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ABSTRACT

A comparison is presented of alternate-choice and true-false item forms used in an undergraduate natural science course. The alternate-choice item is a modified two-choice multiple-choice item in which the two responses are included within the question stem. This study (1) compared the difficulty level, discrimination level, reliability, and criterion related validity of the alternate-choice item form and content equivalent true-false item form; (2) investigated if it is practical to judge whether the alternate-choice item version with the correct answer listed first or the version with the incorrect answer first is the better form of the item, and whether the true form of a true-false item or the false form is the better type of this item version; and (3) examined the effects of placing the correct answer first or the incorrect answer first on item difficulty, item discrimination, reliability, and criterion related validity of the item. The correct answer and best distractor of a multiple-choice item (from a 400 question item pool) were converted to an alternate choice format to produce two tests, a mid-term and a final exam. The alternate-choice item was found less difficult than the true-false item, replicating previous findings for this item type. However, findings concerning greater discrimination and higher reliability of the alternate-choice item were not replicated. (PN)

A COMPARISON OF ALTERNATE-CHOICE AND TRUE-FALSE ITEM FORMS USED IN CLASSROOM EXAMINATIONS

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College instructors have a variety of item forms available for construction of classroom achievement tests. The essay and the objective-type items such as the short-answer, matching, multiple-choice, and true-false items forms have been most commonly used to sample students' knowledge of subject matter taught in the classroom.

Of these item forms, the use of true-false items on educational achievement tests has been controversial. On one side of the controversy are those who contend that the problem of guessing, the low reliability, and the difficulty in preparing good true-false items should be evidence enough that the true-false items should be abandoned in favor of three-, four, or five-response multiple-choice items (Ahman & Glock, 1967; Gronlund, 1965; Brown, 1970; and Frisbie, 1971).

On the other side of controversy are those who point out that true-false items not only have respectibly high reliabilities, but they are more efficient than multiple-choice items (Ebel, 1979; Smith, 1958; Burmeister & Olson, 1966). This high efficiency means that more true-false questions can be asked within a specific time period than can multiple-choice items, and as a result, true-false tests can provide a much broader sampling of students' knowledge of subject matter. There are those instructors who are willing to accept a lower reliability to obtain a more content valid examination.

Recently, Ebel (1982) proposed the use of what he termed the 'alternate-choice' item as a replacement for the true-false item. This alternate-choice item, as described by Ebel, is a modified two-choice multiple-choice item in which the two responses are included within the stem of the question. The placement of the two responses is not restricted to the end of the stem, but there is freedom to place the responses where they might fit best in the structure of the stem. Ebel showed that tests composed of alternate-choice items were less difficult, more discriminating, and more reliable than tests composed of true-false items. Also, because of its brevity, the alternate-choice item form provided an efficiency similar to that of the true-false item in measuring examinees' knowledge. It should be noted that the alternate-choice and true-false items in Ebel's tests were not equivalent in content.

Earlier, Smith (1958) examined what he called the 'double-choice' item. This item is written in a form similar to the alternate-choice item constructed by Ebel, but with more distinct punctuation. Smith found that the items produced reasonably reliable tests, and they were easier and quicker to write than three-, four-, and five-choice multiple-choice items. In addition, student reaction to the use of the double-choice items was extremely positive. This initial evidence indicates that the alternate-choice item form may be a superior substitute for the much disparaged true-false item form without losing the positive quality of item efficiency characteristic of the true-false item.

Need for the Study

Few empirical studies have been conducted that compare the alternate-choice type item form to the true-false item. Those that have compared these items (Ruch & Stoddard, 1925; Charles, 1926) have found results that differ from those of Ebel (1982).

In two research studies comparing the two-choice multiple-choice to true-false items, one study (Ruch & Stoddard, 1925) found the two-choice items to be more reliable than the true-false items; the other (Charles, 1926) found the two-choice items less reliable than the true-false. In both of these studies, it was also found that the two-choice multiple-choice items were less difficult and showed better predictive validity than the true-false items. In a more recent study, Ebel (1982) modified the two-choice multiple-choice item by including the two responses in the stem of the item. He then compared these 'alternate-choice' items to true-false items and found that the alternate-choice items were more reliable, less difficult, and more discriminating than the true-false items. Clearly, further empirical study is needed to help clarify the status of the alternate-choice item relative to the true-false item.

Purpose of the Study

The purpose of this study was threefold: 1) to compare the difficulty level, discrimination level, reliability, and criterion related validity of the alternate-choice item form and content equivalent true-false item form; 2) to investigate if it is practical to judge whether the alternate-choice item version with the correct answer listed first (AC_{ci}) or the version with the incorrect answer first (AC_{ic}) is the best form of the item, and whether the true form of a true-false item (TF_t) or the false form (TF_f) is the best form of this item version; and 3) to examine the effects of placing the correct answer first (AC_{ci} version) or the incorrect answer first (AC_{ic} version) on item difficulty, item discrimination, reliability, and criterion related validity of the item. In this study, the best form was defined as the form that could best maximize both the choice of a correct answer from an informed student and the choice of an incorrect answer from an uninformed student.

Hypotheses

Part I

The major hypotheses in Part I of this study were:

H_1: The alternate-choice items will be less difficult than the content equivalent true-false items.

H_2: The alternate-choice items will show more discrimination ability than the content equivalent true-false items.

H_3: The reliability of the alternate-choice items will be greater than the reliability of the true-false items.

H_4: The criterion related validity of the alternate-choice items will be greater than that of the true-false items.

Part II

The major hypotheses in Part II of this study were:

H_1: Agreement between two departmental colleagues' as to the best version of an alternate-choice item will be no better than chance (50%).

H_2 Agreement between two departmental colleagues as to the best version of a true-false item will be no better than chance (50%).

Part III

The major hypotheses in Part III of this study were:

H_1: Version AC_{ci} and version AC_{ic} of the alternate-choice item will not differ significantly in difficulty level.

H_2: Version AC_{ci} and version AC_{ic} of the alternate-choice item will not differ significantly in discrimination ability.

H_3: The reliability of version AC_{ci} and version AC_{ic} of the alternate-choice item will not differ significantly.

H_4: The criterion related validity of version AC_{ci} and version AC_{ic} of the alternate-choice items will not differ significantly.

Design and Procedure

This research study was conducted in three parts. Part I was designed to examine the difficulty and discrimination levels of alternate-choice and true-false item forms; the reliabilities of the true-false subtest scores and the alternate-choice subtest scores; and the criterion related validity of these two item forms. Part II was designed to investigate practicability of judging the best version (TF_t or TF_f) of the true-false item and to determine whether the alternate-choice version with the correct-answer-first (AC_{ci}) or with the distractor-first (AC_{ci}) is the best form of the item. Part III was designed to examine the effects on difficulty, discrimination, reliability, and criterion related predictive validity of placing the correct answer first (AC_{ci}) or placing the incorrect answer first (AC_{ic}) in the alternate-choice responses.

Part I

Sample. The students that participated in Part I of this research were from seven sections of a natural science course offered at Michigan State University, Fall quarter of the 1983-84 academic year. The lectures of the seven sections were team-taught by the same two professors and although the lab sessions were not team taught, the same material was covered in each section each quarter.

The sample of students who participated did so because their instructors agreed to include the alternate-choice and true-false items on their midterm and final examinations. These students cannot be considered a random sample, since they were not chosen in such a way that each student taking this natural science course in the Fall quarter had an equal and independent probability of being selected. It can be argued, however, that these seven sections can be considered representative of the population of students taking this course in the fall quarter, particularly in regard to the cognitive skills required to master the material taught and to take the course examinations. The self-selection process used by students was not likely to result in systematic differences among sections in relation to the variables relevant to this study.

Of the 255 college freshman students enrolled in these sections, 247 took both the midterm (Test I) and the final examination (Test II). There was one student randomly eliminated to provide for equal numbers of students in the Latin Square statistical design that was used to test hypothesis 1 in Part I and Part III of this study. There were 123 students who took Form A and 123 students who took Form B of each test. More specifically, 55 students took Form A of Tests I and II, 55 students took Form B of Tests I and II, 68 students took Form A of Test I and Form B of Test II, and 68 students took Form B of Test 1 and Form A of Test II.

Materials. The examination items used in this study were drawn from an item pool of approximately 400 questions applicable to the genetics and human reproduction emphasis of the course. All items in the item pool were developed by faculty teaching natural science courses at Michigan State University. Some of the items which were applicable to genetics and human reproduction were in matching form or in a key-type multiple-choice form (the student matches items from a four- or five-item key to subsequently listed statements). However, the majority of the 400 potential items were in four-or five-choice form.

Item Conversion Procedures. The process of converting the midterm (Test I) and final (Test II) examination items from multiple-choice to alternate-choice and true-false forms was identical. The senior instructor selected 65 items for conversion to alternate-choice and true-false items for Test I, and 100 items for Test II. For each item he indicated the correct answer and the distractor he judged the most reasonable answer given by an uninformed student. All key-type items and items in which the correct response contained more than one answer or element (e.g. all the above; a and b above) were excluded from conversion, since extensive revision might effect the content of an item. Only items in which the correct response included a single answer or element were converted. A total of 26 items for Test I and 27 items for Test II met the criteria.

In the alternate-choice form suggested by Ebel, the two responses can be placed at the very end or at any other location within the stem. This freedom on placement permitted multiple-choice items to be converted to alternate-choice form in one of three ways: 1) If the stem of an item was a statement then the stem was kept intact and only the correct answer and the designated distractor were joined to the end of the stem; 2) If the item was a statement and contained duplicate wordings in both the distractor and correct answer. the duplicate wordings were made part of the stem and the word or words that made the statement correct or incorrect became the responses.

For example, the correct answer and best distractor of a multiple-choice item read:

-The most effective way of making human chromosome counts is

b) by utilizing cultured and treated red blood cells.

c) by utilizing cultured and treated white blood cells.*

In alternate-choice form it read:

-The most effective way of making human chromosome counts is by utilizing cultured and treated a) red b) white* blood cells.

3. When the stem of the original item was in question form, some rewriting was necessary. For example, an item in multiple-choice form read:

-In a DNA molecule, one strand contains the following sequence of bases: A-G-A-T-G. Which of the following represents the complementary sequence on the other strand?

a) C-C-T-A-G b) A-G-A-T-C c) T-C-T-A-G* d) U-C-U-A-G e) none of these

The stem was rewritten:

-In a DNA molecule, one strand contains the following sequence of bases: A-G-A-T-C. The complementary sequence on the other strand is a) U-C-U-A-G b) T-C-T-A-G* .

A table of random numbers was used to determine whether the correct answer or distractor would be listed first. Items were then converted from alternate-choice to true-false form by randomly eliminating either the correct response or the distractor, within the parameter that 60 percent of the items would be false. Research (Oosterhof & Glasnapp, 1974; Frisbie, 1974) has shown that true-false items in false form tend to have better discriminating ability than items in true form. Ebel (1979) suggests including more than one-half, and in some cases up to 67 percent of false-form items in a true-false test.

Test Form Development. Each item in its multiple-choice, its alternate-choice, and its true-false form (See Appendix A) was submitted to two measurement experts who independently judged them for equivalence of content. All items were judged equivalent in content. Several items that were identified by the judges as having construction flaws were eliminated. From items that remained, 20 were selected for inclusion on Test I and 20 for inclusion on Test II. These items were returned to the senior instructor who complemented them with 22 multiple-choice and key-type items for Test I and 65 for Test II.

The 20 alternate-choice items were randomly assigned to groups of five items each. It must be noted that on Test I it was necessary to keep questions 1,2, and 3 together due to their relation to the descriptive paragraph preceding the questions; within this grouping, the items were randomly assigned a sequence. It was also necessary to keep questions 7 and 8 in order, as question 8 referred to question 7. These two items were randomly assigned as a pair in the Test I sequence. Two groups of alternate-choice items were then randomly assigned to Form A, their true-false equivalent forms were assigned in the same sequence to Form B, and vice versa. Form A contained the item arrangement alternate-choice, true-false, alternate-choice, true-false; Form B contained the item arrangement true-false, alternate-choice, true-false, alternate-choice. The arrangement of the items on each form for Test I and Test II is shown in Table 1.

The multiple-choice items were arranged in two different sequences by the senior instructor; one sequence was randomly assigned to Form A and the other to Form B (See Table 1). These four- and five-choice multiple-choice items were placed last on each form to reduce the advantage of guessing for students who might have felt rushed near the end of the examination, even though the examination was a power test.

Forms A and B were distributed to students in alternating sequence to discourage the copying of answers and to obtain randomly equivalent groups. Students were given one hour to complete Test I (42 items), and two hours to complete Test II (85 items).

Table 1

Positions of Items on Test I and Test II

Test I		Test II	
Form A	Form B	Form A	Form B
AC_1	TF_1	AC_1	TF_1
.	.	.	.
AC_5	TF_5	AC_5	AC_5
TF_6	AC_6	AC_6	TF_6
.	.		.
TF_{10}	AC_{10}	AC_{10}	TF_{10}
AC_{11}	TF_{11}	AC_{11}	TF_{11}
.	.	.	.
AC_{15}	TF_{15}	AC_{15}	TF_{15}
TF_{16}	AC_{16}	AC_{16}	TF_{16}
.	.	.	.
TF_{20}	AC_{20}	AC_{20}	TF_{20}
MC_{21}	MC_{21}	MC_{21}	MC_{53}
.	.	.	.
MC_{25}	MC_{25}	.	.
MC_{26}	MC_{42}	.	.
MC_{27}	MC_{27}	.	.
MC_{28}	MC_{41}	.	.
MC_{29}	MC_{31}	.	MC_{85}
MC_{30}	MC_{32}	.	MC_{21}
MC_{31}	MC_{29}	.	.
MC_{32}	MC_{30}	.	.
MC_{33}	MC_{33}	.	.
.	.	.	.
MC_{40}	MC_{40}	.	.
MC_{41}	MC_{26}	.	.
MC_{42}	MC_{28}	MC_{85}	MC_{52}

Where: AC_i is the alternate-choice version of item i.
TF_i is the true-false version of item i.
MC_i is the same four- or five-choice multiple-choice item on Form A and Form B.

PART II

Participants. The senior instructor of the natural science sections used in this study and a departmental collaborator who was well versed in measurement methodology were asked to judge the best version of each alternate-choice and true-false item. The senior instructor has been teaching this course for approximately 20 years; the collaborator, now retired, had taught the course for more than 30 years.

Materials. Only the alternate-choice and true-false items administered in Tests I and II were used in this part of the study. Each of the alternate-choice and true-false items on Form A and Form B of these tests was converted to two versions. The alternate-choice items were converted to correct-answer-first (AC_{ci}) and incorrect-answer-first (AC_{ic}) forms, and the true-false items to true form (TF_t) and false form (TF_f).

Procedure. The senior instructor and departmental collaborator were given a packet f each form of each test that contained both versions of each item listed on a separate page, an instruction sheet, and a recording sheet. The judges were asked to choose the best version of each item that would simultaneously maximize the chances of a correct answer from a student who knows the material and an incorrect answer from an uniformed student. The judges independently recorded their choices on the recording sheets and returned the packets to this investigator. The investigator then tallied the percent of agreement.

PART III

Sample. The students that participated in Part III of this study were from three sections of a natural science course taught spring quarter of the 1983-84 academic year. This course had the same course number and emphasis on genetics and human reproduction as the Fall quarter natural science course used in Part I of this study. The three sections were team taught by the same two professors, but only the senior instructor had participated in Part I of this study. There was one student repeating the course who had participated in the Fall quarter Part I study. The students participating in Part III consisted of the population of all students taking Natural Science 115 Spring quarter. A total of 102 students took the final examination (test III). There were 51 students who took Form A and 51 students who took Form B.

Materials. The items used in Part III consisted of a stratified random sample of 20 of the 38 alternate-choice items administered in Tests I and II. Two of the 40 items administered in these tests were excluded from Part III because the material they tested had not been taught Spring quarter. The upper-lower 27% discrimination index, D, was used as the stratifying variable, and the 38 alternate-choice examination items were arranged from lowest to highest discriminating ability, then grouped into strata. Each stratum contained a spread of .10 of these indices, with the exception of the lowest stratum, which contained a spread of .13. A 20/38 or .53 proportional sample of items was selected from each stratum. The distribution of these strata, the number of items in each stratum, and the number selected is shown in Table 2.

Table 2

Strata, Number in Each Stratum, and Results of Random Sample of Items.

Discrimination Index		Number in Stratum f	Number Selected f
-.03 - .09		7	4
.10 - .19		12	6
.20 - .29		6	3
.30 - .39		6	3
.40 - .49		4	2
.50 - .59		3	2
	Total	38	20

Note: Proportion selected form each stratum was 20/38 or .53.

Test Form Development. Two forms of the final examination were developed. From the 20 items selected for inclusion, there were 10 AC_{ci} items randomly assigned to Form A and the AC_{ic} version of these items to Form B, and 10 AC_{ic} items randomly assigned to Form A and their AC_{ci} versions to Form B.

The respective versions of the items were arranged in the same sequence on each form of the examination, and returned to the senior instructor for the inclusion of 46 complementary four- and five-choice multiple-choice items selected from the item pool. These 46 items were arranged in two different sequences; one sequence was assigned to Form A, the other to Form B. To prevent students sitting next to each other from working on the same alternate-choice item at the same time, the 20 alternate-choice items were embedded in the examination and were assigned as items 31 to

50 on each form of the examination. Thus, item 31 on Form A read:

In scientific methodology, prediction means nearly the same as

a) expectancy* b) interpretation of data.

On Form B item 31 read:

In scientific methodology, prediction means nearly the same as

a) interpretation of data b) expectancy*.

The arrangement of all items on Form A and B of the Final examination is presented in Table 3. The specific arrangement of the alternate-choice item versions is shown in Table 4.

Procedure. Forms A and B of Test III were arranged in a regular sequence and administered to the students assembled in the large lecture hall regularly used for lecture and examinations. The forms were alternately ordered to discourage the copying of answers from those sitting on either side of the student and to obtain randomly equivalent groups. Oral instructions were given regarding the taking of the examination. Students were allowed two hours to complete the 66 items.

Table 3

Position of Items on Test III

Test III	
Form A	Form B
MC_1	MC_{17}
.	.
MC_{12}	MC_{28}
MC_{13}	MC_{51}
.	.
.	.
MC_{16}	MC_{54}
MC_{17}	MC_{29}
MC_{18}	MC_{30}
MC_{19}	MC_{55}
.	.
.	.
MC_{30}	MC_{66}
AC_{31}	AC_{31}
.	.
.	.
.	.
AC_{50}	AC_{50}
MC_{51}	MC_{14}
MC_{52}	MC_{15}
MC_{53}	MC_1
.	.
.	.
MC_{65}	MC_{13}
MC_{66}	MC_{16}

Where: AC_i is one of the versions of alternate-choice item i.

MC_i is the same four- or five-choice multiple-choice item on Form A and Form B.

Table 4

Position of Alternate-choice versions on Test III

Test III	
Form A	Form B
AC_{31ci}	AC_{31ic}
AC_{32ci}	AC_{32ic}
AC_{33ic}	AC_{33ci}
AC_{34ci}	AC_{34ic}
AC_{35ic}	AC_{35ci}
AC_{36ic}	AC_{36ci}
AC_{37ci}	AC_{37ic}
AC_{38ic}	AC_{38ci}
AC_{39ci}	AC_{39ic}
AC_{40ci}	AC_{40ic}
AC_{41ci}	AC_{41ic}
AC_{42ci}	AC_{42ic}
AC_{43ci}	AC_{43ic}
AC_{44ic}	AC_{44ci}
AC_{45ci}	AC_{45ic}
AC_{46ic}	AC_{46ci}
AC_{47ic}	AC_{47ci}
AC_{48ic}	AC_{48ci}
AC_{49ic}	AC_{49ci}
AC_{50ic}	AC_{50ci}

Where: AC_{ci} has the correct answer listed first in alternate-choice item i.

AC_{ic} has the incorrect answer listed first in alternate-choice item i.

Analysis and Results

The analyses and results for Part I, Part II, and Part III of this study are presented separately.

Part I

During the initial exploration of the data, a repeated measures analysis of the students' scores on Test I (midterm exam) and Test II (final exam) showed that students performed differently across these two tests. As a result, it was decided to treat Test I and Test II as independent substudies within Part I. The tests were in fact independent from each other because the material taught up to the midterm was tested by Test I, and the material taught after the midterm was tested by Test II. In Part I the alpha level was set at .025 because of the large number of statistical tests needed to test the hypotheses.

The Latin Square Type II design (Lindquist, 1956) was used to test for differences in the difficulty level of the alternate-choice and true-false items. The means and standard deviations for each Item Form within the Latin Square design are shown in Table 5. The results of the Latin Square analyses are shown in Table 6 and Table 7. The main effects of Item Form and Item Position were significant for both tests. Hypothesis 1 which stated: The alternate-choice items will be less difficult than the content equivalent true-false items, was supported for both Test I and Test II.

Table 5

Latin Square Design and Item Statistics fo. Tests I and II

TEST I

Item Position	Item Forms: AC	Item Forms: TF
Items 1-5, 11-15	Group I M = 7.19 SD = 1.71 r_{pbis} = .392 r_{tt} = .413 r = .592	Group II M = 6.03 SD = 1.70 r_{pbis} = .367 r_{tt} = .271 r = .443
Items 6-10, 16-20	Group II M = 6.76 SD = 1.42 r_{pbis} = .325 r_{tt} = .036 r = .425	Group I M = 4.94 SD = 1.57 r_{pbis} = .326 r_{tt} = .111 r = .278

TEST II

Item Position	Item Forms: AC	Item Forms: TF
Items 1-5, 11-15	Group I M = 6.52 SD = 1.68 r_{pbis} = .380 r_{tt} = .333 r = .545	Group II M = 5.48 SD = 1.42 r_{pbis} = .313 r_{tt} = 0.00 r = .272
Items 6-10, 16-20	Group II M = 7.37 SD = 1.59 r_{pbis} = .365 r_{tt} = .329 r = .388	Group I M = 5.48 SD = 1.91 r_{pbis} = .411 r_{tt} = .462 r = .628

NOTE: N = 123 for each cell
r_{tt} = KR20 reliability
r = correlation between Item Form and the Criterion

Table 6

Latin Square Analysis of Test I (Midterm)

Source	df	MS	F	p
Between Subjects	245	2.95	1.01	
A B (b)	1	13.34	4.58	n.s.
Error (b)	244	2.91		
Within Subjects	246	3.62	1.61	
A (Item Form)[a]	1	270.783	120.40	.001
B (Item Position)[b]	1	71.075	31.60	.001
AB (w)	1	0.00	0.00	n.s.
Error (w)	244	2.249		
Total	491			

[a]Item Form AC vs TF
[b]Item Position 1-5,11-15 vs 6-10,16-20

Table 7

Latin Square Analysis of Test II (Final)

Source	df	MS	F	p
Between Subjects	245	3.46	.99	
A B (b)	1	0.59	.17	n.s
Error (b)	244	3.47		
Within Subjects	246	2.89	1.44	
A (Item Form)[a]	1	116.09	57.62	.001
B (Item position)[b]	1	104.73	51.98	.001
AB (w)	1	0.00	0.00	n.s.
Error (w)	244	2.02		
Total	491			

[a]Item Form AC vs TF
[b]Item Position 1-5,11-15 vs 6-10,16-20

A point biserial correlation (r_{pbis}) was computed between each alternate-choice item and the total alternate-choice score of its respective test. Similarly each true-false item was correlated with the total true-false score of its respective test. The r_{pbis} of each of the 20 content-equivalent alternate-choice and true-false items was placed side by side and a sign test was used to test for differences in discrimination ability of these two item forms. No significant differences in discrimination ability of alternate-choice and true-false items were found in Test I or in Test II. Hypothesis 2 which stated: The alternate-choice items will show more discrimination ability than the content equivalent true-false items, was not supported. The average r_{pbis} (r_{pbis}) for each cell in the Latin Square design is shown in Table 5.

The KR-20 reliabilities (r_{tt}) of the 10 alternate-choice items and the 10 true-false items were computed for each form of each test. These KR-20 reliability coefficients are shown in Table 5. The reliabilities of the content equivalent items were tested for equality by use of the Feldt Test for Equality of Two KR-20 Reliabilities (Feldt, 1969). For Test I, the magnitude of the reliabilities were found to be equal. For Test II, the reliability of the alternate-choice items in Item Position 1-5, 11-15 was shown to be significantly greater, $W(123,123) = 1.499$, $p < .025$, than the reliability of the item equivalent true-false items. The magnitude of the reliabilities of the content-equivalent alternate-choice and true-false items in Item Position 6-10, 16-20 were found to be equal. Hypothesis 3 which stated: The reliability of the alternate-choice items will be greater than the reliability of the true-false items, was only partially supported.

The course grade for each student was based on a weighted accumulated score of all quizzes and tests. This accumulated score was adjusted by removing the weighted scores of all alternate-choice and true-false items. For each test, correlations were computed between the total alternate-choice score on each form and the adjusted score, and for the total true-false score on each form and the adjusted score. These correlation coefficients (r) are shown in Table 5.

Differences in the correlations of content equivalent items were tested by transforming them to z_r scores and performing a z test for two independent samples. For Test I, there were no differences found between these correlations. For Test II, the criterion-related correlation of the alternate-choice items in Item Position 1-5, 11-15 was significantly greater than that of the true-false items ($z = 2.56$, $p < .006$). The criterion-related correlation of the true-false items in Item Position 6-10, 16-20 was significantly greater than that of the alternate-choice items ($z = -2.56$, $p < .006$). Hypothesis 4 which stated: The criterion related validity of the alternate-choice items will be greater than that of the true-false items, was only partially supported.

Part II

The two instructors who judged the best version of each alternate-choice item (AC_{ci} and AC_{ic}) and the best version of the true-false item (TF_t and TF_f), expressed a great deal of frustration concerning the completion the task. Both found judging the alternate-choice item versions more exasperating than judging the true-false versions. One judge noted on the recording sheet that: "I have completed this task but I have no confidence that, confronted with the same task again I would make the same choice". The other judge stated verbally that the task was a piece of "nonsense" and that he was certain that he would not be able to produce the same judgments if he were to redo the task--which he wouldn't do.

The percent of agreement between the judges in their choice of the best alternate-choice items was 55 percent, only 5 percent greater than that expected by chance. The same 55 percent agreement was found for the true-false items. Hypothesis 1 which stated:

> Agreement between two departmental colleagues' judgments of the best version of an alternate-choice item will be no better than chance (50 percent).

and hypothesis 2 which stated:

> Agreement between two departmental colleagues' judgments of the best version of a true-false item will be no better than chance (50 percent).

were both accepted.

PART III

The same statistical tests used in Part I of this study were used in Part III. The alpha level was set at .05.

The means and standard deviations for each alternate-choice Item Form within the Latin Square design are shown in Table 8; the results are shown in Table 9. The main effect of Item Form was found to be not significant. Hypothesis 1 which stated: Version AC_{ci} and version AC_{ic} of the alternate-choice item will not differ significantly in difficulty level was accepted.

The r_{pbis} of each equivalent AC_{ci} and AC_{ic} item was placed side by side and a sign test was used to test for differences in discrimination ability. No significant differences in discrimination ability were found. Hypothesis 2 which stated: Version AC_{ci} and version AC_{ic} of the alternate-choice item will not differ significantly in discrimination ability, was accepted.

The KR-20 reliability coefficients (r_{tt}) for each Latin Square cell is shown in Table 8. The Feldt Test for Equality of Two KR-20 Reliabilities showed the reliabilities to be equal. Hypothesis 3 which stated: The reliability of version AC_{ci} and version AC_{ic} of the alternate-choice item will not differ significantly, was accepted.

The accumulated score for each student was adjusted by removing the weighted scores of all AC_{ci} and AC_{ic} items. Correlations were computed between the total AC_{ci} score and the adjusted score, and between the total AC_{ic} score and the adjusted score. These correlation coefficients (r) are shown in Table 8.

Differences in the correlations of AC_{ci} and AC_{ic} items were tested by transforming them to z_r scores and performing a z test for two independent samples. No differences were found between these correlations. Hypothesis 4 which stated: The criterion related validity of version AC_{ci} and version AC_{ic} of the alternate-choice items will not differ significantly, was accepted.

Table 8

Latin Squa-e Design and Item Statistics for Part III

Item Position	Item Forms: ACCI	Item Forms: ACIC
A	Group I M = 6.43 SD = 1.75 r_{pbis} = .333 r_{tt} = .375 r = .692	Group II M = 6.94 SD = 1.67 r_{pbis} = .337 r_{tt} = .271 r = .542
B	Group II M = 7.45 SD = 1.62 r_{pbis} = .328 r_{tt} = .402 r = .649	Group I M = 7.43 SD = 1.66 r_{pbis} = .357 r_{tt} = .453 r = .548

.able 9

Latin Square Analysis of Part III

Source	df	MS	F	p
Between Subjects	101	3.59	0.00	
A B (b)	1	3.57	.99	n.s.
Error (b)	100	3.59		
Within Subjects	102	2.31	2.28	
A (Item Form)[a]	1	3.06	3.03	n.s.
B (Item position)	1	29.06	28.77	.001
AB (w)	1	0.00	0.00	n.s.
Error (w)	202	1.01		
Total	203			

[a] Item Form AC_{ci} vs AC_{ic}

Educational Importance of the Study

The finding in this study that the alternate-choice item was less difficult than the true-false item replicated previous findings for this item type (Ruch & Stoddard, 1925; Charles, 1926; Ebel, 1982). However, the findings concerning greater discrimination, and higher reliability of the alternate-choice item were not replicated. In his research on the alternate-choice type item, Smith (1958) found that good alternate-choice items were easier to write than the other multiple-choice item forms, and that the reactions of his students to this item form was extremely positive. In addition, Smith found that time was saved when the graded examination was reviewed. If the item was marked incorrect, the student immediately knew the correct answer. Given the findings reported in this study, and the above advantages of the alternate-choice item form, the classroom instructor who uses true-false items might seriously consider the use of the alternate-choice item instead. Lastly, those instructors writing alternate-choice items need not be concerned about the placement of the correct and incorrect answers.

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APPENDIX A

Multiple-choice, Alternate-choice, and True-false Forms of Experimental Items

MIDTERM EXAM

TEST 1

The next three items are based on the following information: In snapdragons tallness (T) is dominant over dwarfness (t), while red flower color is due to a gene (R) and white to its allele (r). The heterozygous condition results in pink flower color. A dwarf homozygous red snapdragon is crossed with a plant homozygous for tallness and white flowers.

1. MC form
What is the genotype and phenotype of the F_1's?

A) ttRr, dwarf and pink
B) ttrr, dwarf and white
C) TtRr, tall and red
* D) TrRr, tall and pink
E) None of these

1. AC form
The genotype and phenotype of the F_1's are a) TtRr, tall and pink b) TtRr, tall and red.

1. TF form
The genotype and phenotype of the F_1's are TtRr, tall and pink.

2. MC form
If two plants of the genotypes ttRr and TtRR are crossed and no mutations occur, what are the chances that they will produce a dwarf white plant?

A) 1/2
B) 1/4
C) 3/16
D) 1/16
* E) 0

2. AC form
If two plants of the genotypes ttRr and TtRR are crossed and no mutations occur, the chances are a) 0 b) 1/16 that they will produce a dwarf white plant.

2. TF form
If two plants of the genotypes ttRr and TtRR are crossed and no mutations occur, the chances are 1/16 that they will produce a dwarf white plant.

3. MC form

A plant which is heterozygous for tallness and red flowers is self-pollinated. What is the probability that the offspring will be short and white?

A) 9/16
B) 3/16
C) 3/9
* D) 1/16
E) 0

3. AC form

A plant which is heterozygous for tallness and red flowers is self-pollinated. The probability is a) 0 b) 1/16 that the offspring will be short and white.

3. TF form

A plant which is heterozygous for tallness and red flowers is self-pollinated. The probability is 0 that the offspring will be short and white.

4. MC form

A son is born whose father is normal but whose grandfather, on his mother's side was hemophilic. What are the chances that he, too, would bear this trait?

A) 75%
* B) 50%
C) 10%
D) 1/16
E) 0%

4. AC form

A son is born whose father is normal but whose grandfather, on his mother's side was a hemophilic. The chances that he, too, would bear this trait is a) 50% b) 75%

4. TF form

A son is born whose father is normal but whose grandfather, on his mother's side was hemophilic. The chances that he, too, would bear this trait is 75%.

5. MC form

In a cross between individuals heterozygous for two traits, the expected number of homozygous recessive individuals is

A) 9/16
B) 1/2
C) 1/4
D) 3/16
* E) 1/16

5. AC form
In a cross between individuals heterozygous for two traits, the expected number of homozygous recessive individuals is
a) 1/16 b) 1/4

5. TF form
In a cross between individuals heterozygous for two traits, the expected number of homozygous recessive individuals is 1/16.

6. MC form
Dr. Corcos works with a little plant, Arabidopsis thaliana, whose chromosome number is 2n=10. In such a plant the number of possible combinations of paternal and maternal chromosomes is

A) 64
* B) 32
C) 16
D) 8
E) 4

6. AC form
Dr. Corcos works with a little plant, Arabidopsis thaliana, whose chromosome number is 2n=10. In such a plant the number of possible combinations of paternal and maternal chromosomes is a) 8
b) 32

6. TF form
Dr. Corcos works with a little plant, Arabidopsis thaliana, whose chromosome number is 2n=10. In such a plant the number of possible combinations of paternal and maternal chromosomes is 32.

7. MC form
A streak of white in an otherwise colored head of hair is known as white forelock. It is due to a dominant gene. If a woman with a white forelock marries a normal man and their first child is normal, her genotype is

A) AA
* B) Aa
C) aa

7. AC form
A streak of white in an otherwise colored head of hair is known as white forelock. It is due to a dominant gene. If a woman with a white forelock marries a normal man and their first child is normal, her genotype is a) aa b) Aa .

7. TF form
A streak of white in an otherwise colored head of hair is known as white forelock. It is due to a dominant gene. If a woman with a white forelock marries a normal man and their first child is normal, her genotype is aa.

8. MC form

What are the chances that the second child of the marriage above has a white forelock?

A) 3/4
* B) 1/2
C) 1/4
D) 0

8. AC form

The chances that the second child of the marriage above has a white forlock is a) 1/2 b) 1/4 .

8. TF form

The chances that the second child of the marriage above has a white forelock is 1/2.

9. MC form

Some organisms have sex chromosomes of the XO, XX type, in which males have one X chromosome, females two; in other organisms the female has two X chromosomes, the male an X and a Y; instill other organisms such as birds, the female has XY and the male XX. Some animals and plants can even be male in one situation and female in another, when conditions are favorable; others are hermaphroditic. All this would seem to indicate that sex determination is

A) ultimately a hereditary decision prescribed by the male.
B) by the sex chromosomes only.
C) wholly random and unpredictable in any case
* D) not always entirely determined by the karyotype.

9 AC form

Some organisms have sex chromosomes of the XO, XX type, in which males have one X chromosome, females two; in other organisms the female has two X chromosomes, the male an X and a Y; in still other organisms such as birds, the female has XY and the male XX. Some animals and plants can even be male in one situation and female in another, when conditions are favorable; others are hermaphroditic. All this would seem to indicate that sex determination is a) not always entirely determined by the karyotype b) by the sex chromosomes only.

9. TF form:

Some organisms have sex chromosomes of the XO, XX type, in which males have one X chromosome, females two; in other organisms the female has two X chromosomes, the male an X and a Y; in still other organisms such as birds, the female has XY and the male XX. Some animals and plants can even be male in one situation and female in another, when conditions are favorable; others are hermaphroditic. All this would seem to indicate that sex determination is by the sex chromosomes only.

10. MC form
Few genes are Y linked. The reason for this is probably that

A) the Y chromosome is largely homologous with the X.
B) both sexes possess the Y chromosomes.
C) both sexes possess two X chromosomes.
* D) the Y chromosome occurs only in one sex and is small.

10. AC form
Few genes are Y linked. The reason for this is probably that the Y chromosome a) is largely homologous with the X b) occurs only in one sex and is small.

10. TF form
Few genes are Y linked. The reason for this is probably that the Y chromosome is largely homologous with the X.

11. MC form
The "drumstick" chromosome often found in the female nuclei of white blood cells

* A) indicates the sex of the person involved.
B) represents an inactivated Y-chromosome.
C) could occur in a person with the XYY syndrome.
D) is characteristic of the cri-du-chat disorder
E) none of the above

11. AC form
The "drumstick" chromosome often found in the female nuclei of white blood cells a) represents an inactivated Y-chromosome b) indicates the sex of the person involved.

11. TF form
The "drumstick" chromosome often found in the female nuclei of white blood cells indicates the sex of the person involved.

12. MC form
In guinea pigs black is dominant over white. A cross between a heterozygous black and a white guinea pig would give a ratio of

A) about 3 blacks to 1 white
B) all black
* C) about 1 black to 1 white
D) about 3 whites to 1 black
E) about 1 black to 2 grey to 1 white

12. AC form
In guinea pigs black is dominant over white. A cross between a heterozygous black and a white guinea pig would give a ratio of a) all black b) about 1 black to 1 white.

12. TF form
In guinea pigs black is dominant over white. A cross between a heterozygous black and a white puinea pig would give a ratio of about 1 black to 1 white.

13. MC form
A form of Vitamin D resistant rickets, known a hypophatemia, is inherited as a sex-linked dominant trait. If a male with hypophatemia marries a normal female, which of the following predictions concerning the potential progeny would be true?

A) All their sons would inherit the disease.
* B) All their daughters would inherit the disease.
C) None of their sons would inherit the disease.
D) None of their daughters would inherit the disease.
E) Both b and c are true.

13. AC form
A form of Vitamin D resistant rickets, known a hypophatemia, is inherited as a sex-linked dominant trait. If a male with hypophatemia marries a normal female, all their a) sons b) daughters would inherit the disease.

13. TF form
A form of Vitamin D resistant rickets, known a hypophatemia, is inherited as a sex-linked dominant trait. If a male with hypophatemia marries a normal female, all their sons would inherit the disease.

14. MC form
When children do not express a trait unless at least one parent expresses it, it is an indication that the gene involved is

A) x-linked dominant
* B) autosomal dominant
C) autosomal recessive
D) polygenetically inherited
E) skipping a generation

14. AC form
When children do not express a trait unless at least one parent expresses it, it is an indication that the gene involved is a) skipping a generation b) autosomal dominant.

14. TF form
When children do not express a trait unless at least one parent expresses it, it is an indication that the gene involved is skipping a generation.

15. MC form

If, in testing a genetic hypothesis you found a Chi-square of zero, you should

A) reject the hypothesis.
B) accept the hypothesis.
* C) redo the experiment.
D) discard Mendelian genetics
E) discard the Chi-square method

15. AC form

If, in testing a genetic hypothesis you found a Chi-square of zero, you should a) accept the hypothesis b) redo the experiment.

15. TF form

If, in testing a genetic hypothesis you found a Chi-square of zero, you should redo the experiment.

16. MC form

If the somatic cells of a male were found to contain a Barr body in each of their nuclei, what would be the most likely genetic constitution of the individual?

A) XO
B) XX
C) XYY
* D) XXY
E) XXX

16. AC form

If the somatic cells of a male were found to contain a Barr body in each of their nuclei, the most likely genetic constitution of the individual is a) XYY b) XXY .

16. TF form

If the somatic cells of a male were found to contain a Barr body in each of their nuclei, the most likely genetic constitution of the individual is XYY.

17. MC form

The theory of inheritance during Mendel's time was known as "blending". If this theory were correct, the outcome of a cross between a black animal and a white animal would produce offspring of what color?

A) Black
B) White
C) Spotted
* D) Gray
E) Impossible to tell

17. AC form
The theory of inheritance during Mendel's time was known as "blending". If this theory were correct, the outcome of a cross between a black animal and a white animal would produce
a) Spotted b) Gray offspring.

17. TF form
The current theory of inheritance during Mendel's time was known as "blending". If this theory were correct, the outcome of a cross between a black animal and a white animal would produce Spotted offspring.

18. MC form
The relative distance between linked genes may be determined by

A) cell fusion experiments
* B) crossing over frequencies
C) epistasis
D) pleiotropism
E) a and b above

18. AC form
The relative distance between linked genes may be determined by a) crossing over frequencies b) cell fusion experiments.

18. TF form
The relative distance between linked genes may be determined by cell fusion experiments.

19. MC form
How many possible combinations of gametes could be produced by one individual in a trihybrid cross?

A) 3
B) 6
* C) 8
D) 16
E) 64

19. AC form
The possible combinations of gametes that could be produced by one individual in a trihybrid cross is a) 6 b) 8 .

19. TF form
The possible combinations of gametes that could be produced by one individual in a trihybrid is 8.

20. MC form
If you flip 3 coins, the probability of getting 2 heads and 1 tail is

A) 1/6
B) 1/8
C) 3/9
* D) 3/8
E) none of these

20 AC form
If you flip 3 coins, the probability of getting 2 heads and 1 tail is a) 1/8 b) 3/8

20. TF form
If you flip 3 coins, the probability of getting 2 heads and 1 tail is 3/8.

FINAL EXAM QUESTIONS

TEST II

1. MC form
The main activity of science is to

A. observe nature.
* B. make and test theories.
C. debate issues with organized religion.
D. create machines which will improve human society.
E. support political systems.

1. AC form
The main activity of science is to a) observe nature b) make and test theories .

1. TF form
The main activity of science is to make and test theories.

2. MC form
In scientific methodology, prediction means nearly the same as

A. interpretation of data.
B. generalization from empirical observation.
* C. expectancy.
D. experimentation.
E. none of the above.

2. AC form
In scientific methodology, prediction means nearly the same as a) expectancy b) interpretation of data .

2. TF form
In scientific methodology, prediction means nearly the same as interpretation of data.

3. MC form
The lowest level of explanation is

A. a theory.
* B. an hypothesis.
C. a fact.
D. an assumption.

3. AC form
The lowest level of explanation is a) an hypothesis b) an assumption .

3. TF form
The lowest level of explanation is an assumption.

4. MC form

Which of Mendel's procedures differed from those of his predecessors and contributed most to his success?

A. He kept breeding records.
B. He observed distinct inherited traits.
C. He observed many characteristics for each trait.
* D. He quantitatively (statistically) analyzed his data.
E. He used one of the few organisms which can be grown in a laboratory.

4. AC form

Mendel's procedure that differed from those of his predecessors and contributed most to his success was that a) he observed distinct inherited traits b) he quantitatively (statistically) analyzed his data .

4. TF form

Mendel's procedure that differed from those of his predecessors and contributed most to his success was that he observed distinct inherited traits.

5. MC form

In radishes, long and round are alleles, as are red and white. In a cross between a long, red variety, and a round, white variety the F_1 is oval and purple. How many different phenotypes you would expect to find in the F_2?

A. 16
* B. 9
C. 4
D. 3
E. 2

5. AC form

In radishes, long and round are alleles, as are red and white. In a cross between a long, red variety, and a round, white variety the F_1 is oval and purple. The different phenotypes you would expect to find in the F_2 is a) 4 b) 9 .

5. TF form

In radishes, long and round are alleles, as are red and white. In a cross between a long, red variety, and a round, white variety the F_1 is oval and purple. The different phenotypes you would expect to find in the F_2 is 4.

6. MC form
A characteristic of a dominant trait is that

* A. the trait never skips a generation.
B. the genotype can be determined directly from the phenotype.
C. the phenotype cannot be read from the genotype.
D. the homozygote for the train can be distinguished fr... the heterozygote.
E. more than one above.

6. AC form
A characteristic of a dominant trait is that a) the trait never skips a generation b) the genotype can be determined directly from the phenotype .

6. TF form
A characteristic of a dominant trait is that the genotype can be determined directly from the phenotype.

7. MC form
Two black female mice are mated to a brown male. In several litters, Female I produced 9 blacks and 7 browns, Female II produced 57 blacks. Assuming black to be dominant over brown, what are the respective genotypes of the Female I, Female II, and the male?

* A. Bb, BB, bb
B. BB, Bb, bb
C. Bb, bb, BB
D. bb, Bb, BB
E. BB, BB, bb

7. AC form
Two black female mice are mated to a brown male. In several litters, Female I produced 9 blacks and 7 browns, Female II produced 57 blacks. Assuming black to be dominant over brown, the respective genotypes of the Female I, Female II, and the male are a) BB, Bb, bb b) Bb, BB, bb .

7. TF form
Two black female mice are mated to a brown male. In several litters, Female I produced 9 blacks and 7 browns, Female II produced 57 blacks. Assuming black to be dominant over brown, the respective genotypes of the Female I, Female II, and the male are Bb, BB, bb

8. MC form
A woman who has Turner syndrome is found to have hemophilia; yet neither of her parents have the disease. She

A. got the defective gene from her father.
* B. got the defective gene from her mother.
C. could have gotten the defective gene from either parent.
D. could not have gotten the defective gene from either parent.
E. must be adopted since hemophilia is due to a dominant gene.

8. AC form

A woman who has Turner syndrome is found to have hemophilia; yet neither of her parents have the disease. She a) got the defective gene from her mother b) could have gotten the defective gene from either parent.

8. TF form

A woman who has Turner syndrome is found to have hemophilia; yet neither of her parents have the disease. She got the defective gene from her mother.

9. MC form

The extra Y chromosome of the XYY male was thought for some time to cause

A. stunted and stocky build in affected males.
B. above average intelligence.
C. above average strength.
D. sterility in such males.
* E. aggressive and antisocial behavior.

9. AC form

The extra Y chromosome of the XYY male was thought for some time to cause a) sterility in such males b) aggressive and antisocial behavior .

9. TF form

The extra Y chromosome of the XYY male was thought for some time to cause sterility in such males.

10. MC form

What process probably occurs during meiosis to produce an XXY individual?

A. Segregation
B. Crossing over
* C. Nondisjunction
D. Random assortment
E. None of these

10. AC form

The process that probably occurs during meiosis to produce an XXY individual is a) crossing over b) nondisjunction .

10. TF form

The process that probably occurs during meiosis to produce an XXY individual is crossing over.

11. MC form

Sex chromatin found in body cells and called Barr bodies have a relationship with the number of X chromosomes present in a given individual's body cells. If a given male had a sex chromosome composition of XXXXY, the number of Barr bodies observable in somatic tissue cells would be

A. five
B. four
* C. three
D. two
E. none of these

11. AC form

Sex chromatin found in body cells and called Barr bodies have a relationship with the number of X chromosomes present in a given individual's body cells. If a given male had sex chromosome composition of XXXXY, a) three b) four Barr bodies would be observable in somatic tissue cells.

11. TF form

Sex chromatin found in body cells and called Barr bodies have a relationship with the number of X chromosomes present in a given individual's body cells. If a given male had sex chromosome composition of XXXXY, three Barr bodies would be observable in somatic tissue cells.

12. MC form

More than one man was responsible for proposing the one-gene, one-enzyme hypothesis. Those responsible were

A. Watson and Crick.
B. Mendel and Morgan.
C. Lysenko and Lamarck.
* D. Beadle and Tatum.
E. None of these.

12. AC form

The men responsible for proposing the one-gene, one-enzyme hypothesis were a) Beadle and Tatum b) Watson and Crick.

12. TF form

The men responsible for proposing the one-gene, one-enzyme hypothesis were Watson and Crick.

13. MC form
When cells of certain bacteria are grown on glucose they do not produce beta-galactosidase (an enzyme which is important in breaking down lactose). However, when the same cells are placed in lactose they begin to make beta-galactosidase almost immediately. The results of this experiment support the hypothesis that

A. DNA is a genetic material.
B. genes are influenced by the environment
C. not all the genes are operative all the time.
* D. B and C
E. A, B, and C

13. AC form
When cells of certain bacteria are grown on glucose they do not produce beta-galactosidase (an enzyme which is important in breaking down lactose). However, when the same cells are placed in lactose they begin to make beta-galactosidase almost immediately. The results of this experiment support the hypothesis that
a) genes are influenced by the environment b) DNA is the genetic material .

13. TF form
When cells of certain bacteria are grown on glucose they do not produce beta-galactosidase (an enzyme which is important in breaking down lactose). However, when the same cells are placed in lactose they begin to make beta-galactosidase almost immediately. The results of this experiment support the hypothesis that genes are influenced by the environment.

14. Watson-Crick base pairing requires that the adenine content of one strand of DNA equals the

A. thymine content of the complementary strand
B. thymine content of the same strand
C. adenine content of the complementary strand
D. uracil content of the complementary strand
E. guanine content of the complementary strand

14. Watson-Crick base pairing requires that the adenine content of one strand of DNA equals the thymine content of the a) complementary b) same strand.

14. Watson-Crick base pairing requires that the adenine content of one strand of DNA equals the thymine content of the same strand.

15. MC form
A nucleotide consists of either a purine or pyrimidine, a five-carbon sugar and a

A. carbohydrate.
B. amino acid.
C. peptide.
* D. phosphate group.
E. sulfate group.

15. AC form
A nucleotide consists of either a purine or pyrimidine, a five-carbon sugar and a) a phosphate group b) an amino acid .

15. TF form
A nucleotide consists of either a purine or pyrimidine, a five-carbon sugar and a phosphate group.

16. MC form
Amino-acids are carried to ribosomes by

A. messenger RNA.
* B. transfer RNA.
C. proteins.
D. cytoplasmic DNA.
E. nuclear DNA.

16. AC form
Amino-acids are carried to ribosomes by a) messenger RNA b) transfer RNA.

16. TF form
Amino-acids are carried to ribosomes by messenger RNA.

17. MC form
According to the genetic code, a gene responsible for the formation of a protein of 200 amino-acid subunits should have

A. 200 nucleotides.
B. 400 nucleotides.
* C. 600 nucleotides.
D. 800 nucleotides.
E. Dr Corcos and Dr Marinez, do you think we are math majors?

17. AC form
According to the genetic code, a gene responsible for the formation of a protein of 200 amino-acid subunits should have a) 600 b) 200 nucleotides .

17. TF form
According to the genetic code, a gene responsible for the formation of a protein of 200 amino-acid subunits should have 200 nucleotides.

18. MC form

In a DNA molecule, one strand contains the following sequence of bases A-G-A-T-C. Which of the following represents the complementary sequence on the other strand?

A. C-C-T-A-G
B. A-G-A-T-C
* C. T-C-T-A-G
D. U-C-U-A-G
E. None of these

18. AC form

In a DNA molecule, one strand contains the following sequence of bases A-G-A-T-C. The complementary sequence on the other strand is a) U-C-U-A-G b) T-C-T-A-G .

18. TF form

In a DNA molecule, one strand contains the following sequence of bases A-G-A-T-C. The complementary sequence on the other strand is T-C-T-A-G .

19. MC form

Mongoloid idiocy or Down's Synd is a consequence of abnormalities in:

A. sex-linked heredity
B. sex-influenced heredity
C. the number of sex chromosomes.
* D. the number of autosomal chromosomes.
E. None of these

19. AC form

Mongoloid idiocy or Down's Syndrome is a consequence of abnormalities in the number of a) sex b) autosomal chromosomes .

19. TF form

Mongoloid idiocy or Down's Syndrome is a consequence of abnormalities in the number of sex chromosomes.

20. MC Form

In recombinant DNA research, an alien gene is

A. treated with tRNA.
B. incorporated into a bacterial plasmid.
C. combined with a repressor substance.
D. mixed with histone proteins.
* E. injected into the host cell with a sex pilus.

20. AC form

In recombinant DNA research, an alien gene is a) incorporated into a bacterial plasmid b) injected into the host cell with a sex pilus.

20. In recombinant DNA research, an alien gene is incorporated into a bacterial plasmid.