assigned materials.

Thirdly, experiential background has definitely been shown to have a direct and important bearing upon the ability to learn new facts and skills. This is particularly evident where the need for determining the child's readiness for training in school subjects
is recognised. The increased activity in the construction of tests to evaluate readiness for school and for the materials ordinarily encountered in the academic setting gives evidence of an increasing recognition of this need.

In the fourth place, it must be noted that an accurate evaluation of immediate comprehension for assigned reading materials, and thus the amount of learning taking place during the reading process, must of necessity take into account the previous knowledge and experiential background which is peculiar to each reader.

Finally, it has been shown that except in those rare instances where delayed comprehension has been measured by the use of non-standardised tests of reading, or by the unique use of two equated standardised tests, no attempt has been made to measure the effect of previous knowledge upon comprehension. None of the commercially available tests which are intended for the measurement of reading comprehension take this factor into account.

As has been pointed out in Chapter 1, it seems incredible that so important an aspect of reading and learning has gone so long without some attempt being made to evaluate it objectively and experimentally. The present study is designed as an attempt to correct this oversight.
CHAPTER 3

EXPERIMENTAL METHOD

Briefly, the main objective of the study is the accurate measurement of gains in comprehension made during the reading of assigned, course-like materials. An equally important aim of the study is the demonstration of how such gains in comprehension are related to the other aspects of the reading process, to scholastic achievement, and to rating in intelligence.

The understanding and knowledge which college students possess for selected reading materials and which they reveal on quiz items answered prior to the reading of a prose passage, will be compared to the comprehension shown by the same students on equivalent quiz items answered subsequent to the reading of the passage. The relationship of these two comprehension-test scores will then be given consideration in regard to the student's ratings in reading rate, story comprehension, paragraph comprehension, vocabulary, academic grades, and intelligence.

The plan of Chapter three is as follows: First in order will be a description of the reading selection used. The details of selecting the passage, preparing the equated quiz items, trying out the quizzes, and handling the quiz scores will be discussed.
Next will be the precise description of the population used as subjects in the study. An effort will also be made to show how the group was segmented into three sub-groups for the alternate administration of three forms of the comprehension test.

Third in order is the discussion of how the tests were scored and the scores tabulated. How the other measures of student capacity were obtained and tabulated will also be considered.

Finally, a statement will be made of each question which the study aims to answer, along with a review of the statistical procedures applied to the data in order to provide objective and testable answers to the questions.

I. Description of the Reading Passage

Since it was not possible to find standardised materials which would meet the purpose of the present investigation, it was necessary to select materials, work them up into satisfactory form for a college assignment, and prepare comprehension questions over the content.

The requirements which seemed essential to the obtaining of an adequate reading passage might be stated as follows: The selection had to be similar to textbook materials, attractively written, and of sufficient range of difficulty to suit the reading capacities of the general run of college students.
The reading of the passage and the answering of the quiz items had to be completed within the limits of one fifty-minute class period. Therefore, the selection had to be short enough to permit its completion by the slowest college-level reader in thirty minutes. This would leave twenty minutes for reading directions and answering quiz questions.

On the other hand, there was a need for a passage of sufficient length and difficulty to provide for the presentation of a number and variety of ideas, facts, and meanings. These would be used in the test questions for the three equivalent quizzes. Each quiz had to be long enough and of sufficient comprehensiveness to allow for the reliable and valid checking of comprehension both before and after the reading of the passage.

A. Description of the Original Passage and Its Try-out

Several types of material were given consideration before the final choice of the reading passage for the present study was made. Articles of a science or semi-scientific type were preferred because of the more objective nature of their offerings. Most of these, however, did not seem to have the element of general interest and appeal which would hold the attention of the college-level reader.

Eventually, an article on plant life was found which seemed to have the attention-getting and attention-holding elements, as
well as the factual and comprehensive characteristics we were seeking.

The article appeared in *The Book of Wild Flowers*, published by The National Geographic Society in 1935. Parts of the article entitled "Exploring the Mysteries of Plant Life" (46) by Dr. William J. Showalter, had appeared in the monthly issue of *The National Geographic Magazine* in 1919, and again in 1921.

The possibility of any of the prospective subjects or our study having had access to this material prior to their reading it in our study was practically nil. Even if they had read it before, however, our tests for previous knowledge in the field would take care of that.

Two sections of this article, comprising 2600 words of narrative and descriptive material, were chosen. They dealt with the physical make-up and physiological functioning of the plants which we commonly see about us. Much analogical material was included.

This passage was prepared in typewritten form after copyright permission had been obtained from the publishers. Appropriate headings and sub-headings were used throughout. Where the original headings were considered inappropriate for college level usage, more appropriated ones were substituted.
This material was submitted to the Chairman of the Department of Biology at Bowling Green State University for the inspection and approval of his department regarding the accuracy and authenticity of the botanical facts involved. After one or two changes had been made at his suggestion, the passage was prepared in mimeographed, booklet form for use in the first pilot study.

Two quizzes with thirty items in each were prepared, using the facts, concepts and meanings contained in the passage, or conclusions and interpretations which might reasonably be drawn from them. These items were prepared by the author and by several members of the staff of the Department of Psychology at Bowling Green State University. Four-choice, multiple-choice questions were used exclusively. They were of the type which required materials to be drawn from at least three levels of comprehension for their answering and they were drawn from materials distributed uniformly throughout the reading passage.

The passage with selections from the article "Exploring the Mysteries of Plant Life" and the two thirty-item quizzes were administered to 112 students, mainly sophomores and juniors, in courses in the Psychology of Adolescence, in May 1953. The procedure for administration was as follows:
First, the four class-groups were given the letter designations of A, B, C, and D. The A and C groups were given Form I of the Quis, and the B and D groups were given Form II prior to the reading of the passage.

Second, all the groups read the entire reading selection. The reading time in minutes was recorded on the blackboard by the examiner and the subjects were instructed to read the passage as they ordinarily read their course assignments. The directions told the subjects to note the reading time which was posted on the board at the moment they completed the passage, to mark the time in the space provided for such on the test booklet, and then to start answering questions.

Third, the questions which were answered immediately after reading the passage were the opposites of the one answered by a particular group prior to the reading of the passage. Groups A and C answered Form II, and groups B and D responded to Form I. The three phases of the preliminary study were completed in the one class period.

When the results were evaluated, several deficiencies in the passage and the quizzes were evident. A number of the quiz items needed to be revised or eliminated. They were either too easy, too difficult, or not clearly stated. The standard used for

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1 Copies of the test booklet and quizzes are included in the appendix, p. 156.
judging their quality was an adaptation of one suggested by Guilford (30). If better than 70 percent of the subjects chose the right response, the item was considered to be too easy; if fewer than 30 percent answered the item correctly, it was considered to be too difficult.

Furthermore, if three quizzes were to be constructed on the materials of the passage, they would not be long enough for the adequate checking of comprehension. In short, the passage did not provide sufficient materials for an adequate number of acceptable quiz items.

There were several reasons, however, which supported retaining the original passage. On the basis of group discussions held with the students immediately after they had completed the project, it was learned that most of them had a favorable attitude toward the content materials. In addition to this, the item analysis indicated that a respectable number of the quiz items were acceptable or could be made acceptable by revision. So, the wise thing seemed to be to retain the original passage, revise as many quiz items as possible, and add a second part containing a more technical type of related material.

The passage could be increased in length and still be held within the limits of a fifty-minute period. This was so, because the plan of the main study called for the administration of the
pretest, the reading passage and immediate quiz, and the delayed quiz in three different class periods.

B. Revision of the Original Passage and the Quizzes

In order to meet any criticism that the original passage was not sufficiently high in scientific and objective quality, and to provide materials for creating new quiz items, a second part was added. This included a technical discussion of soil elements and plant nutrition. The length was 1550 words and the terminology suited the vocabulary used in the original passage. The source of this new part was the little instruction booklet which accompanies the Sudbury Laboratories' soil testing kit (51). The original passage was headed Part I and the new section Part II. The entire selection now contained 4200 words.

Those quiz items which were adequate or salvageable from the original quizzes were combined with new ones involving the materials of Part II. Finally, a pool of 140 quiz items was obtained. These were divided into two seventy-item quizzes. As nearly as possible, on the basis of the item analysis and subjective judgment, the questions were paired as to difficulty. One item of each pair was allotted to each quiz. In this way, the two quizzes were made more nearly equivalent than they might otherwise have been.
As in the case of the original quizzes, only multiple-choice items of the four-response type were used. An effort was made to adhere to all the principles of adequate test construction.

II. Trial Run of the Revised Passage and the Two Seventy-Item Quizzes

The revised reading passage and the revised quizzes were prepared in mimeograph form. The passage amounted to nine pages of single-spaced typewritten material. Each quiz booklet comprised seven legal-sized typewritten pages.

On the title page or face sheet of the test booklets used for the pretest, provision was made for checking several questions relating to the student's background and training in the fields of Biology, Botany, Agriculture, and Horticulture. This was done to afford a quick picture of the subject's general background for the facts and ideas presented in the reading passage.

The title page of the question booklet for the immediate quiz made provision for the student's indicating his attitude of like or dislike for the reading materials. He was asked to check his preference for Part I or Part II and to indicate if he considered the whole passage interesting or boring. Each was

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Copies of the revised reading passage and the final three equivalent comprehension quizzes are included in the appendix which starts on page 109.
invited to make any additional comment he wished to make.

A. Administration of the Revised Instrument

In November, 1953, one hundred and seven students, the total enrollment of four classes in general psychology, were given the comprehension tests. Groups A and C responded to Form I and Groups B and D took Form II as a pretest of knowledge and comprehension.

Four days later, the same groups were asked to read the selection, "Exploring The Mysteries of Plant Life." Immediately after the reading the entire selection they answered questions over the content. At this time, Groups A and C took Form II and Groups B and D took Form I as an immediate comprehension quiz.

Since six members of the groups missed either the first or second quiz session, the item analysis was run on the answers of the 101 students having scores on both the quizzes.

B. Results of the Second Pilot Study

The answers to the survey of background and training in the field of knowledge involved in the passage revealed that 88, or
about 81 percent of the 107 individuals, had studied biology in high school. Sixty-two, or 58 percent, had completed or were then enrolled in general biology in college. Twenty-two, or 18.5 percent, indicated they had no special background for the field. Nine of the 107, or 8 percent, were majoring in the field of biology in college.

As in the first pilot study, the reading time was recorded on the blackboard in minutes. Upon completing the reading of the entire passage, each student noted his reading time (the time posted on the board at the moment) and recorded it in a space provided on the answer booklet.

The reading time for the revised selection ranged from 8 to 35 minutes. The average reading time was 23.36 minutes. The reading of directions, and the reading and answering of the quiz questions required additional time. All the subjects completed the project in the fifty-minute class period. It was obvious that the passage would not be too long for the main study since the quizzes at that time would have fewer items.

The average error-score for the group taking Form I as a pretest was 40.04. The mean error-score for those individuals taking Form II as the pretest was 44.51. For the group taking Form I as an immediate test, the average error-score was 31.35.
An average error-score of 29.42 was obtained for those taking Form II as the immediate test. This could be taken to mean that the combined groups A and C had slightly better capacity for and comprehension of the materials than the combined groups B and D. Again, it is possible that the items in Form II tended to be less well known generally but were more obviously answered in the text than those questions in Form I. However, the final revision of the tests tended to equate these differences.

The range of the error-scores on the pretests (Forms I and II) was 29 to 57 out of a possible 70. The mean was 42.3. For the immediate tests (Forms I and II) the range was 12 to 49, with the mean error-score of 30.10. These figures indicated that the difference between the ratings of comprehension on the tests given at the two times would be sufficient for our purposes of measuring gains in knowledge from reading.

C. Preparation of the Three Quizzes for the Main Study

The discriminating power of each item was determined by comparing the response choices of the top-half students (those making lower error scores) with the response choices of the students standing in the lower-half of the total group. The number of low-error-score students who chose the correct response was correlated with the number of high-error-score students who selected the correct choice. By the use of a chart suggested by
Bean (4) the item-test correlation coefficient (a tetrachoric r) was computed for each quiz item.

On this basis, any item showing a tetrachoric r, or an item-test correlation coefficient below .20 was eliminated. Bean indicates that correlations which drop to .15 or .10, even though they are positive, make the items questionable. He adds that high tetrachoric correlations, such as .85 or better, are rarely found. Of the 120 items included in the two quizzes, ninety-seven met the requirement of a tetrachoric correlation coefficient of .20 or better (See Table I). The other forty-three items were discarded.

Since one feature of the quizzes for the main study was to provide for the inclusion of a number of identical items on each of them, enough of the discriminating items were repeated to bring the total number of test items to 120. Thus, there were sufficient items for three forty-item quizzes. These were to be used in measuring the previous knowledge which the subjects possessed for the content materials of the passage, to evaluate their immediate comprehension, and their delayed comprehension.

In order to make the tests as nearly equivalent as possible, the questions were drawn from the pool in triplets. All the items of a triplet had the same or nearly the same tetrachoric correlation coefficient. Each of the three quizzes received one of the items of each triplet. Table I shows how the items were arranged in triplets for selection. This table also identifies the repeat items.
TABLE I

ARRANGEMENT OF THE 120 QUIZ ITEMS IN TRIPLETS ACCORDING TO THEIR TETRACHORIC CORRELATION COEFFICIENT AND COMPREHENSION LEVEL FOR ASSIGNMENT TO THE THREE FORMS OF THE QUIZ

** F - Factual
P - Paraphrase
A - Application

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Another feature which was arranged for in the construction of the quizzes was the equal distribution of items demanding various levels of comprehension for answering with the correct response. For this, each item was rated on a three-point scale according to the following criteria:

Comprehension level F (Factual)—those items which involved direct reference to the materials of the text, and which could be answered by using the exact word or wording of the text. An item illustrating this type, relating to materials on page 1, paragraph 1, of the passage is as follows:

"Compared to the amount used by man in all his activities and operations, plant life develops a super-abundance of: (1) minerals; (2) energy; (3) nitrogen; (4) carbon dioxide."

Comprehension level P (Paraphrase)—those items which involve paraphrasing of the text materials, and which could be answered only by indirect reference to the words of the text but whose relationship to the text materials is fairly obvious. An item of this type, relating to materials in paragraph 2, page 1, of the passage is as follows:

"Of all the raw materials which are available to man for making clothes, the percentage having its basic source in plant life is: (1) 90; (2) 50; (3) 100; (4) 60."

Comprehension level A (Application)—those items which required application or interpretation of the materials presented in the text, and conclusions which could reasonably be drawn from the ideas and meanings presented in the text. An item of this type, relating to the text materials in paragraph 5, page 5, of the passage is as follows:
"The operation of the slender root of the seedling most nearly resembles the reverse operation of a miniature (1) hose nozzle; (2) spigot; (3) plastic tube sprinkler; (4) canvas hose soaker."

Thus, the materials prepared for use in the main study include the following: First, the reading passage, 4200 words in length, comprised of Part I, dealing with a description and discussion of common plants, their characteristics and physiology, and Part II, dealing with the soil and the elements which are afforded the plant for food. Second, three equivalent quizzes over the materials presented in the reading passage, and providing for the evaluation of three levels of reading comprehension. And third, instructions and directions for the administration of the test.

III. The Population Used in the Main Study

The face sheets of each of the three quizzes made provision for the quick checking of certain informational items regarding the subjects. Other details on the composition of the groups submitting to the study afforded some idea as to the potential generalization possible from the results.

The students were drawn from courses in the Department of Psychology at Bowling Green State University. Four sections of
general psychology, three of child psychology, one section of social psychology and one of the psychology of adjustment were used. These nine groups provided a total of 247 subjects.

Due to such factors as absence from one or more of the quiz sessions, lack of intelligence test score, and lack of diagnostic reading test scores, 71 of the initial subjects had to be eliminated. There remained, then a total of 176 individuals whose scores and data were complete. Since these were the students whose scores were used in the main analysis and discussion, the following information about them is pertinent:

**TABLE II**

THE COLLEGE ENROLLMENT AND SEX OF THE SUBJECTS

<table>
<thead>
<tr>
<th></th>
<th>Business Edm.</th>
<th>Education</th>
<th>Liberal Arts</th>
<th>Total</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Woman</td>
<td>21</td>
<td>36</td>
<td>19</td>
<td>76</td>
<td>42</td>
</tr>
<tr>
<td>Men</td>
<td>11</td>
<td>47</td>
<td>42</td>
<td>100</td>
<td>58</td>
</tr>
<tr>
<td>Totals</td>
<td>32</td>
<td>83</td>
<td>61</td>
<td>176</td>
<td>100</td>
</tr>
<tr>
<td>Percent</td>
<td>18.2</td>
<td>47.2</td>
<td>34.9</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>
From these breakdowns it is seen that 58 percent of the retained group was made up of women. Also, the larger portion of the group was drawn from the sophomore and junior classes. These latter two groups comprised 65.3 percent of the total group. In addition to this it is seen that the College of Education contributed the larger part of the 176 subjects. Eighty-three, or 47 percent of the individuals, said they were enrolled in the College of Education. The College of Liberal Arts contributed 61 of the subjects, which is 34.65 percent of the total, and the College of Business Administration students made up 18 percent of the total.

It is not to be assumed that these groups are necessarily representative of any of these larger divisions of the university. We do want to point out, however, that the total group comprised a fair cross-section of the total university population, with the College of Education and the sophomore and junior segments being in the majority.

### TABLE III

**THE COMPOSITION OF THE GROUP OF SUBJECTS AS TO SEX, COLLEGE ENROLLMENT, AND COLLEGE CLASS**

<table>
<thead>
<tr>
<th>Class</th>
<th>Business Administration</th>
<th>Education</th>
<th>Liberal Arts</th>
<th>Totals</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>F</td>
<td>M</td>
<td>F</td>
<td>M</td>
</tr>
<tr>
<td>Freshman</td>
<td>8</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Sophomore</td>
<td>7</td>
<td>4</td>
<td>12</td>
<td>20</td>
<td>6</td>
</tr>
<tr>
<td>Junior</td>
<td>5</td>
<td>2</td>
<td>17</td>
<td>18</td>
<td>3</td>
</tr>
<tr>
<td>Senior</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>7</td>
<td>4</td>
</tr>
</tbody>
</table>
Although the composition of the original group shifted somewhat with the elimination of the seventy-one subjects due to incomplete data, the change was probably not great enough to cause any great increase in the distortion of the results obtained for the 176 retained subjects as compared with what might have been obtained for the total 247. As will be seen by the figures presented in Table IV, the proportion of men and women shifted the most. After the shift, however, we find that the retained group is probably about as nearly like the general university population as the original group.

### Table IV

<table>
<thead>
<tr>
<th></th>
<th>Study Groups</th>
<th>General University</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Original (N 247)</td>
<td>Retained (N 176)</td>
</tr>
<tr>
<td>Women</td>
<td>53 (42)</td>
<td>42 (42)</td>
</tr>
<tr>
<td>Men</td>
<td>47 (58)</td>
<td>58 (58)</td>
</tr>
<tr>
<td>Freshmen</td>
<td>16 (19)</td>
<td>19 (19)</td>
</tr>
<tr>
<td>Sophomores</td>
<td>35 (34)</td>
<td>34 (34)</td>
</tr>
<tr>
<td>Juniors</td>
<td>33 (31)</td>
<td>31 (31)</td>
</tr>
<tr>
<td>Seniors</td>
<td>14 (16)</td>
<td>16 (16)</td>
</tr>
</tbody>
</table>

Actually, the eliminations made the proportion of class composition stand in a slightly better relationship to the general
university population than had the original group. Although the disproportionate picture did not change very much, the overly-small freshmen and senior groups increased in size, while the over-sized sophomore and junior groups reduced slightly. These changes placed all four of these groups into closer relationship to the proportion of these groups in the general university population.

IV. Procedure in Completing the Main Study

There is probably little necessity for pointing out that the method by which a measuring instrument is applied, the way in which the responses are scored, and the procedure for handling results are all very important aspects of any testing program.

Once the test had been constructed, with provisions made for the different ordinary and special features, its administration to the college students, the scoring of responses, and the compiling of results became the next important steps. Errors or oversights occurring in any of these operations might be detrimental to the obtaining of clear and reliable answers to the problem posed by the study.

Consideration will now be given to the details of obtaining the students' responses, to the scoring of the responses, and to the tabulating of the scores.
A. The Administration of the Test and the Scoring of Responses

As might be inferred from the previous descriptions of the instrument used in the research, there were three major phases of administration. Since the three equivalent quizzes over the content of the reading selection were to be given at three different sessions, six different sequences of administration were possible.

In order to be certain that these six orders of presentation would be used in a uniform manner and have equivalent effects throughout the results, the design of administration was as follows:

A different sequence was used for each of the first six of the nine groups tested. Each of the remaining three groups was divided into two equal groups. This resulted in six groups, each of which was subjected to a different sequence.

Referring to Table V, on the following page, we learn that Section 8G and the top half of Section 11A were given Sequence ACB, whereas Section 8C and the bottom half of Section 11A had Sequence BAC. The remaining four sequences were applied to the remaining six sections in a similar fashion.
TABLE V

THE DESIGN USED IN ADMINISTERING THE THREE FORMS OF THE COMPREHENSION TEST TO THE NINE SECTIONS

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Section of Psychology</th>
<th>N</th>
<th>Type of Test, Form and Day Given</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Prettest</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Friday</td>
</tr>
<tr>
<td>I</td>
<td>Introductory (80)*</td>
<td>21</td>
<td>A</td>
</tr>
<tr>
<td>II</td>
<td>Child (8C)</td>
<td>22</td>
<td>B</td>
</tr>
<tr>
<td>III</td>
<td>Introductory (90)</td>
<td>23</td>
<td>C</td>
</tr>
<tr>
<td>IV</td>
<td>Adjustment (9W)</td>
<td>21</td>
<td>A</td>
</tr>
<tr>
<td>V</td>
<td>Child (10C)</td>
<td>17</td>
<td>B</td>
</tr>
<tr>
<td>VI</td>
<td>Introductory (11W)</td>
<td>19</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>Child (11A)</td>
<td>14</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Introductory (11B)</td>
<td>9</td>
<td>B</td>
</tr>
<tr>
<td>III</td>
<td>(12F)</td>
<td>11</td>
<td>C</td>
</tr>
<tr>
<td>IV</td>
<td>Social (2C)</td>
<td>11</td>
<td>A</td>
</tr>
<tr>
<td>V</td>
<td>(2C)</td>
<td>9</td>
<td>B</td>
</tr>
<tr>
<td>VI</td>
<td>(2C)</td>
<td>9</td>
<td>C</td>
</tr>
</tbody>
</table>

* The number indicates the time of meeting of the class. The letter is the first letter in the name of the instructor.
<table>
<thead>
<tr>
<th>Sequence</th>
<th>Sections Involved</th>
<th>N</th>
<th>Total N</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Introductory 8G</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>(ACB)</td>
<td>Child 11A</td>
<td>4</td>
<td>25</td>
</tr>
<tr>
<td>II</td>
<td>Child 8C</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>(BAC)</td>
<td>Child 11A</td>
<td>9</td>
<td>31</td>
</tr>
<tr>
<td>III</td>
<td>Introductory 9G</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>(CBA)</td>
<td>Introductory 12F</td>
<td>11</td>
<td>34</td>
</tr>
<tr>
<td>IV</td>
<td>Adjustment 9W</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>(ABC)</td>
<td>Introductory 12F</td>
<td>11</td>
<td>32</td>
</tr>
<tr>
<td>V</td>
<td>Child 10C</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>(BCA)</td>
<td>Social 2C</td>
<td>9</td>
<td>26</td>
</tr>
<tr>
<td>VI</td>
<td>Introductory 11W</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>(CAB)</td>
<td>Social 2C</td>
<td>9</td>
<td>28</td>
</tr>
</tbody>
</table>
To provide some idea of the number of students submitting to each sequence and to give some indication of the composition of the groups, a summary is presented in Table VI.

From Table VI it is seen that the range of N's for the six sequences runs from 25 to 34. The mean falls at 29. This table also indicates that of the twenty-five subjects who were given Sequence I (ACB), Form A of the quiz was taken as the pretest, Form C was taken as the immediate test, and Form B was taken as the delayed test. Likewise, of the thirty-one students subjected to Sequence II (BAC), Form B of the quiz was given as the pretest, Form A was given as the immediate test, and Form C was given as the delayed test.

In this manner, any of the cross relational effects of taking one set of questions prior to responding to the other sets would be randomised or counter-balanced. The distribution of the application of the six sequences was also randomised in this way over the various groups including different proportions of freshmen, sophomores, juniors, and seniors.

With the use of this design for determining sequence, the nine course groups were subjected to the pretest on Friday. The following Monday, or exactly seventy-two hours later, the subjects read the reading selection and answered the questions of the immediate quiz. Forty-eight hours later, or on the following Wednesday, the delayed quiz was administered.
On this basis, with the elimination of those individuals having incomplete data, 176 college students submitted to the three quizzes and the reading selection.

In the same manner as in the pilot studies, the reading rate for each student over the entire 4200-word selection was determined and recorded in minutes.

Keys were then prepared and applied to the responses. The score was the number of wrong answers out of a possible forty on each quiz. Since the directions for taking the tests emphasized that all the questions should be attempted, non-responses were counted as wrong answers.

The scoring was carried out in a careful manner with a re-check made on approximately every tenth booklet. Since the keys were easily applied and the total errors were not large, with no correction for guessing, few if any errors in scoring resulted.

The error-scores thus obtained provided the means for getting three difference scores, i. e. the difference between the score on the pretest and that on the immediate test; the difference between the score on the immediate test and that on the delayed test; and the difference between the score on the pretest and that on the delayed test.

Sub-scores were obtained for the special feature items so that comparisons might be made of the repeat and non-repeat questions,
of the items involving factual and detail materials, those paraphrasing the text materials, and those requiring application of the materials presented in the text.

B. Tabulation of the Quiz Scores, Other Information and Ratings

The name of each subject, along with such identifying information as college enrollment, major field, college year, and subject number, were placed on the master sheets. Following these, the data from the plant-life selection and tests were listed.

Other, data such as scores on the Diagnostic Reading Test (13), The American Council on Education Psychological Examination (1), and the point hour averages, were obtained for each of the 176 subjects and recorded on the master sheets.

The scores on the Diagnostic Reading Test included the reading rate for the three-minute reading period, the story comprehension score, the paragraph-story comprehension score, the vocabulary score, total comprehension score, and the word-per-minute rate for the three-minute story reading period.

The scores on the ACE Psychological Examination included the raw scores on the Language or "L" sub-tests, the Quantitative or "Q" sub-tests, and the Total, or the score for all six of the sub-tests.
The Diagnostic Reading Test and the ACE Psychological Exam are administered to all entering students at Bowling Green University. These scores were available to the writer in the files at the University Education Clinic and the Admissions Office. In the cases where the scores were not in the files, the subjects were eliminated because of incomplete data, just as were those individuals who were not present for taking one of the quizzes.

A list of the names of the students included in the study was handed to the registrar of the university. He recorded the cumulative point hour average for each of the subjects. This rating on academic achievement included all school grades from the time the individual first entered the university to the end of the first semester of the 1953-54 school year.

The point hour averages for the freshmen were based on grades for one semester only, while those of the sophomores included grades for three semesters; the juniors five semesters, and the seniors seven semesters.

It is generally agreed that the first semester grades for freshmen are usually lower, on the average, than their grades in later semesters. This has frequently been explained as due to the beginning student's immediate concern over problems of adjusting to college life during this period. These problems tend to clear up after the first semester. With the experience, growth, and increased maturity gained in the ways of college life, later course
work tends to improve. It is also generally accepted that the FFA tends to become more stable and a more consistent measure of the student's course work as well as a better indicator of his academic capacity as he advances through the four college year levels. The FFA of the seniors, therefore will be more reliable than those of the freshmen, with the sophomore and junior averages falling between these two extremes.

C. The Reliability of the Scores Used in This Study

Comparison of the error scores for the odd and even items in the three comprehension quizzes for the plant life selection shows the tests are sufficiently reliable for the study. The reliability coefficients, after correction for length with the Spearman-Brown formula (24), stood within six points of each other as follows: Form A, .72; Form B, .68; Form C, .74.

The authors of the Diagnostic Reading Test indicate that the test is applicable from grades seven through the college freshmen year. Norms presented in the test manual (13) show that 883 freshmen in the College of Arts and Sciences at the University of Denver gave the following reliability coefficients: Story Comprehension—.71; Vocabulary—.65; Paragraph and Story Comprehension—.81; and Total Comprehension (all scores except rate)—.82.
The same manual presents norms from 476 freshmen in the College of Business Administration at the same University. This group gave the following reliability ratings: Story Comprehension—.76; Vocabulary—.83; Combined Story and Paragraph Comprehension—.79; and Total Comprehensions—.87.

From these figures we note that the reliability of the instrument for reading evaluation to which we make comparisons for our test results is quite adequate for research comparisons. Also, comparatively, the reliability of the comprehension quizzes on plant life are sufficiently consistent to provide a sound basis for predicting of future reading comprehension of similar materials.

The American Council on Education Psychological Examination has been used in many colleges and universities for a number of years and has held one of the leading positions as a freshman intelligence or academic aptitude test. In the present study only the Language sub-score and the Total score will be used.

D. Questions Which the Present Study Seeks to Answer

In general, the unknowns which the present research seeks to discover are presented in the question: "Can difference scores computed between comprehension-test ratings obtained before and after the reading of assigned materials, and the determination of the relationship of such difference scores to ratings on the
other components of reading ability, to academic achievement, and to scores on an intelligence test, add measurably to the understanding of the reading process?"

By breaking this general question down into a number of specific and particular questions which can be stated in the form of testable hypotheses, the following series of questions results:

a. The first three questions deal with determining if tests actually are sensitive to the effects of reading.

1. Does the mean comprehension score earned by college students in answering questions over the content materials of a reading passage prior to the reading of the passage differ significantly from the mean comprehension score earned by the same students in answering equivalent test questions immediately after reading the passage? Is the direction of the difference constant and predictable?

While the basic hypothesis involved here is that the average comprehension scores earned prior to the reading of the passage will be significantly less than the average comprehension scores earned immediately after reading the passage, this will be stated in the null form and the difference obtained will be tested for statistical significance by means of a "t" test (39).
2. Does the mean comprehension score earned by college students in answering questions over materials of a passage prior to the reading of the passage differ significantly from the mean comprehension scores earned by the same students in answering equivalent questions forty-eight hours after reading the passage? Is the direction of the difference constant and predictable?

Here the basic hypothesis is that the comprehension scores earned prior to the reading of the passage will be significantly less than those earned forty-eight hours after reading the passage. Again, the issue will be stated in the null form and the significance of the difference will be tested by means of a "t" test.

3. Does the mean comprehension score earned by college students in answering questions over the content materials of a passage immediately after the reading of the passage differ significantly from the mean comprehension score earned by the same students in answering equivalent questions forty-eight hours after the reading of the passage? Is the direction of the difference constant and predictable?

The basic hypothesis for this third question is that the mean comprehension scores earned forty-eight hours after reading the passage will be significantly less than the mean comprehension scores earned immediately after reading the passage. This should
be readily recognized as the usual measure of foregetting. The statistical significance of the difference will be tested by "t."

b. The next task is to determine which measure of comprehension is most significant in academic work. Two questions with several subsidiary items are involved here.

4. Which measure of comprehension, including the usual immediate score, shows the highest relationship to grade point average in college? The college GPA will be correlated with the following scores to determine which measure has the highest significant relationship to academic standing:

(a) the pre-test comprehension score
(b) the immediate test comprehension score
(c) the delayed test comprehension score
(d) the pre-immediate tests difference score
(e) the pre-delayed tests difference score
(f) the immediate-delayed tests difference score

5. What factors are related to gains in comprehension as indicated by the "best" measure resulting from question four? The results on the "best" test in question four will be correlated with other measures which are commonly used in evaluating the components of reading ability and of intelligence. If the "best" measure is not the immediate comprehension score (the usual measure of reading comprehension gains) then this immediate test score will be included also for comparative purposes. The reading
measures to which this, or these, scores will be correlated are:

(a) vocabulary rating on the diagnostic reading test
(b) reading rate (words-per-minute) on the diagnostic test
(c) reading rate (words-per-minute) on plant-life
(d) story comprehension on the diagnostic test
(e) paragraph and story comprehension on the diagnostic test

The intelligence test scores to which this, or these, best measures of comprehension will be compared are:

(a) the language sub-score on the psychological exam
(b) the total score on the psychological exam

It is important to note that while in question four we are interested in the test which correlates highest with grades, here in question five we are generally interested in finding measures which although they have fair to good relationship to grades, correlate low with other reading measures. That is, it will be valuable to find scores which measure different aspects of reading performance.

c. Another crucial question which arises, because of the importance of being able to predict whether an entering student will get along well or have difficulty in his college course work, is as follows:
6. To what extent does the above "best measure of comprehension gain" and the usual comprehension measure (the immediate test score) add to the predictive value of the intelligence test rating in forecasting college achievement? In this instance the following multiple correlations will be computed, using the formula suggested by Guilford: (29).

(a) The total score on the intelligence test and the immediate test score and their relationship to the grade point average.

(b) The total score on the intelligence test and the pre-immediate difference score and their relationship to the point hour average.

d. Some secondary issues will also be investigated as planned for in the inclusion of the two special features in the quizzes. These have to do with the nine questions which were repeated on each form of the test, and with items relating to the three levels of comprehensive material, namely, factual, paraphrased, and application. A statement of the question dealing with these issues is as follows:
7. What effect did the inclusion of different types of items in the three quizzes have upon the measure of comprehension gain?

(a) Did the fact that an item appeared on the pretest and again on the immediate and the delayed tests cause it to be answered correctly more often than those items which did not repeat?

(b) Was there a significant difference between the mean number of errors obtained on the factual items as compared to the mean number of errors obtained on the paraphrased items?

(c) Was there a significant difference between the mean number of errors gained on the paraphrased items as compared to the same score for the application items?

(d) Was there a significant difference between the mean error scores gained on the factual, as opposed to the application items?

Since the items in each of the instances cited under question 7 comprise a rather small number, the results are not likely to be very reliable. Simple means will be used in making the com-
parisons and standard errors of the means will be computed to
give some indication of the significance of the differences
existing between them. The results will be given only in an
attempt to point out possible trends.

e. Finally, in order to check the findings of Sherman (15)
who made a study of the nature of delayed comprehension
and its relationship to the other aspects of reading
ability and to academic achievement and intelligence
we have the following general question and its three
phases?

8. Of what value is the delayed test score as a measure
of comprehension gain and its relationship to other measures of
comprehension, to academic achievement, and to ratings on intelli-
gence tests?

(a) Is the inter-correlation between the scores on
the immediate and the delayed comprehension tests
less than their respective reliability coefficients?

(b) What is the relationship of the immediate-delayed
difference score to the grade point average?

(c) What is the relationship of the immediate-delayed
difference score to the total score on the
intelligence test?
CHAPTER 4

PRESENTATION OF THE RESULTS AND CONCLUSIONS

The main objective of this chapter is the presentation of the data which provide the answers to the questions raised in Chapter III, and the drawing of the conclusions which the data seem to warrant. The general plan will be to repeat each question as it was stated in the foregoing chapter, present and discuss the scores, correlation coefficients or other data relating to the question, and then state any conclusions which seem to be supported by the data and which serve to answer the question.

A. In regard to the problem of whether the tests used in this study were sensitive to the effects of reading, the answers to questions one, two and three are pertinent.

Question 1: Does the mean comprehension score earned by college students in answering questions over the content materials of a reading passage prior to the reading of the passage, differ significantly from the mean comprehension score earned by the same students in answering equivalent test questions immediately after reading the passage?

The basic hypothesis involved here, stated in the null form, is: The mean comprehension score earned prior to the reading of the passage does not differ significantly from the mean comprehen-
sion score earned on equivalent questions answered immediately after the reading of the passage.

TABLE VII

THE MEAN ERROR SCORES EARNED ON THE THREE COMPREHENSION QUIZZES

<table>
<thead>
<tr>
<th>Time of Test in Relation to the Reading of the Passage</th>
<th>Mean Error Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td>24.74</td>
</tr>
<tr>
<td>Immediate Test</td>
<td>17.11</td>
</tr>
<tr>
<td>Delayed Test</td>
<td>19.00</td>
</tr>
</tbody>
</table>

TABLE VIII

THE DIFFERENCES BETWEEN THE MEAN ERROR SCORES EARNED ON THE COMPREHENSION QUIZZES AND THEIR SIGNIFICANCES

<table>
<thead>
<tr>
<th></th>
<th>Diff.</th>
<th>$\sigma$ Diff.</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest-Immediate Test</td>
<td>7.63</td>
<td>0.50165</td>
<td>13.24</td>
</tr>
<tr>
<td>Pretest-Delayed Test</td>
<td>5.47</td>
<td>0.4512</td>
<td>12.16</td>
</tr>
<tr>
<td>Immediate Test-Delayed</td>
<td>1.89</td>
<td>0.5400</td>
<td>3.90</td>
</tr>
</tbody>
</table>
As can be seen in the accompanying tables, the differences between the Pretest mean of 24.74 and the Immediate test mean of 17.11 is 7.63. The standard error of this difference is 0.50165 as calculated by the following formula (20):

\[ D_M = \sqrt{\sigma^2_{M_1} + \sigma^2_{M_2} - 2\sigma_{M_1} \sigma_{M_2}} \]

The t value of this difference is 13.24. This t is derived by using the following formula: (20)

\[ t = \frac{M_1 - M_2}{\sqrt{\sigma_1^2 + \sigma_2^2 - 2\sigma_{M_1} \sigma_{M_2}}} \]

This t is significant beyond the one-percent level of confidence, showing that the difference between the means on the pretest and the immediate test are highly significant. Therefore, the difference, in all probability, did not happen by chance but was due to a difference in the reading comprehension of the students and their ability to answer the quiz questions at these two different times. The null hypothesis is rejected.
Question 2: Does the mean comprehension score earned by college students in answering questions over the content materials of a passage prior to reading the passage differ significantly from the mean comprehension score earned by the same students in answering equivalent test questions forty-eight hours after reading the passage?

The basic assumption in this question, stated in the null form, is that the means of the error scores on the comprehension tests taken at the stated times will not differ significantly.

As shown in Table VIII, the difference between the mean error score on the Pretest and the mean error score on the Delayed test is 5.47. The standard error of this difference, as calculated by the question given on page 72, is 0.4512. When the difference is divided by the standard error of the difference, the resulting t is 12.16 (see the equation p. 72).

Just as in the case of the difference between the pretest and the immediate test, this difference in means between the pretest and the delayed test is highly significant. The null hypothesis can again be rejected.

Question 3: Does the mean comprehension score earned by college students in answering questions over the content materials of a passage immediately after reading the passage differ significantly from the mean error score earned by the same students in answering equivalent questions forty-eight hours after the reading?
The null hypothesis in this case is that there will not be a significant difference between the means of the tests taken at the times indicated.

Although the difference of 3.902 in the case of the means for the immediate and delayed tests is not as imposing as the difference obtained for the tests taken at the other two intervals, nevertheless, the difference is significant beyond chance possibilities and the null hypothesis again is rejected. This significance will be dealt with again in answering question eight.

These results in general show that the tests constructed for use in measuring reading comprehension in the present study are sensitive to the effects of reading. We can, therefore, be confident that any further calculations or conclusions based on these tests will be adequate so far as they relate to the capacity of these tests for measuring reading comprehension.

B. The next two questions deal with the matter of determining which measure of comprehension provided by the tests used in this study is most significant in relation to academic work. Since the tests each provide an error score, and the differences between the tests provide three difference scores, six scores are involved in question four as follows:

Question 4: Which measure of comprehension, including the usual immediate comprehension score, shows the highest relationship to grade point average in college?
In this instance the basic hypothesis, stated in the null form is: None of the measures of comprehension provided by the tests, excluding the immediate test score, gives a measure of comprehension whose coefficient of correlation with grade point average is significantly greater than that of the immediate test score.

**TABLE IX**


<table>
<thead>
<tr>
<th>Measure:</th>
<th>Comprehension Score (number right)</th>
<th>r with GPA</th>
<th>Diff. Between r's</th>
<th>t of the Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immediate Test</td>
<td>.4289</td>
<td>0.0333</td>
<td>5.4298</td>
<td></td>
</tr>
<tr>
<td>Delayed Test</td>
<td>.3956</td>
<td>5.4298</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Immediate Test</td>
<td>.4289</td>
<td>0.2247</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest</td>
<td>.2042</td>
<td>0.2247</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Difference Scores:**

<table>
<thead>
<tr>
<th>Measure:</th>
<th>r with GPA</th>
<th>Diff. Between r's</th>
<th>t of the Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immediate Test</td>
<td>.4289</td>
<td>0.0969</td>
<td>1.9409</td>
</tr>
<tr>
<td>Pre-Dimed. Dif. Sc.</td>
<td>.3320</td>
<td>1.9409</td>
<td></td>
</tr>
<tr>
<td>Pre-Delayed</td>
<td>.2416</td>
<td>1.9409</td>
<td></td>
</tr>
<tr>
<td>Dimed-Delayed</td>
<td>.0169</td>
<td>1.9409</td>
<td></td>
</tr>
</tbody>
</table>
The formula used for determining the t of the difference between these correlations is:

\[
    t = \sqrt{\frac{Z_1' - Z_2'}{\sqrt{2 - 2 \left[ \frac{r_{25} - r_{12}r_{13}(1 - r_{23}^2 - r_{12}^2 - r_{13}^2 + 2r_{12}r_{13}r_{23})}{2(1 - r_{12}^2)(1 - r_{13}^2)} \right] \cdot \frac{1}{n - 3}}} \]

From these results in Table IX, it is observed that none of the measures correlates higher with the GPA than does the immediate test score. Although the .43 coefficient of correlation of the immediate test does not stand much above the .40 of the delayed test, the t of this difference shows that it is well beyond chance probabilities, whereas the t of the difference between the immediate test and the pre-immediate difference score does not place that difference beyond chance probabilities.

Thus the data fail to reject the null hypothesis and so far as these measures are concerned, the immediate test score is still the best predictor of college achievement.

In eliminating the effect of previous knowledge upon reading comprehension by using the difference score, the present study actually creates a situation which does not exist in the case of college achievement, therefore, it is not surprising to see that scores on the immediate and delayed tests, which do not create this limiting effect, correlate higher with the grade point.
average. In other words, in college study and the achieving of college grades the student is permitted to utilise previous knowledge in any way he sees fit. Since the same conditions operate in the case of the immediate and delayed comprehension test scores, they should have a higher relationship to the rating in course achievement than the restricting difference score.

Question 5: What factors are related to gains in comprehension as indicated by the "best" difference-score measure provided by the data in Table IX? The results of the difference-score measure which has the highest relationship to college grade point average is here correlated with other measures that are commonly used in evaluating the components of reading ability and of intelligence.

**TABLE I**

**CORRELATION OF THE PRE-IMMEDIATE DIFFERENCE SCORE WITH MEASURES OF FIVE ASPECTS OF THE READING PROCESS AND TWO INTELLIGENCE SCORES**

<table>
<thead>
<tr>
<th>Measures of the Reading Process:</th>
<th>r with Pre-Diffed. Difference Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vocabulary on the DRT Test</td>
<td>.2917</td>
</tr>
<tr>
<td>Reading Rate (WPM) on the DRT Story</td>
<td>.1401</td>
</tr>
<tr>
<td>Reading Rate (WPM) Plant-Life Story</td>
<td>-.0535</td>
</tr>
<tr>
<td>Story Comprehension on the DRT</td>
<td>.2217</td>
</tr>
<tr>
<td>Comprehension on the DRT (w/o the Vocab.)</td>
<td>.3358</td>
</tr>
</tbody>
</table>

**Measures of Intelligence:**

| Language Score on the ACE Psychological Exam       | .1911                               |
| Total Score on the ACE Psychological Exam          | .4094                               |
Using the equation \( \sigma_r = \frac{1}{\sqrt{N-1}} \) for the standard error of the correlation in order to determine the significance of its difference from zero we find that the standard error of these correlation coefficients is \( 1/13.2287 \) or .07559. On the basis of this standard error it will take a correlation coefficient of .1950 to satisfy the .05 level of confidence. Thus we see that the relationship of the Pre-Diff score to the ACE Total Score and the Diagnostic Test's Comprehension Score (without the Vocabulary); as well as to the Diagnostic Reading Test Vocabulary Score and the Story Comprehension Score is better than it would probably ever be by chance. Its relationship to the Language Score on the ACE Test is also highly significant.

In the case of both the rate scores, however, the relationship is so low as to be within the realm of doubtful causation so far as effects on each other are concerned.

C. Since the rating on intelligence tests is one of the most frequently used types of measure when the problem of predicting achievement in college has to be dealt with, and since even this frequently used predictor falls short of giving satisfactory results in many instances, a crucial point is the determination of how much other measures can contribute to this prediction.

Question 6: To what extent does the "best" difference-score measure of comprehension gain and the usual measure of comprehension (the immediate test score) add to the predictive value
of intelligence ratings toward forecasting college grades?

The following multiple correlations are provided as a means of evaluating these effects: The formula used for deriving these multiple correlations is as follows: (29)

$$R_{1.23} = \sqrt{r_{12}^2 + r_{13}^2 - 2r_{12}r_{13}r_{23}}$$

<table>
<thead>
<tr>
<th>Variables Correlated</th>
<th>r</th>
<th>$R_{1.23}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. PMA and ACE (tot. sc.) (1) (2)</td>
<td>0.5283</td>
<td></td>
</tr>
<tr>
<td>2. P-I Dif. Sc. and ACE (3)</td>
<td>0.40937</td>
<td>0.5407</td>
</tr>
<tr>
<td>3. P-I Dif. Sc. and PMA</td>
<td>0.33202</td>
<td></td>
</tr>
<tr>
<td>4. P-D Dif. Sc. and ACE (3)</td>
<td>0.24368</td>
<td></td>
</tr>
<tr>
<td>5. P-D Dif. Sc. and PMA</td>
<td>0.24458</td>
<td>0.29046</td>
</tr>
<tr>
<td>6. Delayed Test and ACE (3)</td>
<td>0.57548</td>
<td></td>
</tr>
<tr>
<td>7. Delayed Test and PHA</td>
<td>0.42894</td>
<td>0.5457</td>
</tr>
<tr>
<td>8. Delayed Test &amp; ACE (3)</td>
<td>0.5374</td>
<td></td>
</tr>
<tr>
<td>9. Delayed Test &amp; PHA</td>
<td>0.39557</td>
<td>0.54118</td>
</tr>
</tbody>
</table>

TABLE XI

From these multiple correlations it is evident that the four scores involved, namely, the pre-immediate difference score, the pre-delayed difference score, the immediate test score, and the delayed test score, add little or nothing to the prediction of the grade point average from rating on the total score of the ACE Psychological Examination. In fact, the pre-delayed difference score even tends to lower the prediction markedly. Therefore, so far as these measures are concerned, the total score on the ACE test is still the best predictor of college grade point average.

D. Although the number of items in some of the categories is small, several secondary comparisons are given consideration as provided for by two special features included in the quizzes. These problems involve the comparison of the mean number of correct responses on the repeat and non-repeat items, and the comparison of the mean error-scores earned on the factual, paraphrased, and application items.

Question 7, with its four sub-divisions relates to these secondary problems as follows: What effect upon the measure of comprehension did the inclusion of different types of items have? The data used in arriving the answers to these questions is as follows:
GRAPH I

COMPARISON OF THE MEAN NUMBER OF CORRECT RESPONSES TO THE REPEAT AND NON-REPEAT QUESTIONS AND THE PERCENT THEY REPRESENT OF THE TOTAL NUMBER OF SUCH ITEMS

<table>
<thead>
<tr>
<th>% of N</th>
<th>Form A</th>
<th>Form B</th>
<th>Form C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre Immed Del</td>
<td>Pre Immed Del</td>
<td>Pre Immed Del</td>
</tr>
<tr>
<td>65</td>
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<td>32</td>
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</tbody>
</table>

Repeats  Non-Repeats
a. Did the fact that an item appeared on the pretest and again on the immediate test and the delayed test cause it to be answered correctly more often than those items which did not repeat?

As might be expected, there was a greater gain in the number of correct responses to the repeat items as compared to the same score for the non-repeat items. Since the total number in each of these classes of items differed greatly (nine repeats and thirty-one non-repeats on each quiz), a special device was needed in order to make the comparisons meaningful. For this purpose, the mean number of correct responses to each type of item is presented (Graph I, p. 81) in terms of its percentage of the total number of items for that category.

It is evident from the graph that the repeat items not only make greater gains in the total number of correct responses, they also retain these gains better on the delayed test than do the non-repeat items. This is particularly so in the case of quizzes A and B. The peculiar trend on Quiz C in this respect is probably accounted for by the fact that due to some imbalance in the testing sequences, fewer seniors and a greater number of freshmen took Quiz C as a delayed test.
GRAPH II

COMPARISON OF THE MEAN ERROR-SCORES ON ANSWERS TO QUESTIONS AT THE THREE LEVELS OF COMPREHENSION AND FOR THE THREE TEST PERIODS

<table>
<thead>
<tr>
<th>Mean Error-Score</th>
<th>Test Period in Relation to the Reading of the Passage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pretest</td>
</tr>
<tr>
<td>9.5</td>
<td></td>
</tr>
<tr>
<td>9.0</td>
<td></td>
</tr>
<tr>
<td>8.5</td>
<td></td>
</tr>
<tr>
<td>8.0</td>
<td></td>
</tr>
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<td>7.5</td>
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<td>5.5</td>
<td></td>
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<tr>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>4.0</td>
<td></td>
</tr>
</tbody>
</table>

Factual Items
Paraphrased items
Application items
When the items relating to the three levels of comprehension, namely, factual, paraphrase, and application, are taken into consideration, several interesting trends are to be noted.

Although the N's are not large enough to give satisfactory reliability, possible explanations for the trends might be of some interest and value. The following questions relate to these trends and the answers deal with the possible explanations of the trends.

b. Was there a difference between the number of errors made in responding to the factual items as compared to the paraphrased items?
According to the means represented in the graph and shown with their standard errors in Table XII, there is actually little if any difference between the error-scores for the factual items and the error-scores for the paraphrased items. The standard errors of the means in these two cases are quite large in comparison to the size of the means. Therefore, the difference between the means is most likely insignificant.

c. Was there a significant difference between the number of errors made in answering the paraphrased items as compared to those made in answering the application items?

Although the mean error score for the application items is, to all intents and purposes, about the same as the mean error score for the paraphrased items when the results on the pretest are singled out, there is less tendency for the errors on the application items to decrease on the immediate test. For the paraphrased items, however, the mean error score on the immediate test decreases markedly from the mean error score on the pretest.

When the delayed test results are observed in this regard, however, there is a tendency for the errors on the paraphrased items to increase, whereas, the errors on the application items continue their downward trend.
GRAPH III

COMPARISON OF THE PERCENTAGES OF THE TOTAL NUMBER OF ITEMS REPRESENTED BY THE MEAN ERROR SCORES MADE ON THE QUESTIONS INVOLVING THE THREE LEVELS OF COMPREHENSION FOR FORMS A, B, AND C COMBINED
d. Was there a difference between the number of errors made in response to the factual items as compared to the errors made on the application items.

As in the case of the paraphrased items compared to the application items, there is a tendency for the errors on the factual items to drop sharply on the immediate test and then increase for the delayed test, whereas, the error score for the application items, as mentioned above, continues to decline.

One explanation for this trend in error-scores for the three levels of comprehension items is that the responses to the application items require knowledge which is more difficult to obtain by the reading process but which is retained more readily than the knowledge needed to answer the paraphrase and factual items.

Another explanation might be that the knowledge required to answer the application items is less subject to the influence and control of the method used in the present study than is the knowledge needed to answer the other two types of items correctly.

Further information on the comparisons between responses to the three levels of comprehension items is provided by the graphs showing the percentage of the total number of items represented by the mean error-score for each of these classes of items.

Here again the tendency for the application items to show a less precipitant decline from the pretest to the immediate test
is evidenced. Also the tendency for this error-score to continue to decline on the delayed test while the error-scores for the other types of items increase is again indicated.

The peculiar tendency on Form C for all of the error-scores to increase rather sharply on the delayed test is probably explained by the previously cited condition (page 82) that fewer seniors and a preponderance of freshmen took Form C as the delayed test.

Finally, in order to see how the pertinent findings of our study compare to the findings obtained by Sherman (15) in his study of the nature of delayed comprehension and its relation to college achievement and intelligence, we have the following:

**Question 8:** Is the inter-correlation between the scores on the immediate and delayed tests greater or less than their correlation for reliability? What is the relationship of the immediate-delayed difference score to the point hour average? What is the relationship of the immediate-delayed difference score to the intelligence test scores?

a. The intercorrelation between the immediate and the delayed test results is .67. This is the highest relationship obtained by any of the measures used in the present study. The reliability coefficients for these two tests after correction with the Spearman-Brown formula lie somewhere between .6789 and .7406. Therefore they neither add much nor detract much from each other.
b. The correlation of the immediate-delayed difference score with the grade point average yields a coefficient of .0169. This indicates a lack of positive or negative relationship that is of any appreciable significance. The immediate-delayed difference score as obtained in the present is therefore a poor measure for predicting college achievement.

c. The correlation coefficient for the immediate-delayed difference score and the total score on the ACE test is .2738. This coefficient is significantly different from a correlation of zero, since a coefficient of .19 would be sufficient to meet the one-percent level of confidence. The correlation coefficient is not high enough to be of any positive predictive value, however, and cannot be recommended as a measure of intelligence.

In general, the results of the study indicate that a positive answer can be given to the original main problem posed in Chapter I, namely, that a difference score can be used as a means of measuring gains in comprehension made through reading. It has
also been determined, however, that such a score does not add significantly to the prediction of college achievement through ratings on tests of intelligence. Neither does it measure any aspect of reading comprehension not already accounted for by the usual, immediate test, measure of reading comprehension.

Since the difference score is more difficult to obtain than the immediate test score, there seems to be little reason for making any move to substitute it for the immediate test measure.
CHAPTER 5

SUMMARY AND SUGGESTIONS FOR FURTHER RESEARCH

A. Summary

1. Introduction

Reading is a very important and essential process which has a profound bearing upon many areas of activity in life. The importance of reading is particularly evident in higher education where success or failure may depend upon the ability or inability to read vast quantities of text and reference materials.

The accurate evaluation of reading capacity in college students is one of the important aspects of counseling students; of helping them to select courses wisely; and of predicting their possibilities of success in fields of study at colleges and universities.

In cases where remedial work is indicated for the improvement of reading skill, the adequacy of methods for measuring reading ability is a problem of equal importance.

Among the factors generally recognized as important components of reading ability is the capacity to comprehend ideas, concepts and meanings presented on the printed or written page.
2. Statement of the Problem

The present study had primarily to do with the measurement of comprehension gained through reading. The main objective was to find a more accurate way of measuring comprehension gains than has so far been discovered.

The plan was to arrive at this new type of measure through the use of difference-scores. The attempt was made to control the effect of previous knowledge upon the reading process. Interest was especially centered upon the effect which previous knowledge has upon the comprehension of materials similar to those found in college textbooks.

3. Historical Background

A search of the literature in the field of reading measurement at the college level failed to reveal any research or information relating to a difference-score method of measuring reading comprehension. Although some test makers have attempted to control the effect of previous knowledge through the use of unfamiliar and strange materials in the reading passages, traditionally, the methods have ignored controlling the effects of previous knowledge upon measurements of reading comprehension.

Workers in the field of the psychology of learning and thinking have probably made the most direct attempt to control the effect of previous knowledge upon these processes through
their use of non-sense syllables. They have failed, however, to relate their findings specifically to the reading process and the measurement of reading ability.

Some aspects of the present study are related to research in reading comprehension as reported by Spitser, Sherman, and others in that they attempt to determine the relationship of measurements of reading capacity to school achievement. The effects of testing comprehension after intervening delay periods have separated the reading period from the testing period has also been evaluated by these investigators. All these studies, however, have failed to take into account the factor of previous knowledge and its effect on gains in comprehension. In no case has a difference-score measure of reading comprehension been attempted.

4. Method

The materials selected for use as the reading passage in the present study met the following criteria: They compared favorably to college textbook assignments on the basis of length, level of difficulty, vocabulary, and style of writing. They were appropriate for use in a 50-minute college class period. A sufficient number of facts, ideas and meanings were presented in them for the making of test items for three adequate and equivalent tests of comprehension.
The three forty-item quizzes constructed over the materials of the passage included only multiple-choice questions of the four-choice type. They were equated for difficulty by use of a tetraehoric coefficient of correlation, and contained features for evaluating the effect of the repetition of items and for the measuring of the effect of items requiring three different levels of comprehension for answering them correctly.

These three forty-item tests and the reading selection were administered to a group of 247 college students. The original main group was composed of four sub-groups including the four college classes of freshmen, sophomores, juniors, and seniors.

Six sequences of administration were used. Each of the three forms of the comprehension test was administered in some one of three test periods related in time to the reading of the passage. The three test periods were defined as the Pretest- given seventy-two hours prior to the reading of the passage, the Immediate test- given immediately after the reading of the entire passage (4200 words) and the Delayed test- given forty-eight hours after the reading of the selection.

Due to two reasons, namely, absence from one of the test sessions, and lack of ratings on standard reading and intelligence tests, the original group shrank to 176. This final group, for which complete data was available, was composed of thirty-four
freshmen, sixty sophomores, fifty-five juniors, and twenty-seven seniors. For these subjects the following scores and measures were available and were tabulated to be used for correlational and other comparative purposes:

The error-score and the number of correct responses to the pretest, the immediate test and the delayed test. The difference scores resulting between error-scores on the pretest and the immediate test, the pretest and the delayed test, and the immediate test and the delayed test. The point hour average. The Diagnostic Reading Test Scores for reading rate (in words per minute), story comprehension, vocabulary, paragraph and story comprehension. The language and total scores on the American Council on Education Psychological Examination, and the reading rate (in words per minute) on the Plant-Life Selection.

5. Presentation of the Data and Conclusions

The data were treated in a manner which would provide answers to eight major questions and several minor ones. The questions and their resulting answers along with the data used for obtaining the answers are as follows:
(1) Does the mean comprehension score earned prior to the reading of the passage differ significantly from the mean comprehension score earned immediately after the reading of the passage?

(2) Does the mean comprehension score earned prior to the reading of the passage differ significantly from the mean comprehension score earned forty-eight hours after the reading of the passage?

(3) Does the mean comprehension score earned immediately after the reading of the passage differ significantly from the mean comprehension score earned forty-eight hours after the reading of the passage?

In each of the three foregoing cases, the difference between the mean comprehension scores is statistically significant as shown by the "t" test. This indicates that the comprehension tests used in the study are sensitive to the reading processes of college students and are capable of providing satisfactory scores for use in comparisons to be made in the other questions.

It is also pertinent to indicate in this connection that the three quizzes showed adequate reliability coefficients of .68, .72, and .74 after corrections were made with the Spearman-Brown formula.
(4) Which of the measures of comprehension showed the highest relationship to grade point average?

The traditional measure of comprehension showed the highest relationship to the grade point average, with a coefficient of \( r = 0.43 \). The next highest measures in their relationship to the grade point average were the delayed test (\( r = 0.40 \)) and the pre-immediate difference score (\( r = 0.33 \)).

(5) What is the relationship of the pre-immediate difference score to commonly used measures of evaluating reading ability?

The correlation coefficient of the pre-immediate difference score relates to the following measures of reading ability as follows:

- a. Vocabulary on the Diagnostic Reading Test—— ———— 0.29
- b. Word-Per-Minute Rate on the Diagnostic Test—— ———— 0.19
- c. Word-Per-Minute Rate on Plant-Life—— ———— 0.05
- d. Story Comprehension on the Diagnostic Test—— ———— 0.22
- e. Paragraph and Story Comp. on the Diag. Test—— ———— 0.34

Thus we see that the difference-score in this instance is more like the combined Paragraph and Story Comprehension score on the Diagnostic Reading Test than any of the other measures listed. The fact that the two passages differed so much in content probably accounts for the lower correlation with the separate Story Comprehension score on the Diagnostic Test.
(6) To what extent do the immediate test score and the pre-immediate difference score contribute to the intelligence test score in its prediction of grade point average?

The correlation coefficient for the total ACE score and the PHA is .53. The multiple correlation coefficient obtained for the three variables of total ACE score, PHA, and Immediate Test is .5457. The multiple correlation obtained for the three variables of total ACE score, PHA, and Pre-Immediate difference score is .5407. Thus, these two scores resulting from the comprehension tests used in the study add nothing of significance to the predictive value of the ACE total score for point hour average.

(7) What was the effect of having different classes of items such as, repeat and non-repeat, factual, paraphrase and application, included in the three comprehension quizzes?

Since the numbers of items involved in these instances was too small for reliable comparison, only trends could be noted. These trends showed the repeat items having a greater percentage answered than the non-repeat items, with the difference between the two classes increasing on the immediate and the delayed tests. The differences in each instance, however, were not statistically significant.
The responses to the factual and paraphrased items followed a closely parallel pattern so far as mean error scores on the three quizzes were concerned. The tendency was for the ratings to be relatively high for the pretest, drop to a low for the immediate test and then increase slightly on the delayed test.

For the application items there was a downward trend in mean error score as they move from the pretest to the immediate test to the delayed test. The means in each instance was always higher for the application items than for the factual and paraphrased items. The differences, it must be remembered, were not statistically significant, and can only be used as indicators of trends.

(6) a. Is the inter-correlation between the scores on the immediate and the delayed tests greater or less than their correlation for reliability? The results here show that the respective correlation coefficients are .67 and two standing somewhere between .68 and .74. It is therefore concluded that neither comprehension test has much to add to or detract from the other.

b. The correlation between the immediate-delayed difference score and the grade point average is .0169 showing that no relationship exists between these two scores and one cannot be predicted from the other.
c. The correlation coefficient obtained between the immediate-delayed difference score and the total ACE score is .24, indicating a relationship that is significantly different from a zero coefficient but of no particular value so far as reliability of prediction from one to the other is concerned.

In general the results of the study indicate that a positive answer can be given to the original query posed in the statement of the problem in Chapter 1, namely, that a difference score can be used as a means of measuring comprehension gained through reading. Also, it has been shown that such a score has little value that is not already to be found in the more easily obtained immediate test score.

Even though few positive results have been obtained in the carrying out of this study, the negative results give support to the customary and usual method of measuring comprehension gained through reading and permit us to conclude that perhaps the method of measuring comprehension immediately after the reading of a passage is about the best that is to be devised.

Some improvements in the methods and materials used in the study, however, might still lead to an improved difference score which could, conceivably, possess more adequate capacity for measuring reading ability than does the usual immediate test score.
For this reason, we offer the following suggestions for further research along lines relating to the present study:

B. Suggestions for Further Research

In regard to the reading passage used in the present study, although its unusual length may have increased the reliability of the scores obtained on the comprehension tests it is also possible and likely that the length had the effect of making the immediate test, actually, a sort of delayed test. In other words, forgetting began to operate the instant the first paragraph was completed. Unless the ideas presented in the forepart of the passage were reinforced in subsequent paragraphs, the effects of forgetting would probably increase in proportion to the amount of material covered. The longer the passage, the greater the possibilities of the students' failing questions involving the early materials.

Studies involving the length of a reading passage and its effect on comprehension and forgetting have not been made on materials having the closeness of meaningful relation that the passage of the present study seemed to have. This might provide a good problem for experimental investigation.

Another area for further research might involve the preparation of the items used for checking the comprehension of
factual, paraphrased and application materials. The effort might be made to see that a greater distinction is obtained between these three types of items by including a greater number of items for each type of by using only two types and then increasing the number of each. Also, the effort might be made to have the number of repeat and non-repeat items more nearly equal. In this way the significance of some of the trends shown by these factors in the present study might be more clearly brought out.

The final suggestion has to do with the sample of subjects used in the present study. A more homogeneous group might have given results which would have afforded a higher predicative capacity to the comprehension test scores where their correlation coefficients were calculated in relation to the other ratings on student capacity. Thus, it is suggested that the study might be done on a group comprised only of sophomores and juniors.


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TABLE XIII

THE SCORES USED IN THE STUDY WITH SUBJECTS NUMBERED AND LISTED IN GROUPS ACCORDING TO THE COLLEGE CLASSES

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WORK SKILL READING TEST
(Experimental form)

By

Francis P. Robinson and
James C. Wright

For

Research Purposes At
The Ohio State University

INSTRUCTIONS

THE PURPOSE OF THIS TEST IS TO MEASURE YOUR ABILITY TO READ SCHOOL ASSIGNMENTS AND LATER TAKE EXAMINATIONS OVER WHAT YOU HAVE READ. YOUR COOPERATION AND BEST EFFORTS ARE ESSENTIAL TO THE OBTAINING OF VALID RESEARCH RESULTS.

WHEN THE SIGNAL IS GIVEN, START READING THE SELECTION IN THIS BOOKLET, USING YOUR USUAL MANNER OF READING SCHOOL ASSIGNMENTS. READ AS RAPIDLY AS YOU CAN AND STILL UNDERSTAND WHAT YOU ARE READING. DO NOT TAKE TIME TO MAKE NOTES. THE EXAMINER WILL KEEP A RUNNING RECORD OF THE TIME ON THE BLACKBOARD. AFTER YOU HAVE COMPLETED THE ENTIRE READING SELECTION, NOTE THE READING TIME WHICH IS WRITTEN ON THE BLACKBOARD, RECORD THIS NUMBER IN THE SPACE MARKED "READING TIME" ON YOUR QUESTION BOOKLET, AND PRINT YOUR NAME IN THE SPACE PROVIDED. THEN START ANSWERING QUESTIONS. GIVE AN ANSWER TO EVERY QUESTION EVEN IF GUESSING IS NECESSARY BUT AVOID WILD GUESSING. THERE IS NO TIME LIMIT. APPROXIMATELY FORTY-FIVE MINUTES, AT THE MOST, WILL BE REQUIRED FOR READING THE SELECTION AND ANSWERING THE QUESTIONS. WHEN YOU HAVE ANSWERED ALL THE ITEMS, DOUBLE CHECK YOUR RESPONSES, THEN TURN QUIETLY TO OTHER WORK OR WAIT QUIETLY UNTIL EVERYONE HAS FINISHED. PLEASE AVOID DISTRACTING OTHERS FROM THEIR TEST.
EXPLORING THE MYSTERIES OF PLANT LIFE

PART I.

HOW PLANTS WORK

All the factories, all the railroads, all the mines, all the automobiles, all the activities of man of whatsoever nature that require power, do not utilise as much energy as is developed in the plant world.

Out of intangible sunshine, insubstantial air, and clear water, coupled with a medium of mineral matter from the soil, plants must manufacture all the food that keeps alive the immemorable hosts of animals of the earth. Plants also store up all the heat that keeps humanity warm and cooks its food, furnish most of the power that drives man's industries, and provide the raw materials for all the clothes mankind wears and for many of the products of which his factories, his houses, his furniture and his books are made.

Would you know how much of a plant is fabricated of sunshine, air, and water, and how little of solids from the earth? Then burn the plant and notice the thin layer of ash remaining. All else has been made up of subtle sunshine, thin air, and plain water.

Every plant, from a simple moss to a giant tree, is in reality a vast aggregation of individual entities working together in fine coordination and close unity to a common purpose. One group pumps up the water required by the community. Another group carries the water to the points where it is needed.

Other groups, respectively, obtain minerals from the ground, mix them with air, sunshine, and water to make a substantial dish; carry the food to various parts of the household; store up the leftovers; build additions to the house; and prepare to send out colonies from the parent roof-tree, fully "grubstaked" and equipped to gain a foothold wherever they may settle down.

One observer sees the individual plant as a counterpart of a busy city, teeming with life and bustling with industry. Here goes on the pulling down and building up characteristic of progressive
communities. The streets and alleys are thronged with workers. Here are dairies and milkshops dispensing their supplies; jewelers' shops preparing crystals; sugar refineries manufacturing sweets; starch factories storing foodstuffs; perfumers' laboratories distilling scents; varnish makers developing resins and waxes; and color establishments preparing dyesUFFS.

EACH PLANT BUILDS ITS OWN CELL CITY

The ways by which individual plants build their houses and do their work form a story no less fascinating than the methods by which flowers hand their lives on to future generations, though they themselves are destined to perish.

The seed that finds its "place in the sun" settles down and waits the hour when propitious conditions of moisture and warmth shall waken the germ of life that sleeps within.

Once this little speck of living matter is aroused in its tiny cell it becomes busy, sending out bits of itself to the neighborhood around it. Each offspring promptly builds itself a tiny house of its own, with walls a thousand times thinner than the finest gossamer, but still constructed of microscopic bricks of cellulose. Between the interstices of these walls the pioneering protoplasm can maintain connection with the parent cell. At the same time, each new structure reaches out and starts its own children to building their cells.

The size of these cells varies. A single cubic inch of fine cork may have as many of them as there are people in the world, yet each one has been built and inhabited by a protoplast, which has not only patiently thickened the wall of its house layer by layer, but has also done its bit in the life of the community of which it is a part.

When the microscope was first invented and philosophers peered into these little houses and saw the inchoate plasma within, amusement and awe possessed them. Jan Swammerdam, the great Dutch student, became almost insane at the marvels his lens revealed, and finally destroyed his notes, holding it a sacrilege to unveil and thereby profane the wonders hitherto unknown to man.
The things the pioneers saw were considered delusions until the members of the Royal Society of London peered through a microscope and jointly signed a paper saying they had seen these wonders with their own eyes.

THE "SILENT ROAR" OF THE FAST PLANT INDUSTRY

A somewhat viscid substance, not unlike the white of an egg though thicker, the bit of protoplasm within a cell, does the fundamental work of all organic matter.

Huxley, in speaking of the stirring activities of the busy little protoplasts or individual bits of protoplasm that build their several cells and do their respective community tasks in the plant's activities, says: "The wonderful noonday silence of the tropical forest is, after all, due only to the dullness of our hearing; and could our ears catch the murmur of the tiny maelstroms, as they whirl in the innumerable myriads of living cells which constitute each tree, we would be stunned as with the roar of a big city."

And whoever has seen the radio receiving set catch the infinitely small impulses of electricity and amplify them into sounds that fill the loud speaker can appreciate his statement.

As it grows, the little community of protoplasts that build a plant divides its labors, and the complex activities of the growing flower begin.

The whole community of cells constitutes the plant, and through the delicate interstices of their walls the inhabitant of each communicates with those of all the other cells, so that the living substance of the entire structure is in constant contact and forms one united mass.

The building of their own tiny houses by the individual protoplasts is an immeasurable boon to humanity. Without these our plants and trees would never exist and all we would know would be masses of slime.
THE INNER-LIFE OF A PLANT

Let us reduce ourselves to the size of a molecule of water and ramble through one of these cell cities we call a daisy, noting the hustle and bustle and industry constantly taking place.

We promptly discover that one of the principal things going on is the manufacture, in the protoplasts, by a myriad of tiny green grains called chloroplasts, of a very important substance called chlorophyll. These grains have the power to screen out all the rays of light except the red and most of the blue, indigo, and violet series, which they use in their work.

Concentrating these useful rays on the stream of minute particles of carbon dioxide which comes into the leaves through their pores or stomata, the chlorophyll breaks the carbon and oxygen apart and unites the carbon with water, which thereupon becomes grape sugar.

In man's laboratories it takes a temperature of 1,300 degrees C., enough to turn the hardest steel into liquid, to separate the carbon and oxygen atoms of the carbon dioxide molecules exhaled by animals and absorbed by plants. But the little laboratories of the cell city do it without difficulty, and in so doing fabricate the basic food of all organic life, grape sugar.

To make a pound of sugar the plant must work over nearly ninety gallons of carbon dioxide, in the extraction of which it has had to filter thousands of gallons of air. The sugar factory works from sunup to sundown, the eight-hour working day being unknown there. But it operates only when the leaves are out.

A LEAF AS A FACTORY

How closely the sugar industry in the plant parallels the activities of the human factory is shown by the fact that the leaf corresponds to the building, the cells to the several rooms therein, the blue and red light rays to the power employed, the chlorophyll to the machinery used, carbon dioxide and water to the raw materials utilized, grape sugar to the manufactured product, and oxygen to the by-product.
As we move along, we see a constant stream of carbon dioxide particles rushing by, passing through the cell walls, where they meet the molecules of water. The chlorophyll grains turn their burning glasses with their red and blue rays upon the materials thus gathered into the retort, and grape sugar is formed.

After the chlorophyll grains have made the grape sugar, some new workers take it and transform it into starch, which is stored in the cells for future use, just as the iron manufacturer converts molten metal into pig iron, stores it, and melts it again when he wants to use it. A thousand square feet of leaf surface will manufacture one pound of starch in five hours of sunlight.

The action of plants in storing up starch closely parallels that of business men in accumulating estates. Just as the business men invests his funds in such a way that they will be available for conversion into ready money if he needs it, so the plant puts by its earnings in the form of starch ready for conversion into the coin of its realm, sugar, if necessary. And just as the business man bequeaths his estate to his children when he dies, so the plant transmits its surplus to its posterity when it passes.

A third material is made by the plant which is used in its building operations--inulin. It closely resembles starch, and is fabricated by another set of workers.

Men and animals have learned to rob the plant of its savings and the plant's children of their patrimony by eating things rich in starch.

While all these manufacturing activities are going on in the cell city we call a daisy, sap must be provided, for without rich supplies of moisture and a small quantity of mineral substance, the wheels of industry of the plant community cannot revolve. So the roots act as pumps and bring into the city vast amounts of water with minerals in solution, in the proportion of a grain of minerals to a gill of water. This sap is pumped to every part of the plant and bathes the protoplasm of every cell, keeping the protoplasts moist and well nourished.
THE ROLE OF CELLULOSE

Out of the sugar, starch, and imulin fabricated by the three
types of worker we have mentioned, other products are built, such
as cellulose, which forms the microscopic bricks out of which the
cell walls are constructed, and the fixed and fatty oils which are
stored in the seeds, bulbs, etc., as reserve materials for future
exigencies.

As we go on through our daisy, we see the cellulose being
fabricated. The fibers of cotton, the pith of woody stems, the
filter paper of the chemist are familiar forms of cellulose. The
plant makes it serve a double purpose, now as cell wall material,
now as a stored product that can be reconverted into sugar if food
is needed.

As the cell ages, lignin may be added to give stiffness to
the plant structure, making wood; other materials are employed to
give hardness to the shell of nuts, waterproof character to cork,
or gumminess to seeds like flax.

It is the cellulose of plants which lived long ages ago that
we burn when we use coal today. Nature bottles up sunshine in
coal and oil, so that every engine driven by these fuels is in-
directly a solar engine, and all the warmth our fire affords in
winter is the heat of summers millions of years past.

If we visited other plants and entered into their cell communi-
tes, we would see them making the malic acid of apples and currents,
the citric acid of lemons and oranges, the tartaric acid of grapes;
the waxes which make some flowers, like the nasturtium, immune to
water; the resins which salve the wounds of injured plants; the
glucosides which make the wonderful hues of autumn; and the poisons
which protect the plant and serve humanity, such as strychnine and
morphine. Still other workers build up the proteins or flesh formers.

Perhaps most interesting of all the products made by plants
are the enzymes. They convert sugar into starch and starch into
sugar. They have been called the tools with which the protoplasm
effects the chemical results it requires. Dr. Frederick V. Coville,
the eminent botanist of the United States Department of Agriculture,
has shown that it is the chilling processes of winter, as well as
the warm sunshine, that causes the buds of the northern trees to
open. He has described how buds are driven out by the terrific
forces released when the enzymes permeate the walls of the starch
cells and convert the starch into sugar.
An examination of the machinery by which plants take in the raw materials for the fabricating of so many marvelous substances, reveals many interesting mechanisms.

If a potted plant is cut down to the surface of the soil and a glass tube slipped over the stump, it will be noted that the sap which would have flowed through the plant rises up in the tube to the approximate height of the original plant. The sap consists of water and mineral matter drawn out of the earth by that strange process of Nature through which the weaker of two solutions passes through a separating membrane into the stronger. The protoplasm acts as a membrane and the water in the soil is drawn through it to join the sap in the root. As the volume increases, the osmotic force drives the excess up into the plant structure.

Inspecting the seedling of a mustard, one finds that it has a slender root covered by a multitude of tiny hairs. At the end of the root is the growing tip. The hairs of plant roots are ever busy pumping water. Through capillary attraction in the soil, particles of earth several feet away are made to contribute their moisture to the hairs. A cubic foot of clay may have as much as three acres of particle surface exposed to the moisture draft of a root system.

Between the water the plant uses in the manufacture of grape sugar and the much larger quantity it must pass through its system to keep the plant from wilting, heavy drafts are levied on the soil. An oak tree with 700,000 leaves is estimated to give off 120 tons of water a season; an acre of grass has been found to give off more than six tons in a single day. From 200 to 500 pounds of water are given off by plants for every pound of dry substance manufactured.
TEMPERATURE CONTROL AND MINERAL SUPPLY

It has been estimated that if the rainfall during the month of July, in the corn belt of the Mississippi Valley, is one-half inch short of the three inches required to make a full crop, the half-inch shortage costs the farmer five dollars for every one of the millions of acres of corn grown in that belt.

The osmotic power of the plant is supplemented by other agencies to carry the water to the top of the tree. As a big tree must do the equivalent of carrying 500 bucketsfuls of water up a ten-foot flight of stairs every ten hours in midsummer, one may judge how important the process is.

The chemical process going on in the interior of the plant in the growing season develops considerable heat, just as the fuel combustion and friction in an automobile motor make it hot. To carry off the heat engendered in his engine, the motorist employs a cooling system, with water caused to circulate in a radiator system.

The plant needs more effective cooling to keep down the heat of chemical change. The major portion of the water it demands is employed to keep its "radiator" full in order that evaporation on the leaf surface may reduce the plant's temperature.

Many plants have damper systems whereby excessive radiation is checked, a method corresponding to our employment of radiator covers and winter fronts on our automobile engines.

The mineral matter drawn into plants in solution is made available in many ways. The earthworms are allies to plant growth. It has been estimated that an acre of arable land contains an earthworm population of 130,000, and that they pass two tons of soil through their gizzards every season, converting it into humus rich in soluble materials.

Lichens will eat into marble like acids in getting mineral matter for their up-building. Different kinds of plants need different minerals. Potatoes and turnips call for plenty of potash, wheat and corn need much silica, beans and clover demand considerable quantities of lime.
PART II.

THE ROLE OF THE GOOD EARTH IN PLANT GROWTH

PLAIN DIRT VS PAY DIRT

Soil is one of the most important factors in the whole agricultural and horticultural picture. It is far more important than the variety of seeds planted or the type of culture used. Soil, and the plant nutrients it contains, generally spell the difference between success and failure in every growing operation. It seems that plants, like people, require a balanced diet. In order to develop properly they must have, among other things, the correct amount of nitrogen, phosphorus, and potash. These minerals when found lacking, are supplied to deficient soils by means of commercial fertilizer in the correct chemical equation to bring the soil back into nutrient balance which promotes healthy plant growth.

ANALYSIS OF IMPORTANT SOIL ELEMENTS

Nitrogen, phosphorus and potash (potassium) are the three mineral elements which have been found to be universally deficient in the soil. These are the ingredients which are contained, generally, in commercial fertilizers. Although other mineral elements are needed in smaller quantities, these three still remain the most important to gardeners and farmers in assuring crop success.

NITROGEN is an essential constituent of proteins. An abundant supply of nitrogen results in dark green foliage and active vegetative growth. However, too much nitrogen causes too rapid growth, softness of tissue and general weakness in the plant. A plant in soil with too much nitrogen is less resistant to disease, infection, and injury. Also, at flowering time, excessive nitrogen causes the plant to overdo active vegetative growth, thus retarding flower and seed formation.
Where vegetables in which leaves, stalks or stems are the important and desired end product, it is preferable to have the soil contain extra nitrogen. In the case of lettuce, for example, an abundance of nitrogen produces soft, crisp leaves. Other vegetables that benefit from extra supplies of nitrogen are asparagus, cabbage, leek, chard, and brussel sprouts. Nitrogen should always be present in lawn soils in generous amounts if a rich, heavy carpet of grass is desired. Nitrogen in organic form, such as cotton seed meal, continues its effectiveness over a long period and is helpful in producing outstanding lawns. This important plant nutrient can be purchased in the following convenient forms: nitrate of soda, 16% nitrogen; cottonseed meal, 6% nitrogen; urea, 46% nitrogen; dried blood, 10% nitrogen; and ammonium sulphate, 20% nitrogen.

PHOSPHORUS compounds are needed by all plants. These compounds are especially necessary in plants that produce flowers, seeds, and grains. They promote good germination of seed, thrifty seedlings, and general plant vigor. Phosphorus hastens the maturity of plants too, speeding up the formation of flowers, seeds, and grains. In short, if you want colorful flowers or plump seeds, use extra phosphorus. This can be applied separately as acid phosphate, 16%; super phosphate, 20%; triple super phosphate, 45%; and bone meal, 25%. Animal manures are notoriously lacking in phosphorus, yet have been used for generations as farm and garden fertilizer. That is why modern plant growers rely on bagged and packaged fertilizers which carry extra amounts of this important plant food.

POTASH (POTASSIUM) is important in the formation and transport of sugar, starch, and other carbohydrates within plants. Adequate supplies of potash help to produce plants with stiff stalks and healthy, disease-resisting growth. Excessive amounts of potash result in an increase in the water content of plants and help them resist droughts and frost injury but delay their maturity. Potassium is also very essential to root growth. If large, mealy potatoes or sweet, juicy carrots, or tasty beets, or healthy tulip and dahlia bulbs are the desired end product, then the soil should be fed extra potassium.

Thus, it is readily seen that adding fertilizer haphazardly may do harm to the garden rather than improve it. For instance, plants may be over-dosed with phosphorus when they are badly in need of nitrogen. And isn’t it obvious that a fertilizer which may be ideal for morning glories in Ohio may be just plain poison to potatoes in Idaho?
THE pH AND WHY IT IS IMPORTANT

Sweet or sour soil means alkaline or acid soil. But since neither of these terms is exact, good gardeners today use the "pH scale" to indicate the degree of acidity or alkalinity of their ground. Literally, "pH," means "percentage of hydrogen ions."

From a practical farm and garden standpoint, it pays to determine exactly the pH or acid-alkaline balance of the soil. It is the only way to be sure that the plant foods that are applied can be used by the plants to be grown. Plants can absorb food from the soil in liquid form only. At certain points on the pH scale, the fertilizers which are applied go quickly into solution, while at other points they turn into insoluble or "inedible" forms, doing no good whatsoever.

While pH has been surrounded by a great deal of hocus-pocus and mystery, after all, it is an actual fact that knowing the pH of the soil is like reading the thermometer. We do not need to understand all the laws of heat exchange, convection, conduction, induction, and radiation to appreciate what our neighbor means when he calls across the fence: "It's ten below zero this morning."

True, our grandfathers grew good crops without knowing anything about this scientific method of telling whether their soil was "sweet" or "sour." Even so, they did considerable talking about such soils and, by rule of thumb and experience they learned to do the things that we now can do deliberately and with full knowledge when we know the pH we have to deal with. What's more, we can do them better and at lower cost.

Just as a thermometer measures the temperature in relation to the freezing point of water, so the pH scale divides the range of alkaline and acid materials into 14 points. Halfway, or 7.0, is called "neutral." This term does not mean that the soil is neither acid nor alkaline but that the two conditions are exactly in balance.

While some plants thrive only in intensely acid soil, others can survive in alkaline soils only. By and large, most garden and field crops do best when the pH ranges between 6.0 and 6.9, a shade below neutral on the acid side. And when we study the effects of acids and alkalines on the solubility of plant foods, we can see why this is so.
PLANT FOODS ARE FUSSY

Take phosphorus, for instance. Phosphorus is a plant food that seems to be lacking in most soils after they have been under cultivation for a while. Notice what happens to the phosphorus as the pH rises and falls. When the pH is high, above 7.3, phosphorus locks up with calcium to form an insoluble calcium phosphate compound. When the pH falls below this point, phosphorus is again released in a soluble form. In other words, add too much lime, raising the pH, and the phosphorus in the soil is no longer available to the plant's feeding roots. But let the pH drop as low as 5.0, and the phosphorus again locks up, this time with soil iron.

TO MUCH VS TOO LITTLE

There is another condition which shows up after too much lime has been applied. Plant leaves begin to turn yellow and soon become vained and mottled in a distinct pattern. Superficially, this condition resembles that of calcium or nitrogen deficiency. But exactly the opposite is true! The effect of lime is often to release nitrogen and what has happened is that the over-dosing of calcium has locked-up iron and manganese with nitrogen. Iron and manganese are two important plant foods called "trace" elements, because needed only in minute quantities, but essential to healthy plant growth. Without iron and manganese the plant cannot produce the chlorophyll or green grains which help to manufacture starches, so the plant begins to show signs of starvation.

Magnesium (which is often confused with manganese) seems to substitute for lime and may affect iron and manganese in the same way.

Nitrogen has a special relation to pH in that the nitrate form which plants can absorb directly is not affected by the acid-alkaline reaction of normal soils. But nitrogen from organic sources such as humus, leaf-mold, manures, compost, etc., is not nitrate nitrogen. It is a more complex material in the form of protein, amino acids, nitrates, or ammonia. These must be broken down by soil bacteria into nitrate nitrogen before they can be absorbed by plants. But, and here is the difficulty, these soil
bacteria do their best work in pH conditions between 6.0 and 6.9. Thus, in highly acid or highly alkaline soils there is very little breakdown of organic nitrogen, and plants can starve even if liberal quantities of manure have been applied.

The natural soil hormones are also affected by pH, since they are released by bacterial activity and are available in about the same range of acid-alkalinity. Like nitrogen, the hormones are highly soluble and highly subject to leaching.

Potash gives very little trouble until the pH goes above 8.0, at which point it becomes unavailable. Another chemical affected by high pH is aluminum, which becomes highly poisonous to plants at a pH above 8.0. It is relatively harmless below that, and looks with phosphorus below 5.0.

OTHER WONDERS WAIT YOU

One might go on indefinitely, rambling through vast amounts of knowledge relating to the plant world and discovering new thoughts that thrill at every turn. The bacteria, the molds, the yeasts—each of a thousand and one groups which represent departures from the original household—have a story to tell. In the biographies of the individual plants many additional and fascinating facts may be found.

DIRECTIONS: Note the reading time posted on the blackboard, record it in the space marked "reading time" in your question booklet, then print your name in the space provided, circle your class, and start answering questions.
Part I of the selection in this booklet was adapted from an article written by William J. Showalter, Sc. D., LL.D., and appearing in The Book of Wild Flowers, published by the National Geographic Society, Washington, D. C., 1933, Pp. 1-8 and used in this study with their permission.

Part II of the selection is found in the little booklet which accompanies the soil testing kit manufactured by the Sudbury Laboratory, South Sudbury, Mass.
QUIZ ON PLANT LIFE
FORM A

NAME: ___________________________ READING TIME: ______ (minutes)

CLASS: FR SO JR SR (circle)
A

DIRECTIONS: Choose the word or phrase which best completes the statement or best answers the question, placing the number of this word or phrase on the blank to the left. There is no penalty for guessing so answer every question even if guessing is necessary.

1. Compared to the amount used by man in all his activities and operations, plant life develops a super-abundance of
   (1) minerals
   (2) energy
   (3) nitrogen
   (4) carbon dioxide

2. Potassium is not available as plant food if the pH of the soil rises above
   (1) 6.9
   (2) 7.3
   (3) 8.0
   (4) 6.5

3. Food is stored in the plant as
   (1) chlorophyll
   (2) starch
   (3) sugar
   (4) sap

4. Of all the materials available to animals for food, the percentage provided by plants is
   (1) 90
   (2) 50
   (3) 100
   (4) 60

5. If the pH rating of a soil stood at 8.0 we could be reasonably certain that any phosphorus contained therein would be insoluble because of its combination with
   (1) calcium
   (2) iron
   (3) nitrogen
   (4) potash
6. Chlorophyll is of great importance in plant physiology in that it
   (1) separates out water for use in the making of sugar
   (2) absorbs the yellow, green and blue-green rays of the sun
   (3) can reach a 1300 degree C temperature while the plant's temperature remains normal
   (4) causes the cells to subdivide, making the plant grow

7. For farm and garden use the pH scale has a point range of
   (1) 1
   (2) 20
   (3) 7
   (4) 50

8. Probably the most important mineral to be used in the promotion of healthy root growth in plants is
   (1) nitrogen
   (2) phosphorus
   (3) potassium
   (4) manganese

9. The rays which cannot penetrate a chloroplast are
   (1) yellow
   (2) red
   (3) blue
   (4) violet

10. To awaken the germ of life that sleeps within it, the plant seed must wait for propitious conditions of
    (1) sunlight
    (2) frost and snow
    (3) warmth and moisture
    (4) minerals in the soil

11. A substance in animals which is comparable to the starch in plants is
    (1) plasma
    (2) cartilage
    (3) fat
    (4) bone

12. So far as percentage yield is concerned, probably the best commercial source of nitrogen for plants is
    (1) nitrate of soda
    (2) dried blood
    (3) urea
    (4) ammonium sulphate
13. Our forests would be masses of slime if plants did not carry on work comparable to
(1) carpenters
(2) miners
(3) salesmen
(4) dairymen

14. A by-product of the conversion of starch to sugar by enzyme action is
(1) carbon dioxide
(2) water
(3) lignin
(4) heat

15. Two trace minerals which are essential to the plant's manufacture of chlorophyll are
(1) manganese and calcium
(2) manganese and iron
(3) calcium and iron
(4) nitrogen and potash

16. Compared to the density of the tree's sap, the density of the mineral solution in the surrounding earth is
(1) variable, sometimes more, sometimes less
(2) equal
(3) greater
(4) less

17. In the manufacture of grape sugar, which of the following is the plant least likely to use?
(1) carbon dioxide
(2) oxygen
(3) water
(4) chlorophyll

18. If it were not for osmotic force
(1) minerals would not be dissolved into the sap
(2) the sap would not reach the upper part of the tree
(3) roots would not seek soil moisture
(4) enzymes would not function in plant physiology

19. The amount of water used by the plant in making sugar, as compared to the amount needed to prevent wilting is
(1) much smaller
(2) much larger
(3) equal
(4) slightly smaller
20. Cellulose, when altered in form (wood, cork, coal, peat, etc.)
   (1) lasts long after the plant is dead
   (2) does not last more than a few months
   (3) seldom last more than a few years
   (4) has been known to last indefinitely

21. The rich supplies of moisture and bits of mineral necessary for the continued operation of the wheels of industry in the plant are transported throughout the factory by the plant's
   (1) roots
   (2) sap
   (3) interstices
   (4) chlorophyll grains

22. Enzymes are called the tools of protoplasm because they are used to
   (1) build cell walls
   (2) convert starch
   (3) break down carbon dioxide
   (4) build resins

23. By passing soil through their gizzards, earthworms produce a plant food which is known as
   (1) compost
   (2) leaf-mold
   (3) manure
   (4) humus

24. The protoplasm is essential to plant life because it
   (1) contains that which distinguishes life from non-life
   (2) serves as a protective buffer
   (3) stores up food
   (4) is a medium of intercommunication

25. Which one of the following mineral elements is the gardener least likely to have to add to the soil to assure successful plant growth
   (1) lime
   (2) nitrogen
   (3) phosphorus
   (4) potash

26. For successful growth, clover and beans need a plentiful supply of
   (1) potash
   (2) humus
   (3) lime
   (4) silica
27. Of all the raw materials available to men for making clothes, the percentage having its basic source in plants is
   (1) 90
   (2) 100
   (3) 50
   (4) 60

28. Which of the following wave lengths of light is the plant most likely to be able to use in its food manufacturing activities?
   (1) yellow
   (2) red
   (3) green
   (4) violet

29. If the pH of the soil stood at 4.5 we could be confident that any phosphorus present would be combined with iron and therefore
   (1) poisonous
   (2) insoluble
   (3) soluble
   (4) irredeemable

30. One of the principal products of the protoplasts is
   (1) carbon dioxide
   (2) indigo
   (3) chlorophyll
   (4) perfume

31. Extra amounts of potassium applied to plants result in
   (1) high drought resistance
   (2) early maturity of crop
   (3) increased flower production
   (4) sustained seed production

32. Ten hours of sunlight acting on 1000 square feet of leaf surface are required to produce
   (1) two pounds of grape sugar
   (2) one pound of starch
   (3) one quart of syrup
   (4) one pound of cotton

33. Dextrin, starch, and cellulose are alike in that they
   (1) are a part of living protoplasm
   (2) are the result of the interaction of light, sugar and water
   (3) may be transformed into sugar by the plant
   (4) are produced at the roots of the plant and then sent to the stem
34. Where the desired end-crop is flowers, seeds, or grain the farmer or gardener should supply the soil with extra amounts of
   (1) manure
   (2) phosphorus
   (3) nitrogen
   (4) potassium

35. For every pound of dry substance a plant produces, water is given off at a rate of from
   (1) 200 to 500 pounds
   (2) 50 to 60 pounds
   (3) 100 to 300 pounds
   (4) 700 to 1000 pounds

36. Extra nitrogen applied to lawn grass will result in
   (1) spotty, discolored blades of grass
   (2) low drought resistance
   (3) low disease resistance
   (4) rich, heavy growth

37. To carry water to the uppermost branches of a tree, the plant's osmotic power must be
   (1) doubled
   (2) tripled
   (3) supplemented
   (4) given artificial aid

38. To avoid wilting on a hot day, a plant must
   (1) cut down on sugar production
   (2) increase the amount of evaporation from its leaves
   (3) convert more starch to sugar
   (4) produce more enzymes

39. If the human ear could hear the full range of wave frequencies, a tropical forest at noonday would sound like
   (1) a hushed temple
   (2) a symphony orchestra
   (3) a busy market place
   (4) the roar of New York City

40. Basic to the furnishing of water to the plant is the power of
   (1) enzyme action
   (2) osmosis
   (3) solar action
   (4) starch conversion

THAT IS ALL! WE ARE MOST GRATETFUL TO YOU FOR YOUR ASSISTANCE. PLEASE DO NOT DISCUSS THESE MATERIALS WITH OTHER STUDENTS. IF YOU ARE INTERESTED IN LEARNING YOUR RATING ON THE QUIZ, MR. WRIGHT WILL BE GLAD TO TALK WITH YOU ABOUT THEM. GET AN APPOINTMENT WITH HIM EARLY NEXT SEMESTER. MANY THANKS!
QUIZ ON GENERAL KNOWLEDGE OF PLANT LIFE

FORM B

By Francis P. Robinson and James C. Wright for Research Purposes at The Ohio State University

Reading time: (minutes)

NAME: ___________________________ COLLEGE: BA ED IA
(please print) (circle)

DIRECTIONS: THE PURPOSE OF THIS QUIZ IS TO MEASURE YOUR GENERAL KNOWLEDGE AND INFORMATIONAL BACKGROUND ON PLANT LIFE. WHEN THE SIGNAL IS GIVEN START ANSWERING THE FORTY MULTIPLE-CHOICE QUESTIONS ON THE FOLLOWING PAGES. GIVE A SERIOUS RESPONSE TO EVERY QUESTION EVEN THOUGH DOING SO MAY SEEM QUITE EASY OR VERY DIFFICULT. EACH ITEM HAS FOUR CHOICES FROM WHICH YOUR ANSWER IS TO BE SELECTED. CHOOSE THE WORD OR PHRASE WHICH SEEMS THE BEST FOR COMPLETING THE STATEMENT OR FOR ANSWERING THE QUESTION AS THE CASE MIGHT BE. GIVE SOME RESPONSE TO EACH ITEM EVEN IF GUESsing IS NECESSARY BUT AVOID WILD GUESsing. THERE IS NO TIME LIMIT. YOU SHOULD, HOWEVER, BE ABLE TO COMPLETE THE QUIZ IN ABOUT FIFTEEN MINUTES.
1. Of the following, the most important to the continued life of mankind is
   (1) the development of electric power systems
   (2) expansion of the food processing and canning industry
   (3) the conversion of starch by plants
   (4) the manufacture of chlorophyll by plants

2. Aluminum is compounded with phosphorus, making the latter unavailable to plants if the pH of the soil drops below
   (1) 7.8
   (2) 6.9
   (3) 5.6
   (4) 5.0

3. Plants manufacture food from sunshine, water, and air coupled with
   (1) soil
   (2) minerals
   (3) oxygen
   (4) carbon

4. Potassium is not available as plant food if the pH of the soil rises above
   (1) 6.9
   (2) 7.3
   (3) 8.0
   (4) 6.5

5. Food is stored in the plant as
   (1) chlorophyll
   (2) starch
   (3) sugar
   (4) sap

6. As an essential for carrying on life processes, each plant cell contains a
   (1) grubestake
   (2) protoplast
   (3) colony
   (4) chloroplast
7. The conversion of starch to sugar is achieved through the action of
   (1) glucosides
   (2) imlin
   (3) enzymes
   (4) plant acids

8. Soil bacteria do their best work when the pH condition of the soil stands between
   (1) 6.0 and 6.9
   (2) 7.0 and 8.0
   (3) 5.5 and 7.3
   (4) 5.0 and 8.0

9. Which of the following desirable conditions would most likely be brought about by feeding a plant extra nitrogen?
   (1) soft, crisp leaves
   (2) heavy root growth
   (3) large flower formation
   (4) abundant seed formation

10. Compared to the density of water, the density of plant sap is
    (1) greater
     (2) the same
     (3) slightly less
     (4) a great deal less

11. Two trace minerals which are essential to the manufacture of chlorophyll in the plant are
    (1) magnesium and calcium
     (2) manganese and iron
     (3) calcium and iron
     (4) nitrogen and potash

12. The amount of water used by the plant in making sugar, as compared to the amount used to prevent wilting is
    (1) much smaller
     (2) much larger
     (3) equal
     (4) slightly smaller

13. The fixed fatty oils which the plant produces are reserve materials which are stored up in the
    (1) seeds
     (2) stem
     (3) leaves
     (4) blossoms
11. It is claimed that the success or failure of a farmer's crop in the corn belt can be decided by the July rainfall varying from its usual quantity as much as
   (1) one inch
   (2) three inches
   (3) 1/4 of an inch
   (4) 1/2 of an inch

15. In summer, a big tree must do the equivalent of carrying 500 bucketfuls of water up a ten-foot flight of stairs every
   (1) 20 hours
   (2) 5 hours
   (3) 15 hours
   (4) 10 hours

16. The operation of the slender root of a seedling plant most nearly resembles the reverse operation of a miniature
   (1) hose nozzle
   (2) spigot
   (3) plastic tube sprinkler
   (4) canvas hose soaker

17. The plant's house is built of bricks composed of
   (1) inulin
   (2) sugar
   (3) starch
   (4) silica

18. If it were not for the construction of individual cells, plants and trees would all be
   (1) masses of slime
   (2) rigid, solid structures
   (3) lifeless
   (4) colorless

19. Probably the most versatile secondary substance manufactured by the plant is
   (1) sugar
   (2) cellulose
   (3) starch
   (4) inulin

20. A single cubic inch of fine cork bark may contain as many cells as
   (1) 9 to 10 billion
   (2) 6 to 8 billion
   (3) 4 to 5 billion
   (4) 2 to 4 billion
21. The bustling activity and diversity of industry observable in the plant factory most nearly reminds us of the human activity in a city like
(1) Washington, D. C.
(2) Miami, Fla.
(3) Cleveland, Ohio
(4) Hollywood, Calif.

22. Which of the following wave lengths of light is the plant most likely to be able to use in its food manufacturing?
(1) yellow
(2) red
(3) green
(4) violet

23. Nitrogen from organic sources can be broken down into the nitrate nitrogen which the plant can use, when nature resorts to the use of
(1) heat
(2) chlorophyll
(3) bacteria
(4) enzymes

24. Which of the following human activities is least likely to have its counterpart in the bustling industry of plant life?
(1) perfume distillery
(2) textile weaving
(3) ceramic design
(4) varnish manufacturing

25. If the pH of the soil stood at 4.5 we could be confident that any phosphorus present would be combined with iron and therefore
(1) poisonous
(2) insoluble
(3) soluble
(4) irredeemable

26. Huxley claimed that we are unable to truly appreciate the industry carried on by the plant kingdom because of our inadequate
(1) eyes
(2) ears
(3) nose
(4) tools
27. The heat regulating system of the plant
   (1) is available but is seldom used
   (2) functions in a simple manner
   (3) is complex and functions in many ways like the complex cooling systems used by man
   (4) consists solely of evaporation at the leaf surfaces

28. In man's laboratories it requires a heat of 1300 degrees C to separate
   (1) the chlorophyll grains from the plant
   (2) grape sugar from starch
   (3) imulin from cellulose
   (4) carbon from carbon dioxide

29. Cellulose is primarily composed of
   (1) sugar
   (2) lignin
   (3) imulin
   (4) starch

30. Sunshine is essential to the production of grape sugar because
   (1) it provides the red and blue light rays
   (2) it furnishes the necessary 1300 degree heat
   (3) it is the only source of chlorophyll
   (4) it supplies the necessary green and purple rays

31. Extra amounts of potassium when applied to plants results in
   (1) early maturity of blossoms
   (2) high drought resistance
   (3) increased flower production
   (4) sustained seed production

32. The wounds of injured plants benefit from their being salved with
   (1) morphine
   (2) tartaric acid
   (3) waxes
   (4) resins

33. Probably the best source of agricultural phosphorus, so far as percentage yield is concerned, is found in
   (1) animal manure
   (2) triple super phosphate
   (3) bone meal
   (4) acid phosphate
34. For every pound of dry substance produced by a plant, water is given off at a rate of from
(1) 200 to 500 pounds
(2) 100 to 300 pounds
(3) 50 to 60 pounds
(4) 700 to 1000 pounds

35. Lignin when added to the plants' cells gives the plants their
(1) woodiness
(2) water-proofing
(3) gumminess
(4) autumn hues

36. In order to carry water to the uppermost branches of the tree, the plant's osmotic power must be
(1) tripled
(2) doubled
(3) given artificial aid
(4) supplemented

37. The interior of a plant develops considerable heat during the growing season due to
(1) poor ventilation
(2) friction
(3) chemical reactions
(4) concentration of the sun's rays

38. To prevent wilting on a hot day, a plant must
(1) convert more starch to sugar
(2) produce more enzymes
(3) increase the amount of evaporation from its leaves
(4) cut down on sugar production

39. Basic to the furnishing of water to the plant is the power of
(1) enzyme action
(2) osmosis
(3) solar action
(4) starch conversion

40. The pH has little or no direct effect upon the manner in which the plant absorbs
(1) ammonia
(2) manganese
(3) nitrogen
(4) potash

This is the end! Many thanks for your cooperation and assistance.
QUIZ ON PLANT LIFE

FORM C

NAME: ___________________________________ READING TIME: __________ (minutes)

MAJOR: ___________________________________ (if decided)

1149
DIRECTIONS: Choose the word or phrase which best completes the statement or best answers the question, placing the number of this word or phrase in the blank to the left. There is no penalty for guessing so answer every question even if guessing is necessary.

1. A radiator is to an automobile as what is to a plant?
   (1) roots
   (2) bark
   (3) limbs
   (4) leaves

2. Potassium is not available as plant food if the pH of the soil rises above
   (1) 7.3
   (2) 8.0
   (3) 6.9
   (4) 6.5

3. The conversion of starch to sugar is achieved through the action of
   (1) inulin
   (2) glucosides
   (3) plant acids
   (4) enzymes

4. Food is stored in the plant as
   (1) sap
   (2) chlorophyll
   (3) starch
   (4) grape sugar

5. Of all the materials available to animals for food, the percentage furnished by plants is
   (1) 100
   (2) 50
   (3) 90
   (4) 60

6. The cells of a single cubic inch of fine cork may number
   (1) one billion
   (2) two one half billion
   (3) one million
   (4) 1/2 billion

7. When we know the pH rating of the soil we can readily tell what minerals are
   (1) present
   (2) present but locked-up
   (3) absent
   (4) needed for plant growth
8. In the description of a parallel between the plant's sugar industry and the human industrial factory, the plant's leaves correspond to the factory's
   (1) raw materials
   (2) building
   (3) work rooms
   (4) workmen

9. In general it can be said that the best pH range for most field and garden crops is
   (1) 7.0 to 7.9
   (2) 5.0 to 6.0
   (3) 5.0 to 7.0
   (4) 6.0 to 6.9

10. Two trace minerals which are essential for the manufacture of chlorophyll in the plant are
    (1) nitrogen and potash
    (2) magnesium and calcium
    (3) manganese and iron
    (4) calcium and iron

11. The production of grape sugar depends upon the action of which of the following light rays on chlorophyll?
    (1) green
    (2) violet
    (3) orange-yellow
    (4) red-blue

12. The fundamental factor causing trees to start budding in the northern springtime is the penetration of the walls of the plant's starch cells by
    (1) frost crystals
    (2) ultra violet rays
    (3) enzymes
    (4) warm water

13. In its natural or original state, the substance which does the fundamental work of all organic matter is
    (1) tougher than shoe leather
    (2) about as thin as egg white
    (3) thinner than water
    (4) about as dense as milk

14. The early settlers grew their plants without commercial fertilizer and for crop success they depended largely upon
    (1) classifying soils "sour" and "sweet"
    (2) the chemistry knowledge of the local schoolmaster
    (3) the experience of the Indians
    (4) crop rotation
15. Starch in plants is potential food which is
   (1) used in the form in which it is stored
   (2) used in a form partially converted to sugar
   (3) used only after being converted to sugar
   (4) not used by the plant but is stored for the use of animals which will eat the plant

16. We are able to use today the warmth and energy given off by the sun millions of years ago through the use of starch converted by nature into
   (1) alcohol
   (2) oil
   (3) cane sugar
   (4) electricity

17. Grape sugar is a product of
   (1) grape vines only
   (2) all types of climbing plants
   (3) all fruit-bearing plants
   (4) all living plants

18. The most essential part of any living cell is its
   (1) wall contour
   (2) chlorophyll
   (3) interstices
   (4) protoplasm

19. One noted Dutch Biologist, upon observing the plant through the newly-invented microscope, destroyed his notes, holding that the observations were
   (1) anti-religious
   (2) sacreligious
   (3) inhumane
   (4) inconceivable

20. Of the following wave lengths of light, which is the plant most likely to be able to use in its food manufacturing?
   (1) green
   (2) yellow
   (3) violet
   (4) red

21. The substance which does the fundamental work of all organic functioning is known as
   (1) chlorophyll
   (2) viscid matter
   (3) protoplasm
   (4) cellulose
22. Of the following activities carried on by human beings, which is least likely to have its counterpart in the bustling industry of plant life?
(1) textile weaving
(2) perfume distillery
(3) varnish making
(4) ceramic design

23. There are grounds for accusing the budding plant seed of
(1) truancy
(2) child labor
(3) tax evasion
(4) sabotage

24. If the pH of a soil was found to stand at 4.5 we could be confident that any phosphorus contained therein would be combined with iron and therefore be
(1) insoluble
(2) poisonous
(3) irredeemable
(4) soluble

25. Bushel for bushel, the crop yields of today, compared with those of our grandfathers are
(1) more costly
(2) more dependent on nature and less costly
(3) more deliberately controlled and less costly
(4) more dependent on rule of thumb and less costly

26. Which of the following is least dependent on cellulose for its make-up
(1) a chair
(2) the chemist's porcelain filter
(3) a rayon dress
(4) the chemist's filter paper

27. Determining the pH of a soil helps to show whether the minerals contained in the soil are
(1) acids
(2) soluble
(3) natural
(4) synthetic

28. Determination of the proper fertilizer to be used in any instance will depend largely on
(1) the condition of the soil
(2) the crop to be raised
(3) the pH factor
(4) the crop and the soil involved
29. When extra amounts of potassium are applied to plants the results are
(1) high drought resistance in the plant
(2) increased flower production
(3) sustained seed production
(4) early crop maturity

30. Plant roots expand their moisture-acquiring power by the use of a soil function called
(1) capillary attraction
(2) capillary extraction
(3) capillary expansion
(4) capillary contraction

31. The main by-product of the plant's food-building chemistry is
(1) oxygen
(2) carbon
(3) sugar
(4) imulin

32. For every pound of dry substance produced by a plant, water is given off at a rate of from
(1) 700 to 1000 pounds
(2) 50 to 60 pounds
(3) 200 to 500 pounds
(4) 100 to 300 pounds

33. In order that water may be carried to the uppermost branches of large trees, the plant's osmotic powers must be
(1) given artificial aid
(2) tripled
(3) supplemented
(4) doubled

34. The functions of a plant are likened to those of a busy city in that
(1) various parts cooperate to maintain the well-being of the whole
(2) the plant duplicates various businesses found in the city
(3) the plant produces various products found in the city markets
(4) the plant also depends on sunshine, air, minerals, and water
35. One of the most important man-controlled factors in plant cultivation is
   (1) the variety of seed planted
   (2) the type of cultivation followed
   (3) the amount of moisture provided
   (4) the type of nourishment available

36. To prevent wilting on a hot day, a plant must
   (1) cut down sugar production
   (2) increase evaporation from its leaves
   (3) convert more sugar to starch
   (4) produce more enzymes

37. A good slogan for any member of the plant kingdom might be
   (1) "cooperate or die"
   (2) "independence or death"
   (3) "love thy neighbor"
   (4) "leaders are made not born"

38. Basic to the furnishing of water to the plant is the power of
   (1) enzyme action
   (2) solar action
   (3) lunar action
   (4) osmosis

39. Lichens have been known to eat marble in order to obtain
   (1) bacteria
   (2) starch
   (3) mineral matter
   (4) moisture

40. The particle surface exposed to the moisture draft of a tree root system in just one cubic foot of clay may be as much as
   (1) 5 acres
   (2) 3 acres
   (3) 6 acres
   (4) 1 acre

That's all for now, folks! Your assistance and cooperation are really appreciated. Please avoid disturbing others who may still be working on the quiz.
I, James Clyde Wright, was born in Gregg, Pennsylvania, January 4, 1913. I received my secondary school education in the public schools of the town of Oakdale, Pennsylvania. My undergraduate training was received at Muskingum College, from which I received the degree Bachelor of Arts in 1935. While I was in residence at Duke University, I acted in the capacity of research assistant to Dr. William McDougall during the years 1936–38. From The Ohio State University I received the degree Master of Arts in 1944. While in residence at Ohio State I acted as graduate assistant, teaching assistant, and assistant instructor in the Department of Psychology. I held these positions off and on over a period of two and one-half years while completing the requirements for the degree Doctor of Philosophy.
TEST MATERIALS USED IN THE FIRST PILOT STUDY

1. The Reading Selection
2. Two Thirty-item Quizzes
   Group I
   Group II
EXPLORING THE MYSTERIES OF PLANT LIFE
By William J. Showalter Sc.D., L.L.D.

PART I

HOW PLANTS WORK

All the factories, all the railroads, all the mines, all the automobiles, all the activities of men of whatsoever nature that require power, do not utilize as much energy as is developed by the plant world.

Out of intangible sunshine, insubstantial air, and clear water, coupled with a modicum of mineral matter from the soil, plants must manufacture all the food that keeps alive the innumerable hosts of animals of the earth, store up all the heat that keeps humanity warm and cooks its food, furnish most of the power that drives its industries, and provide the raw material for all the clothes mankind wears and many of the products of which his factories, his houses, his furniture, and his books are made.

Would you know how much of a plant is fabricated of sunshine, air, and water, and how little of solids from the earth? Then burn the plant and notice the thin layer of ash remaining. All else has been made up from subtle sunbeams, thin air, and plain water.

Every plant, from a simple moss to a giant tree, is in reality a vast household of individual entities working together, in fine cooperation and close harmony, to a common purpose. One group pumps up the water required by the community, which is carried to the points where it is needed by another group.

Others, respectively, obtain the solid food from the ground, mix it with air, sunshine and water to make a substantial dish; carry the food to the various parts of the household; store up the leftovers; build additions to the house; and prepare to send out colonies from the parent rootler, fully "grubstaked" and equipped to gain a foothold wherever they may settle down.

One observer sees the individual plant as a counterpart of a busy little city, teeming with life and bustling with industry. Here goes on the pulling down and building up characteristic of progressive communities; the streets and alleys are thronged with workers; here are dairies and milkshops dispensing their supplies; jewelers' shops preparing crystals; sugar refineries manufacturing sweets; starch factories storing foodstuffs; perfumers' laboratories distilling scents; varnish makers developing resins and waxes; color establishments preparing dyestuffs.
EACH PLANT BUILDS ITS OWN CELL CITY

The ways by which individual plants build their houses and do their work form a story no less fascinating than the methods by which the flowers hand their lives on to future generations, though they themselves are destined to perish.

The seed that finds its "place in the sun" settles down and waits the hour when propitious conditions of moisture and warmth shall awaken the germ of life that sleeps within.

Once this little speck of living matter is aroused in its tiny cell it becomes busy, sending out bits of itself to the neighborhood around it. Each of these promptly builds itself a tiny house of its own, with walls a thousand times thinner than the finest gossamer, but still constructed of microscopic bricks of cellulose, between the interstices of which the pioneering protoplasm can maintain connection with the parent cell, and at the same time reach out and start its own children to building their cells.

The size of these cells varies. A single cubic inch of fine cork may have as many of them as there are people in the world, yet each one has been built and inhabited by a protoplast, which has not only patiently thickened the wall of its house, layer by layer, but has also done its bit in the life of the community of which it is a part.

When the microscope was first invented and philosophers peered into these little houses and saw the inchoate plasm within, amusement and awe possessed them. Jan Swammerdam, the great Dutch student, became almost insane at the marvels his lens revealed, and finally destroyed his notes, holding it a sacrilege to unveil and thereby profane the wonders hitherto beyond human knowledge.

The things the pioneers saw were considered delusions, until the members of the Royal Society of London peered through a microscope and jointly signed a paper saying they had seen these wonders with their own eyes.

NOONDAY "SILENCE" IN A TROPICAL FOREST

A somewhat viscid substance, not unlike the white of an egg, though thicker, the bit or protoplasm within a cell does the fundamental work of all organic matter.

Huxley, in speaking of the stirring activities of the busy little protoplasts, or individual bits of protoplasm that build their several cells and do their respective community tasks in a plant's activities, says: "The wonderful noonday silence of a tropical forest is, after all, due only to the dullness of our hearing; and could our ears catch the murmur of these tiny melastromas, as they whirl in the innumerable myriads of living cells which constitute each tree, we should be stunned, as with the roar of a big city."
And whoever has seen the radio receiving set catch the infinitely small impulses of electricity and amplify them into sounds that fill a loud speaker can appreciate his statement.

As it grows, the little community of protoplasts that build a plant divides its labors, and the complex activities of the growing flower begin.

The whole community of cells constitutes the plant, and the delicate interstices of their walls the inhabitant of each communicates with those of all the other cells, so that the living substance of the entire structure is in constant contact and forms a united mass.

The building of their own tiny houses by the individual protoplasts is an immeasurable boon to humanity. Without these our plants and trees would never exist and all we would know would be masses of slime.

THE INNER-LIFE OF A PLANT

Let us reduce ourselves to the size of a molecule of water and ramble through one of these cell cities we call a daisy, noting the hustle and bustle and industry constantly taking place.

We promptly discover that one of the principle things going on is the manufacture, by the protoplasts, of a myriad tiny green grains which have been named chlorophyll. These grains have the power to screen out all rays of light except the red and most of the blue, indigo, and violet series, which they use in their work.

Concentrating these useful rays on the stream of minute particles of carbon dioxide which comes into the leaves through the pores or stomata, the chlorophyll breaks the carbon and oxygen apart and unites the carbon with water, which thereupon becomes grape sugar.

In man's laboratories it takes a temperature of 1,300 degrees C., enough to turn the hardest steel into liquid, to separate the carbon and oxygen atoms of the carbon dioxide molecules exhaled by animals and absorbed by plants. But the little laboratory of the cell city does it without difficulty, and in so doing fabricates the basic food of all organic life, grape sugar.

To make a pound of the sugar, our guide tells us, the plant must work over nearly ninety gallons of carbon dioxide, in the extraction of which it has had to filter thousands of gallons of air. The sugar factory works from sunup to sundown, the eight-hour day being unknown there. But it operates only when the leaves are out.

A LEAF AS A FACTORY

How closely the sugar industry in the plant parallels the activities of the human factory is shown by the fact that the leaf corresponds to a building, the cells to the several rooms therein, the blue and red sunlight rays to the power employed, the chlorophyll to the machinery used, carbon...
dioxide and water to the raw material utilized, grape sugar to the manufactured product, and oxygen to the by-product.

As we move along we see a constant stream of carbon dioxide particles rushing by, passing through the cell walls, where they meet the molecules of water. The chlorophyll grains turn their burning glasses with their red and blue rays upon the materials thus gathered into the rotort and grape sugar is formed.

After the chlorophyll grains have made the grape sugar, some new workers take it and transform it into starch, which is stored in cells for future use, just as the iron manufacturer converts his molten metal into pig iron, stores it, and melts it again when he wants to use it. A thousand square feet of leaf surface will manufacture one pound of starch in five hours of sunlight.

The action of plants in storing up starch closely parallels that of business men in accumulating estates. Just as the business man invests his funds so that they will be available for conversion into ready money if he needs it, so the plant puts by its earnings in the form of starch ready for conversion into the coin of its realm, sugar, if necessary. And just as the business man bequeaths his estate to his children when he dies, so the plant transmits its surplus to its posterity when it passes.

Men and animals have learned to rob the plant of its savings and its children of their patrimony by eating things rich in starch.

A third material is made by the plant which is used in its building operations— inulin. It closely resembles starch, and is fabricated by another set of workers.

While all these manufacturing activities are going on in the cell city we call a daisy, sap must also be provided, for without rich supplies of moisture and a tiny bit of mineral substance, the wheels of industry of the community cannot revolve.

So the roots act as pumps and bring into the city vast supplies of water with mineral in solution, in the proportion of a grain of minerals to a gill of water. This sap is pumped to every part of the plant and bathes the protoplasms of every cell, keeping the protoplasts moist and in high spirits.

### THE ROLE OF CELLULOSE

Out of the sugar, starch, and inulin fabricated by the three types of workers we have visited, other products are built, such as cellulose, which forms the microscopic bricks out of which the cell walls are constructed, and the fixed or fatty oils which are stored up in seeds, bulbs, etc., as reserve materials for future exigencies.

As our guide leads us on through our daisy we see the cellulose being fabricated. The fibers of cotton, the pith of woody stems, the filter paper of the chemist are familiar forms of cellulose. The plant makes it serve a double purpose, now as cell wall material, and now as a stored product that may be reconverted into sugar if needed for food.
As the cell ages, lignin may be added to give stiffness to the plant structure, making wood; other materials are employed to give hardness to the shell of nuts, waterproof character to cork, or gumminess to seeds like flax.

It is the cellulose of plants which lived long ages ago that we burn when we use coal to-day. Nature bottles up sunshine in it, so that every engine driven by coal is indirectly a solar engine, and every bit of warmth our fire affords in winter is the heat of summers millions of years past.

If we visited other plants and entered into their cell communities we would see them manufacturing the malic acid of apples and currants, the citric acid of lemons and oranges, the tartaric acid of grapes; the waxes which make some flowers, like the nasturtium, immune from wetting; the resins which salve the wounds of injured plants; the glucosides which make the wonderful hues of autumn, and the poisons which protect the plants and serve humanity, such as strychnin and morphine. Still other workers are building up the proteins or flesh formers.

But most interesting of all the products made by plants, perhaps, are the enzymes. They convert sugar into starch and starch into sugar. They have been called the tools with which the protoplasm effects the chemical results it requires. Dr. Frederick V. Coville, the eminent botanist of the United States Department of Agriculture, has shown that it is the chilling processes of winter, and not the warm sunshine alone, that causes the buds of the northern trees to open. He has described how they are driven out by the terrific forces released when the enzymes penetrate the walls of the starch cells and convert the starch into sugar.

Pumping Up a Water Supply

An examination of the machinery by which plants take in the raw materials out of which they fabricate so many marvellous substances reveals many interesting mechanisms.

Inspecting the seedling of a mustard, one finds that it has a slender root covered by a multitude of tiny hairs. At the end of the root is a growing tip.

If a potted plant is cut down to the surface of the soil and a glass tube slipped over the stump, it will be noted that the sap which would have flowed through the plant rises up in the tube to the approximate height of the original plant. This sap consists of water and mineral matter drawn out of the earth by that strange process of Nature through which the weaker of two solutions passes through a membrane separating them into the stronger.

The protoplasm acts as a membrane, and the water in the soil is drawn through it to join the sap in the root. As the volume increases the osmotic force drives the excess up into the plant structure.

The hairs of plant roots are ever busy pumping in water. Through capillary attraction in the soil, particles several feet away are made to contribute their moisture to the hairs. A cubic foot of clay may have as much as three acres of particle surface exposed to the moisture drafts of a root system.
Between the soil the plant uses in the manufacture of grape sugar and the much larger quantity it must pass through its system to keep the plant from wilting, heavy drafts are levied on the soil. An oak tree with 700,000 leaves is estimated to give off 120 tons of water a season; an acre of grass has been found to give off over three tons in a single day. From 200 to 500 pounds of water are given off by plants for every pound of dry substance manufactured.

**SUCTION AND FORCEFUL PULLS**

It has been estimated that if the rainfall during the month of July, in the corn belt of the Mississippi Valley, is one-half inch short of the three inches required to make a full crop, the half-inch shortage costs the farmer five dollars for every one of the millions of acres of corn grown in that belt.

The osmotic power in the plant is supplemented by other agencies to carry the water to the top of the tree. As a big tree must do the equivalent of carrying 500 bucketfuls of water up a ten-foot flight of stairs every ten hours in mid-summer, one may judge how important the process is.

The chemical processes going on in the interior of a plant in the growing season develop considerable heat, just as the fuel combustion and friction in an automobile motor makes it hot. To carry off the heat engendered in his engine the motorist employs a cooling system, with water caused to circulate in a radiator system.

The plant needs even more effective cooling to keep down the heat of chemical change. The major portion of the water it demands is employed to keep its "radiator" full in order that evaporation on the leaf surface may reduce the plant's temperature.

Many plants have damper systems, whereby excessive radiation is checked, a method corresponding to our employment of humidifiers in our home heating units.

The mineral matter drawn into plants in solution is made available in many ways. The earthworms are allies of plant growth. It has been estimated that an acre of arable land contains an earthworm population of 130,000, and that they pass two tons of soil through their gizzards every season, converting it into humus rich in soluble materials.

Lichens will eat into marble like acids in getting mineral material for their up-building. Different kinds of plants need different minerals—potatoes and turnips call for plenty of potash, wheat and corn for much silica, beans and clover for considerable quantities of lime.
DIRECTIONS: Choose the word or phrase which best completes the statement or best answers the question, placing its designating letter in the blank. Answer every question even if it requires guessing.

1. Relative to the amount used by man in all his activities and operations, plant life develops a super-abundance of (1) minerals; (2) energy; (3) oxygen; (4) perfume.

2. Plants manufacture food from sunshine, water, and air coupled with (1) mineral salts; (2) soil; (3) oxygen; (4) carbon.

3. Every plant, whether it is a giant tree or a simple moss is dependent for its existence upon the operation of (1) a community of entities; (2) by animals; (3) insect life; (4) seasonal variations.

4. Of all the raw materials available to animals for food, the percentage provided by plants is (1) 90; (2) 50; (3) 100; (4) 60.

5. The cells of a single cubic inch of fine cork may number (1) 2³ billion; (2) one billion; (3) 1½ billion; (4) one million.

6. Like the 17th Century political powers, some plants can prepare and send out (1) spores; (2) explorers; (3) colonies; (4) armies.

7. The things the scientific pioneers saw when they peered at plant life through the early microscope were termed (1) delusions; (2) scientific; (3) profane; (4) biological.

8. To awaken the germ of life that sleeps within it, the plant seed must wait for (1) moisture; (2) propitious conditions; (3) warmth; (4) sunlight.

9. The community of cells which constitute the plant are in constant intercommunication by means of (1) electrical impulses; (2) delicate interstices; (3) chemical messengers; (4) air waves.

10. Each plant cell enshrouds a (1) grubstake; (2) colony; (3) protoplast; (4) cork.

11. If it were not for the construction of individual cells, plants and trees would be (1) masses of slime; (2) rigid, solid structures; (3) invisible; (4) invisible.

12. In the description of the parallel between the plant factory and the human factory, the plant's leaves correspond to the factory's (1) raw materials; (2) building; (3) work rooms; (4) finished product.

13. In the plant factory, the carbon of the CO₂ is separated from the oxygen and permitted to unite with H₂O through the action of (1) chlorophyll; (2) ultra violet; (3) pores; (4) stomachs.

14. Grape sugar production is dependent upon the action of chlorophyll in (1) green rays; (2) violet rays; (3) orange-yellow rays; (4) red rays.

15. The basic food fabricated by plant chemistry for all organic life is (1) chlorophyll; (2) protoplasm; (3) grape sugar; (4) starch.

16. To make the beautiful hue of green leaves, the plant must produce of (1) strychnine; (2) result; (3) chlorophyll; (4) starch.

17. In order to permit storage, the plant converts fat to carbohydrate into (1) honey; (2) starch; (3) cellulose; (4) chlorophyll.

18. The power of the plant's root system to pump water is usually in relation to the growth of the plant beyond (1) the surface of the soil; (2) its first branch; (3) its longest branch; (4) its first root.

19. The basic material used by the plant to build its buildings of atoms manufactured by the plant itself is (1) carbon dioxide; (2) oxygen; (3) water; (4) cellulose.
20. The amount of water used by the plant for manufacture of oxygen as compared to the amount of water used to prevent wilting is (1) much smaller; (2) much larger; (3) about the same; (4) slightly smaller.

21. The rich supplies of moisture and bits of mineral necessary for the continued operation of the wheels of industry in the plant are carried to it by (1) its roots; (2) sap; (3) fat; (4) intestine.

22. The financial success or failure of farmers in the corn belt can be determined by the July rainfall varying from the usual quantity as much as (1) one inch; (2) three inches; (3) 4 inches; (4) 6 inches.

23. The fixed fatty oils which the plant produces are stored in materials which are stored up in the seeds are (1) beans; (2) peas; (3) beans; (4) limes.

24. In midsummer a big tree must do the equivalent of carrying 5,000 bushels of water up a ten-foot flight of stairs every (1) 20 hours; (2) 16 hours; (3) 14 hours; (4) 10 hours.

25. We are able to use today the warmth and energy given off by the sun millions of years ago through the use of cellulose converted into (1) oxygen; (2) alcohol; (3) coal; (4) wood.

26. In order to keep its temperature down, the plant resort to evaporating much water at its (1) leaf surfaces; (2) root tips; (3) twig ends; (4) bark crevasses.

27. The "tools of protoplasm" which are used to convert sugar to starch and starch to sugar are called (1) glucosides; (2) starches; (3) proteins; (4) enzymes.

28. By passing soil through their gizzards, earthworms produce a plant food which is known as (1) humus; (2) nitrogen; (3) guano; (4) vegetable.

29. Water and minerals from the soil are drawn into the plants through their roots by a physical process known as (1) syphonage; (2) osmosis; (3) suction; (4) filtration.

30. The proper growth of beans is dependent upon a plentiful supply of (1) humus; (2) lime; (3) potash; (4) water.

IF THIS IS YOUR SECOND SET OF QUESTIONS,
PLEASE MAKE CERTAIN TO FILL IN THE FOLLOWING:

Reading Time: ___________ minutes

Name: _______________________

College Year (i.e. Freshman or Senior)
1. The least of the sources supplying plants with materials for self-building is (1) the sun; (2) the air; (3) water; (4) the earth.

2. Of all the raw materials which are available to man for clothing, the percentage provided by plants is (1) 90; (2) 50; (3) 100; (4) 60.

3. A plant's house is built of bricks composed of (1) inulin; (2) plastic; (3) chlorophyll; (4) cellulose.

4. In respect to food preparation and handling, the plant compares favorably with the (1) bakery; (2) restaurant; (3) grocery; (4) cafeteria.

5. One noted Dutch biologist, upon observing the marvels of plant life through the microscope, destroyed his notes, holding that the observations were (1) inaccurate; (2) unbelievable; (3) unreligious; (4) beyond imagination.

6. The diversity of bustling activity observable in plants readily reminds one of a modern (1) farm; (2) athletic event; (3) battle; (4) industrial city.

7. The material which does the fundamental work of all organic matter is known as (1) chlorophyll; (2) viscid matter; (3) protoplasm; (4) cellulose.

8. There are grounds for accusing the plant seed of (1) child labor; (2) treason; (3) tax evasion; (4) sabotage.

9. Huxley claimed that if our ears were more acute, we would hear the forest at noonday as (1) a great orchestra; (2) a roaring city; (3) a lullaby; (4) a purring cat.

10. Chlorophyll grains have the power to screen out certain (1) impurities; (2) chemicals; (3) light rays; (4) gross granules.

11. One of the principal products of the protoplasts is (1) carbon dioxide; (2) chlorophyll; (3) indigo; (4) perfume.

12. Ready cash obtainable from convertible investments in man's economy is comparable in the plant world to (1) starch; (2) grape sugar; (3) sap; (4) chlorophyll.

13. In man's laboratories, carbon is separated out of CO₂ only after applying centigrade heat of (1) 500 degrees; (2) 100; (3) 1300; (4) 1000.

14. Cotton fiber, the pith of woody stems, the chemist's filter paper, are all common forms of (1) plant starch; (2) cellulose; (3) chlorophyll; (4) inulin.

15. To make one pound of basic food, a plant must consume Carbon Dioxide to the extent of nearly (1) 130 gallons; (2) 60; (3) 90 gallons; (4) 270 gallons.

16. The wounds of injured plants benefit from their being salved with (1) morphine; (2) tartaric acid; (3) waxes; (4) resins.

17. The duration of sunlight required for 1000 square feet of leaf surface to produce one pound of basic food is (1) 10 hours; (2) 20 hours; (3) 8 hours; (4) 5 hours.

18. Plant roots expand their moisture acquiring power 800 by the use of a soil phenomenon called (1) osmosis; (2) mitosis; (3) capillary attraction; (4) capillary contraction.

19. The main by-product of the plant's food building chemistry is (1) oxygen; (2) carbon; (3) sugar; (4) inulin.
20. For every pound of dry substance a plant produces, they give off at a rate of (1) 200 to 500 pounds; (2) 50 to 60; (3) 100 to 300; (4) 700 to 1000.

21. The proportion of mineral in solution in the water supplied to the plant by its roots-pumps is (1) 2 grains to a gill; (2) 5 grains to a quart; (3) 10 grains to a quart; (4) 16 grains to a gallon.

22. To carry water to the uppermost branches of a tree, the plant's osmotic power must be (1) doubled; (2) tripled; (3) supplemented; (4) given artificial aid.

23. Linguin may be added to the plant cells as they age, giving the plant its (1) water-proofing; (2) woodiness; (3) gumminess; (4) rubbery character.

24. The interior of a plant during the growing season develops considerable heat due to (1) poor ventilation; (2) friction; (3) chemical reactions; (4) moving molecules.

25. Just as orange and lemon plants produce citric acid, apples and currants produce (1) tartaric acid; (2) malic acid; (3) oxalic acid; (4) formic acid.

26. Earthworms provide plants with (1) diseases; (2) ventilating perforations; (3) soluble minerals; (4) moisture.

27. The primary factors causing buds to open on northern trees in spring are (1) the chill of winter; (2) the warmth of spring; (3) conversion of sugar to starch; (4) a combination of choices 1 and 2.

28. In order to obtain mineral matter, marble has been eaten by a type of plant life known as (1) silica; (2) humus; (3) lichens; (4) potash.

29. The particle surface exposed to the moisture draft of a tree root system in just one cubic foot of clay can be as much as (1) 10 acres; (2) 6 acres; (3) 1 acre; (4) 3 acres.

30. To assure proper growth, potatoes need a goodly supply of (1) lichens; (2) lime; (3) potash; (4) silica.

Your Name: ____________________________________________________________________

College Year: _________________________________________________________________

(i.e. Fr Soph, Jr, Sr Grad)

If this is your second set of questions:

Reading time: Minutes ________________ Second: ________________