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An Experimental Study Utilizing Integrated / Right Brain Processes in Teaching Biology

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AN EXPERIMENTAL STUDY UTILIZING INTEGRATED/RIGHT BRAIN PROCESSES IN TEACHING BIOLOGY

BY

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Abstract

The purpose of this study was to determine any measureable differences in student academic outcomes when they participated in activities designed to involve both hemispheres as compared to when they participated in activities designed to involve the left hemisphere. It was predicted that students who participated in more integrated/right brain activities would show higher academic achievement. It was further predicted that students who were right hemisphere preferenced would do better than those who were left hemisphere preferenced.

Two intact groups of Biology I students were taught the same four-chapter unit on cells, utilizing the same learning objectives and the same tests. For the control group, the enabling activities were designed to stimulate left hemispheric processes. Enabling activities used by the experimental group were designed to stimulate integrated/right hemispheric processes. Both groups were taught by the same teacher. Both groups were given pretests and post tests for each of the four chapters in the unit and a unit test. Student achievement on these tests was

measured and compared to see if the two teaching approaches had statistically significant effects.

The students were in grades 9 through 12, ages 14-17, enrolled in the first level of high school biology at Washington High School, Washington, Missouri.

Since intact groups were used, two tests were given to help measure the characteristics of each group. Scott, Foresman's Biology Test was used as an indicator of prior knowledge of biology and Torrance's Style of Learning and Thinking was administered in order to determine the hemispheric preferences of the students in each group. The tests showed a significant difference in hemisphericity. Although the test for prior knowledge did not show a significant difference between the two groups, the chapter pretests showed differences which led to the need for using an analysis of covariance.

Enabling activities used in the study were selected on the basis of relevance to learning objectives and hemispheric processes the activity involved.

An analysis of the post test scores of each group showed that the experimental group did not score significantly higher than the control group on any of the tests. A further analysis showed that there was no

significant correlation between student hemisphericity and post test scores. Therefore, both experimental hypotheses were rejected.

Regardless of the results of this study, the researcher felt that there was enough other research on record to indicate that students actually benefited from brain compatible learning opportunities. It would seem that the two major factors affecting the results of this study were unequal intact groups and the threat of artificial setting. Future studies could be carefully designed to overcome these threats and limitations.

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CHAPTER I

General Description of Area of Concern

Purpose of Study

The purpose of this study was to address the issue of developing hemispherically balanced activities to implement a high school level biology course. It measured whether or not students demonstrated higher academic achievement when they participated in activities designed to stimulate both right and left brain processes as opposed to participating in left hemisphere oriented activities.

Need for Study

The need for further investigation of brain compatible education was identified as a possible way to improve biology instruction after hemisphericity tests were given to students and teachers at Washington High School. It was determined that 64% of the students tested were either right brain dominant or whole brain favoring the right. Only 26% of the students were left dominant or whole favoring the left. On the other hand, 47% of the teachers were either left dominant or whole favoring the left (see Table 1).

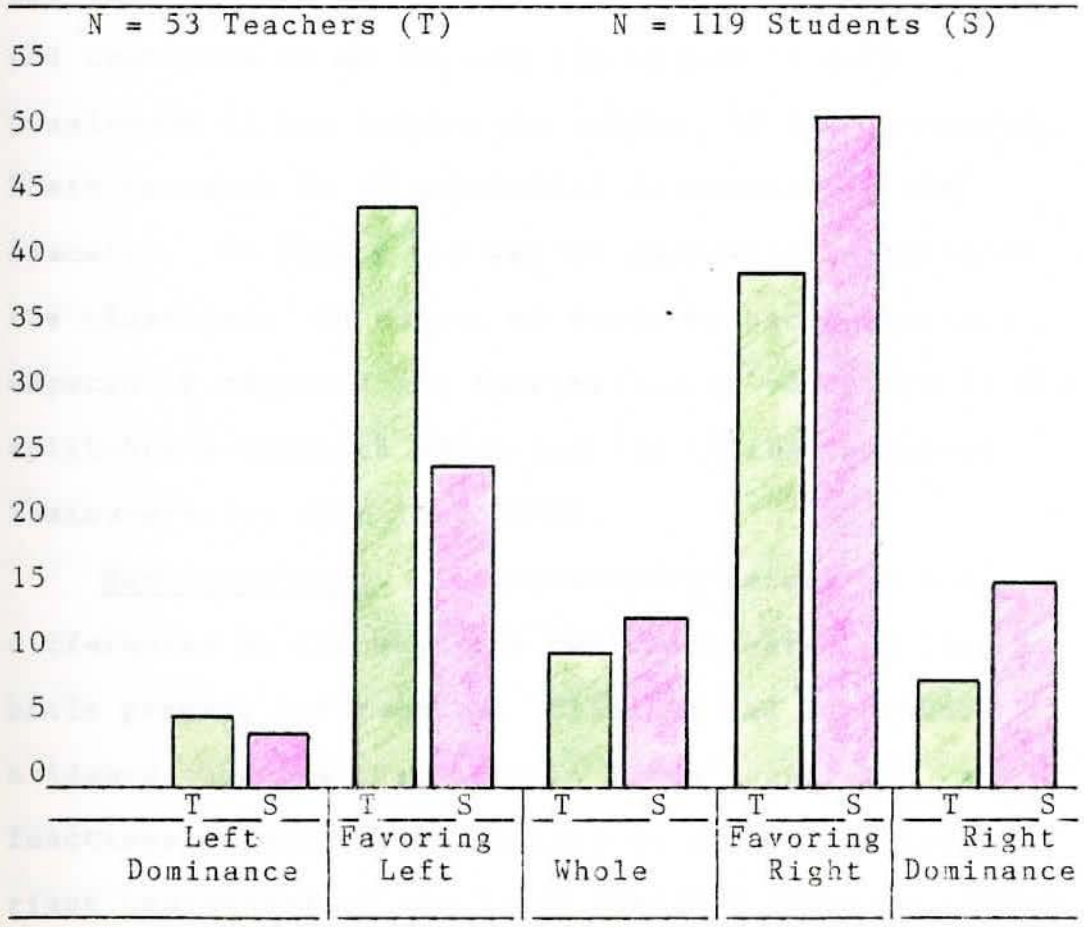
Table 1

Results of Hemispheric Dominance Tests
Washington High School

Preference	Teachers	Students
Left Dominance	4%	3%
Favoring Left	43%	23%
Whole	9%	11%
Favoring Right	38%	50%
Right Dominance	6%	14%

Figure 1

Results of Hemispheric Dominance Tests
Washington High School



Since hemisphericity is a part of a person's learning style, these figures have educational significane (Dunn, Cavanaugh, & Zenhausern, 1982). Assuming it is more natural for a teacher who is left dominant to develop activities involving left processes, the learning styles of 64% of the students were being neglected, to say nothing of the remaining 36% who also needed stimulation of the right hemisphere.

Brain Research

The brain is perhaps the least understood part of the anatomy. It has puzzled man for thousands of years and continues to do so. As the object of such puzzlement it has become the subject of much research. Brain research is of particular importance to the educator. It points the way to improving learning in the classroom. An aspect of brain research that has especially captured the fascination of educators is the split-brain research which has led to the theory of hemisphericity (Hopkins, 1984).

Hemisphericity. Hemisphericity refers to the differences in the ways the two hemispheres of the brain process information. Clinical and laboratory evidence suggests that certain human cognitive functions depend predominantely on either the left or right hemisphere of the brain (Galin & Ornstein, 1972).

Each hemisphere of the brain is specialized for a particular type of information processing, for which it is dominant. Although both hemispheres receive and process information, each processes it separately. The right hemisphere and the left hemisphere both have specialized thinking characteristics, yet they both use high level cognitive modes (Grady & Luecke, 1978).

Left hemisphere processes. The left hemisphere seems better at sequential ordering, analyzing essentials, and making direct relationships. It is dominant in speaking, reading, writing, and simple calculation. The left hemisphere processes in a linear way and seems related to the ordering of thoughts through a linear concept of time, or a linear progression of printed symbols. It seems to excel at recognizing a direct relationship or an association with previous experience (Gazzaniga, 1975). In addition to being linear, the left mode is considered to be symbolic, sequential, logical, verbal, reality-based, temporal, abstract, analytic, rational, and digital.

Right hemisphere processes. The right hemisphere seems to be better at simultaneous patterned thinking and integrating parts into wholes. Often this has been associated with the visual, but goes far beyond that. The patterning of the right hemisphere is in the

abstract, tactile, kinesthetic, and auditory realms as well as the visual. The right hemisphere mode is holistic, concrete, random, intuitive, nonverbal, fantasy-oriented, non-temporal, analogical, synthetic, nonrational, and spatial (Hopkins, 1984).

Dangers of simplifying. It should be understood that this is not a simple dichotomy. Even though the differences in the specialized abilities of each side are seen in the contrasting contributions each hemisphere makes to all cognitive activities, it must be remembered that to the extent that regions are differentiated, they must integrate their activities. The two hemispheres do not function independently. Each functions simultaneously and contributes its special capacities to all cognitive activities. It is impossible to educate one hemisphere at a time in a normal brain even though there is both psychological and physiological evidence that people vary in the relative balance of activation of the two hemispheres. Not even those with the most asymmetrical activation between hemispheres think with only the more activated side. Rather, there is a continuum. These differences in activation of the hemispheres are but one of the many factors affecting the way we think. Levy (1985) and other researchers have expressed much concern over the problem of oversimplificatiaon of these ideas.

The neglected right. One aspect of research on the brain is the realization by educators that many educational approaches are directed only to the left hemisphere. It has been proposed that the right side of the brain is suffering educational neglect and that students are being educated lopsidedly (Bogen, 1975). Webb (1983) established that a large percentage of students failing school prefer right brain learning.

Integrated approach needed. The goal of the classroom teacher should be to integrate the strengths of both hemispheres so that learning can be facilitated by promoting complementary hemisphere interaction says Luvaas-Briggs (1984). The term integrated/right refers to the idea that an integrated approach is needed and that in most cases this means more right hemisphere processes need to be added to the curriculum. Instructional strategies that integrate modes from both hemispheres are needed (Richards, 1984). Using balanced instructional strategies is a way to reach an entire class of students in a situation where individualized instruction is impossible. There are a number of ways that a teacher can stimulate individual students and address their learning styles while still meeting the needs of the whole class. Grady (1984) feels strongly that the integration of the two sets of hemispheric functions will help balance instruction,

increase learning, and provide effective instructional techniques for more students.

Problem to be Studied

This project addressed the issue of developing hemispherically balanced activities for a high school level biology course in order to determine student outcomes. Since current research indicates that students will do better, learn more when both hemispheres are involved in learning, the purpose of this project is to corroborate the research. Two groups of Biology I students were taught the same unit, following the same learning objectives, but using two different sets of enabling activities. One set of activities was designed to stimulate integrated/right hemispheric processes while the other set of activities was designed to stimulate left processes. Both groups were given the same pretest and post test for each of the four chapters and following the entire unit.

Hypotheses

Primary hypothesis: Students who participate in enabling activities designed to involve both hemispheres will show greater achievement by scoring higher on comprehension tests than students participating in left hemispheric activities.

Secondary hypothesis: Achievement of students who have right hemispheric preference will show higher achievement than those who are left preferenced.

Summary

It would appear that teachers are able to increase learning in the classroom by designing activities that stimulate both the left and right hemispheres. Teachers need to choose enabling activities carefully in order to help give the opportunity for the synergistic affect of utilizing both hemispheres. This study was designed to measure whether or not an integrated approach can increase learning.

CHAPTER II

Review of the Literature

Historical Aspects

Brain asymmetry. In 1836 a French country doctor, Marc Dax, presented a paper outlining his observations of patients suffering speech loss following brain damage. He concluded that each half of the brain controls different functions and that speech is controlled by the left half. The paper aroused no interest at the time, but was one of the first indications that the brain has asymmetry of function. For several years scientists argued over the idea that particular functions could be localized to specific regions of the brain. In 1961 a young French physician named Broca published a paper describing the area in the brain that controls speech. Additional work has corroborated his findings and the location of this region of the brain has become known as Broca's area. Broca was credited with being the first person to bring to the attention of the medial community as a whole the asymmetry of the human brain, even though there was some argument as to whether or not he was aware of Dax's work (Springer & Deutch, 1981).

Cerebral dominance. Following Broca's publication the concept now known as cerebral dominance began to

emerge. An English physician, Wigen, had published a paper describing a patient and friend who was discovered to have only one cerebral hemisphere. He had been neurologically normal in every other respect. Wigen concluded that if only one hemisphere is required to have a mind, the presence of two hemispheres make possible two minds (Restak, 1982). In the 1960s and 1970s other researchers, including Jackson, Wernicke, and Liepmann contributed evidence to the idea that the left hemisphere has functions not shared by the right and that the left controls purposeful movements as well as language. For many years it was thought that the left hemisphere was the major hemisphere, directing the functions of the minor right hemisphere (Nebes, 1975).

Split brain research. Theories of hemispheric dominance remained largely untested until brain researchers began performing a procedure to control epileptic seizures. They cut the corpus callosum (a tract of nerve fibers, also called the cerebral commissure, connecting the two hemispheres). This was commonly referred to as split-brain surgery. It prevented nerve impulses from being relayed from one hemisphere to the other. William Van Wagenen performed the first commissurotomy (split-brain operations) on humans in the early 1940s in an effort to treat epilepsy.

The earliest researchers reported that the operation had no detectable effect on behavior. However, during the 1950s Roger Sperry and his students began conducting animal studies at the California Institute of Technology. It was established that a main function of the corpus callosum was to provide communication between the two hemispheres and to allow transmission of memory and learning. Furthermore, it was determined that if the connecting cable was severed the two brain halves continued to function independently (Sperry, 1966).

Further split-brain research on humans. During the 1960s further study on human subjects, referred to as split-brain patients, provided further information to Sperry and his students, Gazzaniga, Levy, and others. The commissurotomies were performed by Vogel and Bogen after all other remedies for controlling seizures had failed. The Cal Tech group worked with these patients. The results of their tests revealed the separated functions of the two hemispheres. Sperry concluded that each hemisphere perceived reality in its own way. He studied the different ways in which the two hemispheres process information, as did his student, Jerry Levy, in her doctoral studies. Evidence of split-brain studies suggested that both hemispheres used high-level cognitive modes which, though

different, involve thinking, reasoning, and complex mental functioning. Scientists continued to find evidence supporting this view (Sperry, 1974).

Hemisphericity. The hemispheric model has been considered to be significant in helping educators understand some of the workings of the brain. A basic understanding of hemisphericity is necessary in order to understand the educational implications. Carl Sagen (1977) described how each hemisphere of the brain specialized in a different mode of consciousness. Although both hemispheres receive and process information, each processes it separately. The right and the left hemisphere each have specialized thinking characteristics. A behavior analysis of the two hemispheric modes (Vitale, 1982) shows that the left mode specializes in the following things:

Arranges things in logical order
Thinks from part-to-whole
Thinks in symbols
Approaches life sequentially
Has reasons for its answers
Has a good vocabulary
Deals with reality as it is
Is time oriented
Can deal with and accept abstract ideas
Figures things out step by step

Uses numbers in counting

Draws conclusions based on reason and logic

A behavior analysis of the right mode shows that it specializes in the following activities:

Thinks from whole-to-part

Perceives a whole pattern

Has trouble with sequencing

Deals with the concrete

Learns by doing, touching, moving

Thinks randomly and not sequentially

Is intuitive

Has trouble labeling or naming

Fantasy-oriented

Not time oriented

Sees how parts go together

Learns through absurdities

Sees likenesses between things

Has leaps of insight

Deals with imagery and imagination

Creates from within

Has difficulty expressing self in words

Hemispheric dominance. Normal individuals, that is non split-brain patients, use both hemispheres of the brain by means of the corpus collosum, but one side may be used more than the other. For instance, a person might have a dominant right hemisphere, which

means that is the preferred or stronger hemisphere. It is the one which tends to process most of the information first. Rigidity of specialization should not be overemphasized according to Barbara Vitale (1982). There is generally a balance between hemispheres, with each taking control of the tasks it is best at handling. However, a person can be identified as right brain or left brain dominant. Blakeslee (1982) emphasizes that even though a student tends to favor a right or left brain approach it does not mean that only the favored approach should be developed. The ideal would be to develop both halves of the brain and their ability to work together.

Bihemspheric approach. The idea of a holistic, integrated, balanced approach has been studied for about ten years. Bogen (1975) seems to have started the trend. As Linda Luvaas-Briggs (1984) pointed out, most educators are aware of the dominant functions of the right and left hemispheres of the brain. It is accepted that the left hemisphere's domain is verbal, analytical, and reductionistic, while the right hemisphere specializes in imaging, synthesizing, and holistic thinking. The emphasis in schools has been on the development of left brain types of skills. She states that the goal in the classroom should be to integrate the strengths of both hemispheres. Learning

can be facilitated through promoting complementary hemisphere interaction--by offering all students more than one cognitive approach to learning material.

Grady and Luecke (1978) described a synergistic mode of consciousness that operated infrequently, but produced exciting results. It was a peak experience that occurred when intuition and reason were in perfect synchronization, sometimes known as the "ahaa" experience. They said it was the development of the previously neglected and underevaluated right hemisphere that was the catalyst that produced synergistic experiences. The implication for schools appeared to be that nonlinear processes must also be stressed in the curriculum.

Grady (1984) further suggested that using balanced instructional strategies was a way to reach an entire class of students in a situation where individualized instruction was impossible. He strongly believed that the integration of the two sets of hemispheric functions would help balance instruction, increase learning, and provide effective instructional techniques for more students.

Richards (1984) stated that we need instructional methods and strategies that integrate modes from both hemispheres. It has been estimated that between two and three million students in kindergarten through

grade twelve have predominantly right brain styles for learning. Max Rennels (1976) who investigated educable mentally handicapped children also concluded that equal educational attention should be given to all facets of intellectual capacity and said that an urgent concern for education should be developing equal qualities of cerebral functioning.

Bihemispheric research. Grady (1984) found that classroom teaching-learning techniques was based primarily on the linear, sequential, and analytic functions of the left hemisphere of the brain. In addition, certain subjects such as reading, writing, and arithmetic relied heavily on the left brain processes. Research indicated that equal emphasis should be given to methods and subjects which integrated the two sets of hemispheric functions.

1. A major study by Noller and Parnes (1972) found that divergent (right brain) production scores on the SOI (Structure of Intellect) test significantly increased as a result of creativity training. The training procedures provided opportunity for the students to shift back and forth from left hemisphere to right hemisphere processing, depending on the demands of the task (integrating processes). It was discovered that the left brain (convergent) task performance on the SOI also improved significantly by

creativity (integrated) training. These findings suggested optimal cognitive functioning required interdependency between hemispheres.

2. In a study conducted by Kraft in 1976 (cited in Rubenzer, 1982) on six to eight year olds engaged in selected "Piagetian" tasks showed that those children who were both hemispheres (as indicated by EEG readings) throughout all tasks, performed better on both verbal and nonverbal activities. In other words, when the relatively nonverbal right hemisphere was used in processing the verbal task with the left hemisphere, performance was better than those who used only their left hemisphere on verbal tasks.

3. In another study Rennels (cited in Rubenzer, 1982) found that stimulation of the right hemisphere processing also increased measured intelligence. He reported that 60% of the abilities that IQ tests are reported to measure were found to involve right hemispheric processes.

4. Zaidel and Sperry conducted a study in 1974 which showed that short term memory, a left hemisphere function, was significantly decreased when communication between the two hemispheres was impaired.

5. Studies of hemidecorticates (children who had to have one brain hemisphere removed to control convulsions) reported by Maureen Dennis (1980) showed

no basic differences in IQs between patients with the left hemisphere removed and the patients with the right hemisphere removed. She concluded that either hemisphere can provide the substrate for verbal cognitive skills.

6. Studies conducted by Marcel, Katz, and Smith in 1974 compared good and poor readers. Poor readers correctly identified more words and almost twice the number of letters presented to the right hemisphere than did good readers. These results indicated nonverbal right brain involvement in literacy learning.

7. Using 20 good readers and 20 poor readers Oexle and Zenhausern (1981) found that the good readers activated both hemispheres almost equally (nine right and eleven left); but 17 of the 20 poor readers indicated a preference for right brain activation.

Classroom Implications

Identification of students' preferences. Educators interested in hemispheric preferences will want to identify their own students' preference for right or left mode thinking patterns. There are several methods available. One such test which was validated is Your Style of Learning and Thinking (SOLAT) developed by Torrance, Reynolds, Riegel, and Ball. Another test was developed by Robert Zenhausern, the Differential Hemispheric Activation Test. These

tests measured hemispheric preference for processing information, one element of student learning style. Learning style was defined by Levy (1983) as the preferred method of introducing material, not the type of understanding a student may have. However Dunn, Cavanaugh, Ederle, and Zenhausern conducted a study (1982) correlating learning style and hemispheric preference. Their results indicated a statistically significant correspondence between individual students' learning styles and their hemispheric preference.

In addition to formalized tests teachers may use observable behaviors to identify hemispheric preference. Barbara Vitale (1982) developed one such list of 26 behaviors commonly seen in right preferenced students. Other indicators of hemispheric preference are eye dominance, hand dominance, hand position when writing, muscle testing body symmetry, and lateral eye movements.

Curriculum approaches. Several people have developed curricular approaches that address the needs of both the right brain and the left brain. One approach was developed by Bernice McCarthy. It is called the 4MAT System and concentrates on teaching alternately toward the child's left and right brain strengths. Another approach was described by Barbara Clark (1983). It is the Integrative Education Model:

Using Brain/Mind Research in the Classroom. She stated that integrated activities are important for optimizing the learning experience. A third method was examined by Gloria McLendon (1982). She described an instructional technique which can be implemented across the curriculum to produce holistic thinkers.

Classroom activities. In developing any curriculum which is going to include right brain, left brain, and integrated activities, teachers need to be aware of the types of enabling activities that encourage each mode. Vitale (1982), Edwards (1970), and Grady (1984) have extensively explained types of right brain activities that can be used. Dombrower (1982) and Richards (1984) also described activities in detail. The activities listed in these sources include the following ideas:

Working at random

Allow students to choose own order

Vertical writing

Scanning

Looking over whole assignment before starting

Remembering by visualizing

Visual models

Gluing other materials onto dittos

Learning while moving or standing

Singing vocabulary words to self

Guided imagining

Brain storming

Silly mnemonics

Metaphors--how one thing is like another

Estimation--making sensible guesses

Hapatic activities--writing in the air, tracing numbers

Total environment activities such as dramatizing, role playing, pantomine, searching for something, slow motion

Teachers need to be aware of the skills associated with the specialties of each hemisphere (Vitale, 1982).

Left hemisphere skills.

handwriting	locating details and facts
symbols	talking and reciting
language	following directions
reading	listening
phonics	auditory association

Right hemisphere skills.

hapatic awareness	singing and music
spatial relationships	art expression
shapes and patterns	creativity
visualization	mathematical computation
color sensitivity	feelings and emotions

Integrated or alternating.

problem finding	computer graphics

problem solving poetry

singing geometry

Techniques for the formal reasoning stage.

Sometimes it is difficult to utilize some of these methods in higher level science classes. Even though much of science is organized around hands-on activities many concepts cannot be dealt with in this manner. Virginia Johnson (1985) suggested that older students who are in the formal reasoning developmental stage can be stimulated by concentrating on the higher level thinking skills that occur in the frontal lobes. These would include divergent thinking, comparison, evaluation, synthesis, and analysis. She suggested a problem solving approach needs to be included.

The frontal lobes direct the simultaneous functioning of the left and right hemispheres. They combine, compare, and synthesize images until the thinker comes up with a solution. If the insight to a problem appears in the right hemisphere as an image, the left side must transform the image so that the thinker can talk about it. At the same time the frontal lobes must compare the abstractions with the original image (in the right hemisphere) to verify the progress, adjusting continually until the final product resembles the original intent.

Johnson (1985) said that if chores are complex enough they activate both sides of the brain and force the two hemispheres to interact. Students at this stage need interesting, formal, and challenging tasks for the mental exercise they need to build up the total brain. They need problems with no black and white solutions, problems that require decision making. Activities need to demand selective encoding of information, selective combining of relevant information, selective comparison of information, and the recognition of problems similar to those previously encountered. To find and develop these is a challenging problem for teachers.

Current teaching techniques in biology. Currently many biology classes are taught using the following format. A concept is introduced by the teacher in any of a number of ways: an interesting anecdote, a question, an example, a current event. More often than not the introduction is a verbal presentation by the teacher. With students at the formal reasoning stage the verbal presentation may or may not stimulate both hemispheres. Often it stimulates only the left with the average teacher. Next students will be given a reading assignment, sometimes with questions to answer about the content. This is definitely a left brain activity. In addition the teacher will lecture about

the subject either before or after the reading. The average lecture, even when given with visual aids, mainly stimulates the left hemisphere. In most biology classes this original presentation of information about a concept is followed by some sort of laboratory or hands-on activity that may or may not involve problem solving. At this point students are involved in an integrated activity. Quite often the activity is followed by a class discussion and another supplementary or summarizing activity using pencil and paper. This usually involves left hemisphere operations.

In the average biology classroom today an observer will see students involved in some integrated activities and many left brain activities. It should be noted that at the formal reasoning stage a teacher can easily change a normally left brain activity into an integrated one by carefully or intuitively changing the mental activities required of the student. For instance, the teacher can ask divergent type questions that require creative answers, decision-making, analysis, or problem solving. Wheatley (1977) concluded that problem solving will be enhanced by greater use of the right hemisphere. At present, it would seem that most biology classrooms utilize

integrated/left brain activities and few right brain activities.

Summary

Brain research has led to the idea that the two hemispheres process information in different ways and that both modes are important in higher level thinking. Schools have traditionally neglected the right hemispheric processes. Educators need to focus more attention on the right processes in order to formulate a balanced approach. The balanced approach stimulates both hemispheres to interact so that one stimulates the other creating a synergistic effect. Teachers can use this information by selecting and designing classroom activities which are bihemispheric.

CHAPTER III

Method

Brief Description of Overall Approach

Two groups of Biology I students were taught the same four chapter units on cells utilizing the same curriculum objectives and the same tests. For one group the enabling activities were designed to stimulate left hemispheric processes. Enabling activities used by the other group were designed to stimulate both hemispheric processes. Both groups were taught by the same teacher. They were pretested and post-tested for each of the four chapters in the unit. Their test scores were compared.

Students

The students were in grades 9 through 12, ages 14-17, enrolled in the first level of high school biology at Washington High School, Washington, Missouri. Most students who enroll for Biology I have an average reading ability. Students with extremely low abilities are normally channeled into other science classes. Washington High School students are mainly white middle class with very few minority groups represented. The community itself is a combination rural-suburban, being located 50 miles from a major city, St. Louis. The

total high school enrollment is approximately 1150 students.

Groups

Since the two groups were intact rather than random, additional information was considered when analyzing the results. The following data were gathered:

1. Prior knowledge of biology in general as indicated on Scott, Foresman's Biology Test, a nationally normed instrument

2. Hemispheric preference of students as indicated by Torrance's Style of Learning and Thinking (SOLAT) test

3. Scheduling factors that may have affected the characteristics of the groups.

Measurement of Student Achievement

Student achievement was measured at the end of each of the four chapters. In addition a unit test was given six weeks following the actual study of the unit. The tests were teacher constructed, utilizing criterion referenced questions which had been tested for reliability by the Scott, Foresman Publishing Company. A pretest for each chapter was constructed in the same way.

Activities Used

Enabling activities used in the study were selected on the basis of two criteria:

1. Relevance to stated curriculum objectives for the unit

2. Hemispheric processes involved in the activity.

In order to determine the hemispheric processes involved in an activity, each activity was evaluated in terms of the following criteria:

1. Activities stimulating right hemispheric processes include visualizing, brainstorming, working at random, creativity, hapatic involvement, total involvement such as role playing or dramatizing, perceiving patterns and relationships, or concrete and visual models.

2. Activities stimulating left hemispheric processes include handwriting, reading, locating details and facts, talking and reciting, following directions, listening sequential or logical order, or taking notes.

3. Activities like problem finding and problem solving seem to involve both hemispheres.

Uncontrolled Variables

In this study there were several variables which were not possible to control:

1. The use of intact groups created variables which were impossible to overcome. There were several significant differences between the two groups.

2. It was impossible to control historical factors which may have affected the outcome. That is, previous educational experiences undoubtedly affected the students' responses to the activities.

3. It was impossible to control the teacher's ability to vary the teaching style from one group to the next. Even though the activities were designed to stimulate a particular hemisphere, as previously noted, verbally a teacher can change the thrust of the type of mental activity required.

4. It was impossible to control varying student responses to the testing procedures. It is possible that the type of testing used did not truly measure each student's overall comprehension of the objectives being tested.

Analyses of Data

Data collected were analyzed in the following ways:

1. The mean and standard deviation was calculated for each pretest and post test.

2. The mean scores of each group were compared by means of *t*-tests.

3. An analysis of covariance was used to adjust for initial differences between the two groups.

4. A Pearson Correlation was calculated to determine whether or not there was a relationship between hemisphericity and achievement.

Summary

Two intact groups of Biology I students were taught the same unit using two different sets of enabling activities. Student academic achievement was measured and compared to see if the two teaching approaches had statistically significant different effects.

CHAPTER IV

Results

It was predicted that students who participated in enabling activities designed to involve both hemispheres would show higher academic achievement by scoring higher on comprehension tests than students participating in left hemispheric activities. In order to test this hypothesis two intact groups of Biology I students were taught the same unit using two different sets of enabling activities. All students were given the same pretest and post test at the beginning and at the end of each of four chapters and following the entire unit.

A further prediction was that after exposure to the greater number of right brain activities, students with right brain tendencies would attain higher achievement scores than the students with left brain preferences. In order to test this secondary hypothesis a Pearson r Correlation was calculated.

Groups

Since intact groups were used, two tests were given to help measure the characteristics of each group. Scott, Foresman's Biology Test, a nationally normed instrument, was used as an indicator of prior knowledge of biology. A t-test was used to analyze the

difference in scores between the two classes, as shown in Table 2.

Table 2

t-Test for Scott, Foresman's Biology Test

	n	M	SD	*t*	df	*p*
Experimental Group	28	26.11	6.27	-.39	44	.35
Control Group	18	25.41	5.51			

The *p* value shown on Table 2 indicates there was no significant difference in the two groups on the test for prior biology knowledge. Although the means on this test were not different, the chapter pretests showed differences which led to the need for using an analysis of covariance.

Torrance's Style of Learning and Thinking test was administered in order to determine the hemispheric preference of the students in each group. Table 3 shows the results of this test.

The mean score of the experimental group was in the "favoring right" category while the mean score of the control group was 3.3 points lower, near the whole brain category. In the experimental group 78% either favored the right or were right hemisphere preferenced

as compared to 38% in the control group. The differences in standard deviation indicate more dispersion of scores in the experimental group. This broader range in hemisphericity may or may not have affected the characteristics of the group. The *t* test results shown on Table 3 indicate that there was a significant difference in the hemispheric preferences of the students in the two groups.

Table 3

Hemispheric Preference

	Experimental Group	Control Group
Left Dominance	3.6%	0.0%
Favoring Left	17.8%	27.7%
Whole	0.0%	33.3%
Favoring Right	46.0%	38.8%
Right Dominance	32.0%	0.0%
Mean	+4	+0.7
Standard Deviation	7.48	2.28
t-test	-1.84	
p value	.035*	

* Significant

as compared to 38% in the control group. The differences in standard deviation indicate more dispersion of scores in the experimental group. This broader range in hemisphericity may or may not have affected the characteristics of the group. The t test results shown on Table 3 indicate that there was a significant difference in the hemispheric preferences of the students in the two groups.

Table 3

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Left Dominance	3.6%	0.0%
Favoring Left	17.8%	27.7%
Whole	0.0%	33.3%
Favoring Right	46.0%	38.8%
Right Dominance	32.0%	0.0%
Mean	+4	+0.7
Standard Deviation	7.48	2.28
t-test	-1.84	
p value	.035*	

* Significant

Additional information about the characteristics of the groups includes differences in number. The experimental group had 28 students while the control group had 18. Both classes were taught in the afternoon. The experimental group met during the last hour of the school day while the control group met during the next-to-the-last hour of the day.

Primary Hypothesis

The primary null hypothesis was: Students who participate in enabling activities designed to involve both hemispheres will not show higher academic achievement by scoring higher on achievement tests than students participating in left hemispheric activities.

A four chapter unit in biology was taught, giving a pretest and a post test for each chapter. The experimental group participated in integrated/right activities while the control group participated in primarily left hemisphere activities. To compare longer term retention, a unit test was given five weeks after the unit had been completed, without warning the students ahead of time.

A separate t-test was used to compare the results of the two groups on each unannounced unit test. Table 4 shows an analysis of these comparisons. The t-test shows that on two of the pretests the groups had

significantly different scores. On one significantly different pretest the experimental group scored higher; and on the others, lower than the control group. On two of the post tests the control group scored significantly higher than the experimental group. Other scores were not significantly different.

Table 4

t-Tests of Comprehension Tests

Test	Experimental Group		Control Group				
	M	SD	M	SD	df	*t*	*p*
Test 1							
Pretest	50	14	49	12	47	.18	.43
Post Test	75	7	85	12	45	3.24	.001*
Test 2							
Pretest	43	12	31	12	46	-3.21	.001*
Post Test	72	11	74	16	45	.48	.32
Test 3							
Pretest	48	19	48	15	45	.05	.48
Post Test	78	8	82	11	44	1.20	.12
Test 4							
Pretest	30	15	45	17	45	2.88	.003*
Post Test	73	10	83	15	42	2.38	.011*
Unit Test	58	11	68	14	39	-2.61	.006*

* Significant

As shown on Table 5 the differences between the pretest and post test scores in the experimental group

increased consistently as the study went on. There was no similar trend in the control group.

Table 5

Differences Between Pretest and Post Test Scores

Group	Test	#1	#2	#3	#4
Experimental Group	Pretest	50.18	43.15	48.15	30.73
	Post Test	75.50	72.11	78.56	73.12
	Difference	25.32	28.96	30.41	44.39
Control Group	Pretest	49.50	31.24	48.42	45.25
	Post Test	85.50	74.21	82.39	83.28
	Difference	36.00	42.97	33.97	40.03

In addition, an analysis of covariance was calculated in order to adjust for initial differences between the two intact groups. Table 6 shows that, when adjusted, the differences in scores on all post tests were not significantly higher for the experimental group.

Table 6

Analysis of Covariance
of Differences in Post Test Results

Test	F ratio	Significant Level
Post Test 1	13.5	.001*
Post Test 2	1.9	.168
Post Test 3	.97	.669
Post Test 4	6.13	.017*

* Experimental group significantly lower

These analyses did not verify the predicted results. Therefore, the null hypothesis was accepted.

Secondary Hypothesis

The secondary null hypothesis was: In the experimental group, the achievement of students who have right hemispheric preference will not be higher than those who are left preferenced.

In order to test for a relationship between student hemisphericity and achievement, a Pearson *r* Correlation was calculated after transposing the hemispheric preference scores to positive numbers with left brain references indicated by lower numbers and the right by higher numbers. The Pearson *r* was +.17. This is not a significant correlation. The secondary null hypothesis was also accepted.

Summary

It was predicted that students who participated in enabling activities designed to involve both hemispheres would show higher academic achievement than students participating in left hemispheric activities. It was further predicted that there would be a positive correlation between hemispheric preference and academic achievement. After an analysis of the data, both predictions were rejected.

CHAPTER V

Discussion and Recommendations

The purpose of this study was to determine any measureable differences in student academic outcomes when they participated in activities designed to primarily involve the right hemisphere as compared to when they participated in activities designed to mainly involve the left hemisphere. It was predicted that students who participated in more integrated/right brain activities would show higher academic achievement. It was further predicted that students who were right preferenced would do better than those who were left preferenced. Both experimental hypotheses were rejected.

Threats to Internal Validity

A major threat to internal validity that was not adequately controlled was the selection of the two intact groups. The two groups had several differences:

1. The results of the SOLAT hemisphericity pretest showed a statistically significant difference between the experimental and contol groups.
2. It is unknown how the differences in group sizes may have affected the results of the study.
3. The fact that the experimental group met the last hour of the school day while the control group met

the preceding hour may have been a factor that affected student achievement.

4. The researcher taught both the experimental and control groups, opening the possibility for expectancy.

Several potential differences were not measured or considered:

1. Possible differences in student aptitude may have affected the outcomes.

2. Differences in overall grade point averages of the students were not considered, except as mentioned below, but may have been an indicator of student motivation and past academic performance.

3. Differences in the learning styles of male versus female students were not considered.

The teacher's personal observations of the two groups indicated that the control group was highly self-motivated and on task most of the time with three of the 18 students having a 4.0 overall grade average. The experimental group was not self-motivated and needed almost constant teacher guidance in order to stay on task. None of the 28 students in this group maintained a 4.0 grade average. These differences were observed throughout the school year, not just during the time of the study.

Threats to External Validity

Two threats to external validity may have affected the results of this study. First, is the threat of the interaction of treatment with persons. This group of Biology I students may not be typical of other Biology I students. If this study was repeated with other groups, the results could be different. Second, is the threat of interaction of treatment with setting. All students in the study were exposed to a change in the established teaching style in the class. The students had grown accustomed to a certain approach in the class and many seemed to be threatened by the abrupt change, particularly students in the experimental group where the change was more drastic. For a while this change seemed to cause students to feel insecure, as indicated by students' comments included in Appendix A. This change may have created an artificial setting which affected the results of the study.

Limitations

The results of this experiment may have been affected by certain limiting factors:

1. The groups used for the study were not randomly selected.

2. A longer period of time may have allowed a stronger effect from the treatment.

3. The study was carried out during the middle of the school year after the students had established study patterns for the class.

4. The students had little prior experience with being accountable for information learned by participating in right brain activities.

5. The study required the teacher to make changes in teaching techniques from one hour to the next. The change not only involved differences in activities, but differences in questioning techniques and differences in approaches to explanations. The teacher may not have adequately varied the teaching style used with the experimental group from the style used with the control group.

6. The activities themselves may not have always stimulated the hemisphere at which they were aimed.

Recommendations for Further Study

Future research in the field of the educational implications of hemisphericity might consider the following recommendations:

1. One might consider changing the operational definition used and measure achievement with more right brain, divergent type tests.

2. A change in the operational definition and type of testing might allow the use of gain scores rather than post test scores.

3. In the experimental group, a more integrated approach could be used with fewer, specifically right brain activities.

Summary

Regardless of the results of this study, the researcher felt that there was enough other research on record to indicate that students actually benefited from brain compatible learning opportunities. Grady (1984), Clark (1983), Rubenzer (1982), and Bogen (1975) all presented convincing evidence of the educational significance of hemispheric specialization.

It would seem that the two major factors affecting the results of this study were unequal intact groups and the threat of the artificial setting. Future studies could be carefully designed to overcome these threats and limitations.

APPENDICES

APPENDIX A

Student Comments concerning the Activities

This section contains student comments concerning the activities. The comments were made by students in the experimental group.

The following comments were made by students in the experimental group:

"I think that with the change in activities we have had to work harder. I don't like working harder, but I think it will be better for us in the long run. I don't know if it's helping out so much on tests, but the added bit of responsibility and hard work is helping out character wise and it's a step in the right direction."

"I feel that the activities are neat and I think that it is easier to understand what's going on with these activities."

"I want it the way it used to be!"

"The activities are confusing and don't get right to the point."

"The activities have changed too much. We don't learn from the book the way we used to."

"I'm getting better grades and it seems like more people are turning in all their assignments."

"After using the ones last semester we got used to them and the new ones are harder to get used to."

"The new activities help me. They are in more detail and they explain more sometimes."

"I like the new activities better. There is a lot more demonstration instead of just writing questions

and doing everything on your own. The new ones help a lot more."

"I like this better. We do more activities and I learn better with hands-on-experience."

"I've noticed the activities are different and they help me learn."

"I think the old way was better."

"I've noticed a difference in the activities we've done lately. Before we did questions in the book and went slower. Now we do lots of experiments, but I'm not sure I'm learning as much. Maybe we could change it back for a couple of chapters."

APPENDIX B

Learning Objectives

This section contains the learning objectives for the chapters taught in this study:

I. Chemistry of Life

II. Cell Structure

III. Functions of Cells

IV. Information Storage and Transfer in Cells

I. Chemistry of Life

A. The student will describe the structure of an atom.

B. The student will name three examples of compounds.

C. The student will explain the difference between ionic and covalent bonding.

D. The student will describe what happens in a chemical reaction.

E. The student will describe how an enzyme helps control the flow of energy in a chemical reaction.

F. The student will describe the basic building blocks from which proteins, carbohydrates, lipids, and nucleic acids are made.

II. Cell Structure

A. The student will state the four basic ideas of the cell theory.

B. The student will describe at least three ways in which cells differ from each other and three ways in which they are similar.

C. The student will describe the main functions of the major cell structures.

D. The student will list the major differences among moneran cells, protist cells, fungal cells, plant cells, and animals cells.

III. Functions of Cells

A. The student will describe the differences and similarities among the five types of cell transport: diffusion, passive transport, osmosis, active transport, and bulk transport.

B. The student will differentiate between hypertonic, hypotonic, and isotonic solutions and how they affect osmosis.

C. The student will understand how ATP functions as an energy-carrier compound.

D. The student will compare two energy releasing processes: cell respiration and fermentation.

E. The student will understand photosynthesis as an energy storing process.

F. The student will understand the relationships between photosynthesis and cell respiration.

G. The student will understand the meaning of homeostasis and its importance.

IV. Information Storage and Transfer in Cells

A. The student will understand the chemical structure of a DNA molecule and how it replicates.

B. The student will understand how DNA controls the functions of a cell.

C. The student will understand how a segment of a DNA molecule can code for the amino acids in a protein.

D. The student will understand how a cell makes mRNA and how it functions in the cell.

E. The student will understand the steps in the process of protein synthesis.

F. The student will understand how changes in DNA can cause mutations.

G. The student will understand the stages in mitosis and meiosis and the importance of each process.

APPENDIX C

Integrated/Right Brain Activities

This section contains samples of the integrated/right brain enabling activities used by the experimental group.

Chapter Three Chemistry of Life

CREATE YOUR OWN WORD PUZZLE

LEARNING OBJECTIVE: The student will describe the structure of an atom.

PURPOSE: To become familiar with the terms used when describing atomic structure.

MATERIALS: Pencil and paper

PROCEDURE: You are to create your own word puzzle or word game. It may be in the form of a crossword puzzle, find-a-word, or any other type of word game you can imagine. Whatever form you choose, your game needs to show that you understand the meaning of the following words: proton, neutron, electron, nucleus (of an atom), element, chemical symbol, organic compound, chemical bonding, ions, benzene ring.

Make your answer sheet separate from your game so that we can make copies of your game to share with the class

EVALUATION: Games will be evaluated in terms of completeness and accuracy of information included.

Note to Teacher:
This activity can be used anytime as an alternative to writing definitions. Students enjoy working each other's puzzles and hunting for mistakes.

Chapter Three Chemistry of Life

ATOM MODELS

LEARNING OBJECTIVE: The student will describe the structure of an atom.

PURPOSE: To help the student visualize the structure of an atom.

MATERIALS: Five different colors of felt and scissors

PROCEDURE: Using the felt make your own model of an atom. Use one of the colors for the space for energy levels. The other colors should represent the nucleus and the protons, neutron, and electrons. Make eight each of the protons, neutrons, and electrons.

Manipulate your model to show atoms of oxygen, hydrogen, and carbon.

EVALUATION: This activity will be evaluated in terms of accuracy of model and your ability to manipulate it to show the three types of atoms.

Note to Teacher:
these models are easy for the students to manipulate and easy for you to store for future use. They create both a visual and tactile impression on the student.

Chapter Three Chemistry of Life

CHEMICAL COMPOUNDS

LEARNING OBJECTIVE: The student will name three examples of compounds.

PURPOSE: To observe the way inwhich carbon, hydrogen, and oxygen atoms combine to form molecules of five different chemical compounds.

MATERIALS: Molecular models containing 10 hydrogens, 5 carbons, 2 oxygens, and springs to represent bonds. Note: If molecular models are not available styrofoam balls and toothpicks can be used.

PROCEDURE:

1. With one carbon atom, four springs, and four hydrogen atoms, build a model of the methane (CH_4) molecule. Remember that a carbon atom always forms four bonds and a hydrogen atom always forms one bond. Have yor teacher check your model before going on to step 2.

2. With one oxygen atom, two hydrogen atoms, and two springs, make a model of the water molecule (H_2O). Recall that each oxygen atom always forms two bonds.

3. The formula for ethane is C_2H_6. Construct a model for this molecule.

4. The formula for butane is C_4H_{10}. Construct a model for this molecule. Now, see if you can find more than one way to put together four carbon atoms and ten hydrogen atoms.

5. Ethyl alcohol is C_2H_5OH. Make a model of this molecule. See if you can find another way to put together this same set of atoms. Make sure every atom has the right number of bonds on it.

6. Two organic compounds have the formula C_3H_6. Try to make models of both of these compounds.

ANALYSIS QUESTIONS:

1. How many different ways are there to make a methane molecule? Why?
2. How many different ways are ther to make a butane molecule? Draw diagrams of each way.
3. Why does a carbon atom form four bonds while an oxygen atom only forms two bonds?
4. Write the name and chemical formula for five chemical compounds.

EVALUATION: This activity will be evaluated in terms of your participation and the quality of answers to the analysis questions.

Chapter Three Chemistry of Life

SPONTANEOUS MONOLOGUE ON CHEMICAL REACTIONS

LEARNING OBJECTIVE: The student will describe what happens in a chemical reaction.

PURPOSE: To extend the concept of the term "chemical reaction" by developing visual images.

MATERIALS: Pencil and paper

PROCEDURE:

1. Have students relax, sit comfortably, with hands on laps and eyes closed. Tell them to let go of worries or thoughts that are cluttering their minds.

2. Students need to silently read the assigned passage that describes what a chemical reaction is.

3. Ask students to write down three things that are important to know about chemical reactions.

4. Have students write down three facts about each of the three things written in step 3.

5. Ask students to pick any one of the first "important" things with its list of three facts, and write down feelings related to the concept.

6. Have students sit back, relax, and close their eyes. Then ask them to visualize everything their minds contain about the idea, chemical reactions. Encourage them to be sensitive to color, odors, textures, motion, relationships, sounds, temperature. Allow itme for them to visualize.

7. Have students open their eyes and write in a "free flowing" form, with no attention to spelling, grammar, whatever comes to mind about the visualization. Whatever flows, goes.

8. When they have finished, have them re-read what they have written and make any changes they feel necessary. At this point you may either ask for some form of sharing or just collect the papers.

EVALUATION: This activity will be evaluated in terms of your participation and the completeness of your monologue.

Note to Teacher:

This activity may be used to enhance the understanding of any concept. You may select any appropriate reading that explains the concept. During this activity you may choose to play music by Tchiakovsky Chopin, Haydn, or Rachmaninoff.

Chapter Three Chemistry of Life

INTERVIEW AN ENZYME

LEARNING OBJECTIVE: The student will describe how an enzyme helps control the flow of energy in a chemical reaction.

PURPOSE: To understand how an enzyme functions and what its job is in the cell.

MATERIALS: Pencil and paper. Casette recorder optional.

PROCEDURE: You are to write a dialogue in which you are interviewing an enzyme. During your interview you need to find out such things as: why he (or she) exists, what does he do for a living, how he does it, why he is important, where he lives.

In order to gather information for this assignment you will need to refer to biology books that explain the functions of enzymes. It will be helpful to view the filmstrip, Enzymes: Regulators of of Body Chemistry Part 1 produced by Health Relations Media.

If you prefer you may record your interview on a casette tape and turn in the tape.

EVALUATION: This activity will be evaluated on the quality of questions asked and the completeness and accuracy of the answers.

Note to Teacher:
You may prefer to have students work in pairs. Sometimes students enjoy presenting their interviews to the class. Encourage the use of humor!

Chapter Three Chemistry of Life

DESIGN A TEST

LEARNING OBJECTIVE: The student will review the six objectives for this chapter.

PURPOSE: To review all important concepts

MATERIALS: Pencil and paper.

PROCEDURE: You are to create a test for this chapter. The class will decide on a topic to be covered in each question. Include the correct answer to each question. Do not write on the back of your paper because after tests are completed they will be cut apart. All questions of each number will be given to one student. That student will select the best question and read it to the class as part of a trial test to be taken by all students.

EVALUATION: This activity will be evaluated on the quality of the questions you create.

Note to Teacher:
Having the students redistribute the questions was the part the class enjoyed.

Chapter Four Cell Structure

PERSUADE YOUR AUDIENCE

LEARNING OBJECTIVE: The Student will be able to state the four basic ideas of the cell theory.

PURPOSE: To understand the cell theory.

MATERIALS: Pencil and paper, casette player optional.

PROCEDURE: You are to prepare a eprsuasive speech. Your job is to persuade your audience that the cell theory is the most importnat theory in biology. Tell what the cell theory is (include all four parts) and why it's important.

Your work may be submitted in any one of the following forms:
1. Deliver your speech in front of the class. (No written work turned in)
2. Record your speech on a casette and turn in the tape.
3. Hand in your speech written word for word.

EVALUATION: This activity will be evaluated in terms of the ideas presented about the cell theory.

Chapter Four Cell Structure

WHO IS MORE OBSERVANT? YOU OR AN AUTHOR?

LEARNING OBJECTIVE: The student will describe at least three ways in which cells differ from each other and three ways in which they are similar.

PURPOSE: To observe the differences and similarities in cells.

MATERIALS: Microscope slides showing different types of cells
Filmstrip showing several different types of cells
Several different biology books which discuss differences and similarities in cells

PROCEDURE:

1. Make you observations of cells using microscope slides supplied by your teacher. Keep notes of your observations about differences and similarities.

2. Observe filmstrip of types of cells, again keeping notes.

3. After filmstrip brainstorm with members of your team. Make two lists: Ways cells can be different and ways cells can be similar. List as many ideas as possible.

4. Share your results with the class. Add any ideas to your list you did not already have written.

5. Now read sections in biology books about differences and similarities in cells.

6. Write a comparison between authors' ideas and the class' ideas. Evaluate which is best and tell why you arrived at your opinion.

EVALUATION: This evaluation will be based on the completeness of your notes from your observations and brainstorming as well as the quality of your comparison (step 6).

Chapter Four Cell Structure

CELL MODELS

LEARNING OBJECTIVE: The student will describe the main functions of the major cell structures.

PURPOSE: To better visualize the cell organelles.

MATERIALS: wax coated paper bowls
melted agar
students may decide on and supply items to represent organelles such as:
raisins, rice, olives, beans, peas, pieces of celery, carrots, radishes

PROCEDURE: Work with a partner to make your cell model. You need do decide on things to use to represent each of the parts of the cell studied. Teacher will list parts to be represented. The wax coated bowls can represent the cell membrane and cell walls. The agar will represent the cytoplasm. You decide on the rest.

Each person will make a labeled drawing of his model with a key to the objects used and a description of the functions of each organelle.

EVALUATION: This activity will be evaluated on the number of types of organelles shown in the model, the accuracy of the diagram, and the completeness of the description of functions.

Chapter Four Cell Structure

I AM THE MOST IMPORTANT CELL ORGANELLE

LEARNING OBJECTIVE: The student will describe the main functions of the major cell structures.

PURPOSE: To gain an understanding of the functions of the different cell organelles.

MATERIALS: Biology books for reference
Other materials optional as needed for preparing commercials

PROCEDURE: You will work with your team (2 to 4 people). Your team will prepare and coach one person to be a participant in a presentation titled "I am the Most Important Cell Organelle". Your team will be assigned one organelle. Your job is to convince the rest of the class that this organelle is the most important organelle.

Your team member will be allowed to make a presentation.

In addition, your team may present one commercial for your organelle. All team members may participate in the commercial if you want. You commercial may include music and visual aids.

After all teams have made their presentations, your team member will be allowed a brief rebuttal or summary.

EVALUATION: This activity will be evaluated on participation and the accuracy and completeness of information.

Note to Teacher:
Students may want to devise some method of deciding on "The Most Important Organelle" such as non-partial judges or a type of voting.

Chapter Five Functions of Cells

CREATE A CHART

LEARNING OBJECTIVE: The student will understand the differences and similarities among the five types of cell transport: diffusion, passive transport, osmosis, active transport, and bulk transport.

PURPOSE: To visually organize information about the five types of cell transport

MATERIALS: Pencil and paper

PROCEDURE: Create a wall organized chart comparing the five ytpes of cell transport. Include definitions, how a membrane is involved, concentrations of molecules involved, if energy is required, size and types of materials, carrier molecules.

EVALUATION: Evaluation for this activity will be based on the accuracy and organization of the chart.

Chapter Five Functions of Cells

A FAMILY AFFAIR

LEARNING OBJECTIVE: The student will understand how ATP functions as an energy-carrier compound.

PURPOSE: To visualize the ATP/ADP cycle.

MATERIALS: Four students to role play
Narrator (usually teacher)
Name placards for the four students

PROCEDURE: You are to read or participate in the playlet, "A Family Affair". Afterwards you are to write your own description of how ATP fucntions as an energy-carrier compound OR you may create your own script for the play.

To the Teacher:
The narrator is to read the following script while the four characters 'act out' the playlet. It needs to be read with all the humor and drama possible!

NARRATOR: A significant compound in the energy processes of cells is a substance known as adenosine triphosphate, usually abbreviated ATP. This compound is used by cells to store energy until it is needed. When the energy is needed ATP will be broken down into another substance, Adenosine diphosphate or ADP, and the energy that has been stored in its chemical bonds is released. The following playlet is intended to help you visualize this process.

Our characters are:
Father-Father's first name is Adenosine
Mother-Mother's name is Phosphate

Mother and Father have two children:

Phosphate 2--the second born child
Phosphate3--the first born child

(The fur members of the cast will stand in front of the class hilding placards to remind the audience of their names.)

I would like to further introduce you to the Phosphate family. Here is father. He actually insists that everyone but his children call him Adenosine. It is a name passed on to him by his ancestors. Adenosine's adoring wife is Phosphate. She and Adenosine are truly in love and will never part. Their youngest child is Phosphate 2, named after her mother, of course. Since she is the youngest she stays closest to mother and will be the last to leave home. Now I would like to present the star of our show, the oldest child, Phosphate 3.

Friends and neighbors refer to the family as Adenosine and the Three Phosphates, or just plain ATP for short. The ATP family has been a typical, happy American family, up until now. Phosphate 3 is now a teenager. In fact, she has become a rebellious teenager. Mother and Father have tried everything. Not knowing what else to do with their energetic teeny bopper, they have told her she is grounded for three weeks. Phosphate3 says, "I'll show them!" She runs away! (Have Phosphate 3 move to the other side of room) As you can imagine, this causes much turmoil in the family. They release a lot of their energy by screaming and yelling. Friends can no longer call them the ATP family. They now refer to them as the ADP's (Adenosine and his Duel Phosphates).

Meanwhile, Phosphate 3 is getting tired of not having her own stereo and not being able to afford to buy new lipstick. After consulting her friend Glucose, who is really

broken up over the whole thing, Phosphate 3 gathers her energy and returns home. (Have Phosphate 3 move back to be with the family.) Friends and neighbors were happy and immediately began to call them the ATP's again.

However, the story is not completely over. This family is doomed to have many break ups and reconciliations over and over again. Adenosine and the Duel Phosphates will always love Phosphate 3. No matter how many times she gets mad and runs away, they will always yell and scream, but they will always take her back.

We will now leave our Indian family for now. How did we know it is an Indian family? You should have already guessed....it is because they live in ATP (a teepee)!!!

EVALUATION: Evaluation will be based on the accuracy and completeness of your description or script.

Chapter Five Functions of Cells

DOING AN ADI

LEARNING OBJECTIVE: The student will compare two energy releasing processes: cell respiration and fermentation.

PURPOSE: To discover how cell respiration and fermentation are alike and different.

MATERIALS: Pencil and paper

PROCEDURE: ADI stands for ALIKE, DIFFERENT, and INTERESTING. In order to do an ADI you will make three lists regarding the two processes, fermentation and cell respiration.

In one list tell ALL the ways you can think of that they are alike.

In another list tell ALL the ways you can think of that they are different.

In a third list tell any interesting facts about each or both that you know.

EVALUATION: This activity will be evaluated on the completeness and accuracy of each list.

Chapter Five Functions of Cells

PHOTOSYNTHESIS: THE LIGHT AND DARK OF IT

LEARNING OBJECTIVE: The student will understand photosynthesis as an energy storing process.

PURPOSE: To visualize the chemical processes involved in the light and dark reactions of photosynthesis.

MATERIALS: Worksheet
Placards for students to hold:
2 marked 12 Hydrogens
1 " 6 Carbons
4 " 6 Oxygens
2 " Water
1 " Carbon Dioxide
1 " Glucose
1 " Light Reaction on one side and Dark Reaction on the other
1 " Fold it so that one student can carry it to show "Light Energy", then "Energy Stored in ATP and $NADPH_2$", and then "Energy Stored in Glucose"

PROCEDURE: You are to take part in the role playing activity "Photoysnthesis: The Light and Dark of It" as directed by your teacher. After the activity complete the worksheet.

EVALUATION: This activity will be eveluated on participation in role playing and accuracy and completeness of worksheet.

Note to Teacher:
Students should have already read about the light and dark reactions in photosynthesis. Distribute the placards to 13 students. Write the following formula on the board:
$12\ H_2O + 6\ CO_2 \text{ ----------> } C_6H_{12}O_6 + 6O_2 + 6H_2O$

Now direct the movements of students through the activity:
1. Student should hold Light Reaction placard on one side of the room.
2. On same side of room direct one student to hold Water placard and behind this student have 2 students marked "6 Oxygens" and two student marked "12 Hydrogens" stand
3. In addition have one student hold "Carbon Dioxide" placard and behind this student have students stand who hold "6 Carbons" and two "6 Oxygens"
4. Have Light Energy enter
5. Water breaks apart by having the 12 Oxygens move to another location in room to represent going into the air. Then have the 24 Hydrogens move to another side of the room and wait.
5. Energy now changes placard to read "Energy Stored in ATP and ANDPH2.
6. Student holding "Light Reaction" placard changes it to read "Dark Reaction".
7. Now have the "Carbon Dioxide" placard leave and the 6Carbons and the two ¢ Oxygens are to move across the room to join the Hydrogens in the following way.
8. One of the 6 Oxygens joins 12 Hydrogen to form Water. (Have student hold the other water placard)
9. The 6 Carbons and the remaining 6 Oxygens join the 12 Hydrogens to form Glucose. (Have student hold the Glucose placard)
10. Now have Energy change placard to read "Energy Stored in Glucose"
11. Review all movements with students before having them complete the work-sheet.

Worksheet to Accompany

PHOTOSYNTHESIS: THE LIGHT AND DARK OF IT

1. Write the formula for photosynthesis.

2. Complete the following chart telling where each of the listed elements came from (name the compound) and where they went to during the process of photosynthesis.

ELEMENT	FROM	TO
12 Hydrogens	Water	Glucose
6 Carbons		
6 Oxygens		
6 Oxygens		
12 Hydrogens		
12 Oxygens		

ANSWER THE FOLLOWING QUESTIONS

3. During the light reaction which compound breaks apart?
4. At the end of the light reaction where is the energy stored?
5. During the dark reaction what happens to the carbons that were in carbon dioxide?
6. Where did the oxygens that form glucose come from?
7. During the dark reaction where is energy stored?
8. What is the energy that is stored in $NADPH_2$ used for?
9. Where did the oxygen that is released to the air come from?

Chapter Five Functions of Cells

DOING AN IMPERSONATION

LEARNING OBJECTIVE: The student will understand the relationships between photosynthesis and cell respiration.

PURPOSE: To understand how photosynthesis and cell respiration are opposites and how they work together.

MATERIALS: Pencil and paper
Biology reference books

PROCEDURE: You are to write a monologue titled "I Am Photosynthesis."

In this monologue you are to pretend that you are photosynthesis. You will explain the statements: "I am photosynthesis. I am the opposite of cell respiration. Even though we are opposites we work together."

The ideas you express need to be scientifically accurate yet will require a little creativity to personify the ideas of photosynthesis and cell respiration. For instance, they could be very good friends, even lovers. You know how opposites attract!!!

EVALUATION: This activity will be evaluated on the number of accurate ideas presented.

Chapter Five Functions of Cells

CREATE A STUDY GUIDE

PURPOSE: To review the six learning objectives regarding the functions of cells and all important related concepts.

MATERIALS: Pencil and paper

PROCEDURE: Yor are to create a study guide which will be useful to students who are getting ready to take a test over this chapter. Your guide may be in any form you want...outline, questions, explanations, a review sheet, etc.

EVALUATION: This activity will be evaluated on completeness and accuracy of information.

Chapter Six Information Storage and Transfer in Cells

DNA MODEL

LEARNING OBJECTIVE: The student will understand the chemical structure of a DNA molecule and how it replicates.

PURPOSE: To visualize the structure of DNA.

MATERIALS: Pencil, colored construction paper, scissors, biology reference books

PROCEDURE: After reading about the structure of DNA, construct a paper model of the components of a DNA molecule from construction paper. Be sure to show the four types of nitrogenous bases, the phosphates, and sugars. Label each part. Use different colors if you want.

After you have demonstrated how the DNA molecule replicates, glue your model parts to a paper so you can save it for future reference.

EVALUATION: Evaluation for this activity will be based on the accuracy of the model and the student's ability to use it do demonstrate the events in DNA replication.

Chapter Six Information Storage and Transfer in Cells

CHOOSE YOUR OWN FATE

LEARNING OBJECTIVE: The student will understand how DNA controls the functions of a cell.

MATERIALS: Will vary from student to student.

PROCEDURE: In this activity you are to explain how DNA controls the functions of a cell. To do this you may choose to present your information in any of the following ways or if you have another idea, get approval from the teacher.

1. You may make a speech explaining how DNA controls the functions of a cell. You may present your speech in front of the class or on a casette tape.

2. You may write an interview of a DNA molecule. You will be a reporter asking DNA questions in order to find out just how he/she controls the functions of a cell.

3. You may present a commercial for DNA. Your commercial may be done on tape or in front of the class. You will be advertising the fact that DNA controls a cell and how it does this.

EVALUATION: This activity will be evaluated on the completeness and accuracy of information presented.

Chapter Six Information Storage and Transfer in Cells

PROTEIN SYNTHESIS

LEARNING OBJECTIVE: The student will understand the steps in the process of protein synthesis.

PURPOSE: To visualize the process of protein synthesis.

MATERIALS: Construction paper models of DNA strand, mRNA, tRNA, amino acid.

PROCEDURE: Referring to a text with an explanation of protein synthesis use the construction paper models to simulate the steps in the process of protein synthesis.

EVELUATION: Evaluation for this activity will be based on your ability do manipulate the models to demonstrate the steps of protein synthesis.

APPENDIX D

Post Tests

This section contains the post tests used at the end of each chapter and at the end of the unit.

CHAPTER THREE CHEMISTRY OF LIFE

POST TEST

1. A substance made of only one kind of atom is
   a. a compound b. an element c. an ion d. a nucleotide

2. Starch and glucose are
   a. carbohydrates b. lipids c. nucleic acids d. proteins

3. Nucleic acids are important because they
   a. break bonds in starch b. conserve body heat c. are the building blocks of all body tissues d. contain information that instructs cells what to do

4. The bond that is formed when molecules share pairs of electrons is a(n) a. ionic bond b. covalent bond c. partial bond d. neutron bond

5. A substance that consists of only one type of atom is
   a. a catalyst b. a compound c. an element
   d. a nucleotide

6. The building blocks of proteins are
   a. carbohydrates b. lipids c. amino acids d. nucleic acids

7. Negatively charged particles around an atom's nucleus are
   a. electrons b. lipids c. neutrons d. protons

8. Denaturing is the process of destroying a protein's
   a. shape b. size c. ability to bond d. location

9. A compound that contains one atom of carbon for every two atoms of oxygen has the formula a. C_2O b. CO c. CO_2 d. O_2C_2

10. Substances that change the speed of a reaction but are not used up themselves are a. neutrons b. protons c. catalysts d. ionic

11. When two or more atoms rearrange their outer electorns with each other, the atoms a. undergo chemical bonding b. release energy slowly c. cause an explosion d. always remain neutral

12. An atom that does not have an equal number of positive and negative particles is electrically charged and called
    a. a catalyst b. a covalent c. an enzyme d. an ion

13. A chemical reaction always results in
    a. an explosion b. the formation of a new substance
    c. the release of carbon dioxide d. the release of energy

14. Sugar compounds form
    a. carbohydrates b. monosaccharides c. lipids d. proteins

15. Organisms can change the speed of a chemical reaction by a. taking heat away from the reaction b. using compounds called catalysts c. adding heat to the reaction d. breaking the bonds of enzymes

16. Butter, lard, and corn oil are a. carbohydrates b. lipids c. nucleic acids d. proteins

17. Nucleic acids are important becuase they a. are the building blocks of all body tissues b. conserve body heat c. bread bonds in starch d. contain information that tells cells what to do

18. During a chamical reaction a. new elements are made b. new atoms are made c. bonds are rearranged d. atoms are destroyed

19. Which of the following elements is the most common in living matter? a. aluminum b. carbon c. chlorine d. iron

20. H_2O, NaOH, NaCl, and MnO_2 are examples of a. atoms b. compounds c. elements d. protons

21. Organisms store energy by a. breaking chemical bonds b. releasing energy a little at a time c. breaking down compounds d. building compounds, which contain chemical bonds

22. An atom with the same number of protons and electrons is a. positively charged b. negatively charged c. electrically neutral d. ionically bonded

MATCHING

A. carbohydrates
B. lipids
C. nucleic acids
D. proteins

23. includes starch, cellulose, and glucose
24. made up of amino acids
25. composed of sugar molecules, phosphate groups, and nitrogen bases
26. includes fats and oils
27. includes all enzymes

TRUE - FALSE

28. Water is an organic substance
29. Atoms that share electrons are covalently bonded
30. Organisms can slow the release of energy from chemical reactions by breaking them down into smaller steps
31. The shape of a protein is unimportant in determining its function
32. The chemical bonds in glucose are a major source of energy for many organisms

MATCHING

A. carbohydrates
B. chemical bonding
C. enzymes
D. molecules
E. pathway
F. proteins

33. groups of two or more atoms that share electrons
34. the rearrangement of electrons to complete the outer energy levels of atoms
35. catalysts found in living organisms
36. organic compounds made up of sinple sugars
37. ten breakdown of a chemical reaction into many smaller steps

FILL IN THE BLANK

38. Two common monosaccharides found in living organisms include fructose and _____.

39. Substances in your body that speed up chemical reactions are ____.

40. A sugar, phosphate group, and a ____ can combine to form a nucleotide.

41. A nucleic acid is made of ____ joined in a long chain.

42. A substance which changes the rate of a chemical reaction is a ____.

43. A ____ is an atomic particle that has no electrical charge.

44. The element ____ is important to the chemistry of life because its atoms can join with each other in so many different ways.

45. The symbol H_2O represents a. an atom b. a molecule c. an ion d. an element

Chapter Four Cell Structure

Post Test

1. Part of the cell theory states that
a. new cells arise only from old cells b. no two cells carry out the same functions c. all organisms are made of more than one cell d. some known organisms are not made of cells

2. The set of ideas about what a cell is and how it functions is called the
a. Virchow principle b. Hooke theory c. cell theory d. schleiden/Schwann principle

3. The basic shape of a cell depends on its
a. age b. color c. function d. size

4. All cells are alike in that they all
a. have nuclei b. have cytoplasm and a cell wall c. have the same kind of organelles d. are made of the same organic matter

5. The human body contains
a. two kinds of cells b. thousands of different kinds of cells c. only one kind of cell d. over 100 different kinds of cells

6. The command center of the cell is the
a. Golgi apparatus b. nucleur c. nucleolus d. ribosome

7. The energy that a cell needs to carry out its functions is stored in ATP, which is produced in the
a. mitochondria b. nucleolus c. nucleus d. vacuoles

8. A cell with no nucleus is a
a. eukaryotic cell b. fungal cell c. protist cell d. prokaryotic cell

9. A major function of vacuoles in plant cells is to
a. produce chlorophyll b. transport water up the stem c. support the stem and leaves d. carry on photosynthesis

10. Ribosomes are found
a. attached to the Golgi apparatus b. floating in the cytoplasm and attached to the endoplasmic reticulum c. only in the nucleus d. floating in the cytoplasm and attached to the centrioles

11. The thin, outer boundary of an animal cell is the
a. cell emebrane b. cell wall c. endoplasmic reticulum d. nuclear membrane

12. An organelle is a
a. small part of an organ b. group of tissues working together c. group of organized cells d. structure in the cytoplasm

13. The instructions that tell a cell what functions to perform are stored in the
    a. lysosomes b. cell membrane c. Golgi apparatus
    d. nucleus

14. Protein synthesis occurs in the
    a. vaucoles b. microtubules c. ribosomes d. nucleolus

15. Animal cells have organelles called
    a. centrioles b. chloroplasts c. leucoplasts d. cell walls

16. The function of ribosomes is to
    a. synthesize codons b. serve as a messenger to the nucleus
    c. synthesize proteins d. produce amino acids

17. Chloroplasts are found in
    a. animal cells b. fungal cells c. moneral cells
    d. plant cells

Answer questions 18 - 24 using the following answer key:

a. Golgi apparatus
b. lysosome
c. microfilament
d. nucleolus
e. ribosome
f. endoplasmic reticulum
g. microtubules
h. chloroplast

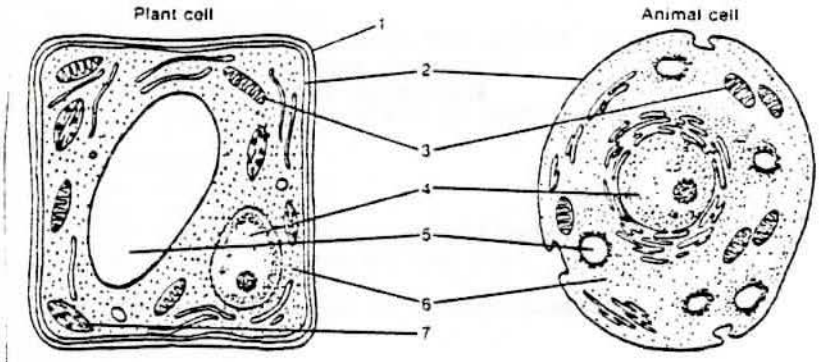
18. manufactures cell protein
19. assists in cell movement
20. help give a cell shape and structure
21. produces RNA
22. break down foreign material in the cell
23. packages and distributes proteins
24. serves as a transport network for substances in the cell

Answer questions 25 - 28 using the following answer key:

a. animal cells
b. fungal cells
c. moneran cells
d. plant cells
e. protist cells

25. have no nucleus
26. have large vacuoles that help give support to organism
27. have an outer cell wall made of chitin
28. lack a cell wall and use microtubules to give cell its shape

Use the two diagrams below to answer questions 29 - 32



29. Structure 7 uses the sun's energy to make carbohydrates. This structure is a
    a. leucoplast b. chloroplast c. centriole d. vacuole

30. A cell needs structure 3 to
    a. remove wastes b. digest materials c. produce RNA
    d. produce energy

31. Hereditary information is contained in structure
    a. 2 b. 4 c. 5 d. 6

32. Cellulose is a main component of structure
    a. 1 b. 2 c. 3 d. 4

For questions 33 - 37 answer <u>each choice</u> YES or NO

33. Cell wall
    a. selectively permeable
    b. encloses all parts of the cell
    c. made of cellulose
    d. blocks passage of all materials

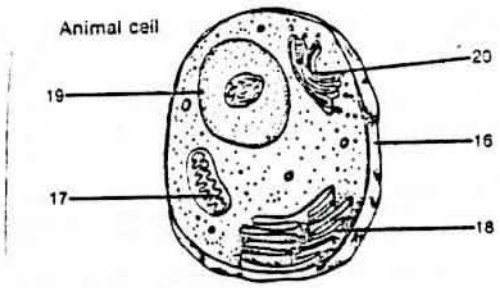
34. Nucleolus
    a. produces granules rich in one kind of RNA
    b. surrounded by nuclear membrane
    c. site for the assembly of ribosomes
    d. produces ATP

35. Ribosomes
    a. manufactures proteins
    b. stores proteins
    c. bound to membranes of ER
    d. floats freely in cytoplasm

36. Golgi apparatus
    a. packages proteins for export from cell
    b. removes wastes from cell
    c. digests food materials
    d. looks like a stack of pancakes

37. Mitochondrion
    a. an organelle
    b. produces ATP
    c. releases energy to the cell
    d. gives support to the cell

Use the diagram below to answer questions 38 - 42



38. Structure 16 represents the
    a. cell wall b. cell membrane cytoplasm c. cytoplasm
    d. endoplasmic reticulum

39. Structure 17 represents
    a. chloroplast b. endoplasmic reticulum c. mitochondrion
    d. vacuole

40. Structure 18 represents
    a. endoplasmic reticulum b. golgi apparatus c. mitochondrion
    d. nucleus

41. Structure 19 represents
    a. golgi apparatus b. lysosome c. nucleus d. ribosome

42. Structure 20 represents
    a. golgi apparatus b. centriole c. nucleolus d. vacuole

CHAPTER FIVE: FUNCTION OF CELLS

POST TEST

1. A membrane through which some substances can pass but others cannot is called a. cellulose b. permeable c. porous d. selectively permeable

2. If a cell is placed in a hypotonic solution, water will tend to diffuse a. into the cell faster than it diffuses out b. out of the cell faster than it diffuses in c. in and out of the cell at the same rate d. out of the cell before any water can diffuse in

3. A cell placed in an extremely hypertonic solution might a. increase its size b. fill up with water c. shrivel d. burst

4. The diffusion of water through a selectively permeable membrane is a. bulk transport b. homeostasis c. plasmolysis d. osmosis

5. During cell respiration, the energy used to make ATP comes from a. phosphate molecules b. splitting carbon atoms c. breaking the chemical bonds in glucose d. ADP

6. Cell respiration occurs in the a. nucleus b. mitochondrion c. chloroplast d. ribosomes

7. During the light reactions of photosynthesis, chloroplasts use the sun's energy to make a. ATP and $NADPH_2$ b. glucose c. phosphates d. water

8. Plants capture the sun's energy and use it to make a. carbon dioxide b. chlorophyll c. glucose d. water

9. As the rate of waste production increases in a cell, the rate of excretion usually a. decreases gradually b. stays the same c. stops suddenly d. increases

10. Which statement is an example of homeostasis? a. a cell forms a pocket around large solids b. glucose breaks down into pyruvic acid c. pyruvic acid converts to carbon dioxide and alcohol d. oxygen enters a damaged cell at an increased rate to help repair the cell

11. Which process produces the most ATP? a. aerobic respiration b. fermentation c. glycolysis d. plasmolysis

12. During passive transport, small molecules pass through a selectively permeable membrane by a. diffusion b. bulk transport c. phagocytosis d. pinocytosis

5post test

13. The ability of an organism to maintain a stable internal environment is called a. ADP-ATP exchange b. glycolysis c. homeostasis d. respiration

14. In the absence of oxygen, some cells get energy from carbohydrates by a. aerobic respiration b. photosynthesis c. fermentation d. active transport

15. Homeostasis is a trait of a. water b. living things c. oxygen d. glucose

16. The overall process of cell respiration can be shown by this equation: ADP+phosphate+glucose+oxygen-----> carbon dioxide+ water+ ? . a. light b. energy c. chlorophyll d. pyruvic acid

17. Which of the following is true of photosynthesis? a. occurs in all living cells b. results in the production of CO_2 and H_2O c. releases stored energy from sugars d. results in the production of glucose and O_2

18. The leaves and stems of plants are kept stiff by a. plasmolysis b. turgor c. fertilizer d. photosynthesis

19. the process by which glucose is broken down into alcohol or lactic acid is a. glucolysis b. aerobic respiration c. fermentation d. photosynthesis

20. During cell respiration ATP is produced in the a. ribosomes b. nucleus c. chloroplast d. mitochondria

TRUE/FALSE

21. During diffusion, molecules tend to move from a region of low concentration to a region of high concentration.

22. Chlorophyll is located in the grana of a chloroplast.

23. Turgor helps keep a plant stiff and upright.

24. Fermentation takes place in the presence of oxygen.

COMPLETION

25. Inside organisms, molecules are broken apart to release energy in a process called _____.

26. The movement of materials through a cell membrane from a region of low concentration to a region of high concentration is known as _____.

27. Photosynthesis takes place in two major series of reactions, the _____ reaction and the _____reactions.

28. Cells adjust to changes that take place both inside and outside the cell membrane by using various _____ mechanisms.

post test

MATCHING

A. active transport
B. bulk transport
C. passive transport

29. Molecules move from a region of higher concentration to a region of lower concentration.

30. Protein molecule might change shape to channel material through the cell membrane.

31. Cell forms a pocket around large solids.

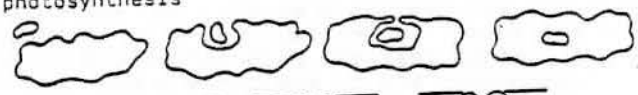
32. Does not require an input of energy by the cell.

33. Uses energy to move molecules against the direction of diffusion.

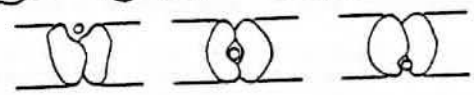
34. allows white blood cells to capture disease-causing bacteria.

A. active transport
B. cell respiration
C. bulk transport
D. glycolysis
E. photosynthesis

35.



36.



37.

38.

CHAPTER 6 INFORMATION STORAGE AND TRANSFER IN CELLS

POST TEST

1. Which property of the DNA molecule is most important in DNA replication? a. the molecule forms a twisting snape b. the parts of a nucleotide are covalently bonded. c. the nitrogen bases always pair in the same way d. only part of the DNA molecule unwinds at any one time.

2. Cytosine, guanine, thymine, and adenine are the four kinds of a. nucleotides in a DNA molecule b. phosphate groups in a DNA molecule c. nitrogen bases in a DNA molecule d. DNA molecules found in all cells.

3. DNA controls cell functions by instructing the cell to make a. nucleotides b. proteins c. phosphates d. hydrogen.

4. Three consecutive bases in a DNA molecule code for a single a. amino acid b. enzyme c. nucleotide d. protein

5. The function of messenger RNA is to a. carry free nucleotides to the DNA b. act as a pattern for the synthesis of new DNA strands in DNA replication c. break the hydrogen bonds in DNA to allow unwinding for replication d. carry information in DNA from the nucleus to the ribosomes.

6. The function of the tRNA molecule is to a. interpret the DNA message b. bring ribosomes to the RNA c. carry amino acids to the ribosomes d. carry information in DNA to the ribosomes

7. An error in the amino acid sequence of a protein is a a. mutation b. replication c. transcription d. translation

8. Proteins are aynthesized a. in the nucleus b. on the ribosomes c. on the nuclear membrane d. on the tRNAs.

9. How many bases are necessary to code for a protein that consists of 100 amino acids? a. 10 b. 50 c. 100 d. 300

10. The two divisions that occur during meiosis result in a. four diploid cells b. four monoploid cells c. two diploid cells d. two monoploid cells

MATCHING

A. DIFFERENTIATION B. DNA REPLICATION C. MUTATION E. TRANSLATION F. TRANSCRIPTION

11. process by which a DNA molecule makes exact copies of itself
12. process by which a cell reads codons on an mRNA molecule to synthesize a protein
13. process by which an mRNA molecule is synthesized from part of a DNA molecule
14. process by which cells develop into different types by "turning off" certain genes

15. A loss, replacement, or addition of a base pair to a DNA molecule results in a. an enzyme b. a mutation c. a nucleotide d. a protein

16. By the process of differentiation, a. DNA molecules form mRNA molecules b. a DNA molecule makes an exact copy of itself c. cells develop into different types by "turning off" certain genes d. a cell reads codons on a mRNA molecule to synthesize a protein

17. When a DNA molecule replicates a. two different kinds of DNA molecules are produced b. a messenger RNA is produced c. two identical DNA molecules are produced d. a protein is produced

18. The number of DNA bases that codes for a single amino acid is a. two b. three c. four d. thirty

19. The sequence of bases in DNA determines a. the sequence of mutations b. the sequence of proteins c. the sequence of amino acids d. the sequence of ribosomes

20. The molecule that carries the coded information in DNA from the nucleus to the ribosomes is a. tRNA b. DNA c. amino acid d. mRNA

21. The part of a tRNA molecule that matches up with a codon on an mRNA molecule is a. amino acid b. protein c. uricil d. anticodon

22. The process by which a cell produces two cells with identical copies of DNA is called a. prophase b. meiosis c. interphase d. mitosis

23. The process by which sperm and egg unite to form an offspring is called a. meiosis b. fertilization c. differentiation d. monoploid

MATCHING

A. CHROMOSOME B. TRANSCRIPTION C. DIPLOID D. MITOSIS
E. MEIOSIS F. MONOPLOID

24. process by which monoploid sex cells form
25. structure in a cell consisting of a coiled DNA molecule wrapped around proteins
26. number of chromosomes in the body cells of an organism

27. In DNA, thymine forms hydrogen bonds with ___. a. uracil b. cytosine c. adenine d. guanine

28. In DNA, guanine forms hydrogen bonds with___. a. uracil b. cytosine c. adenine d. thymine

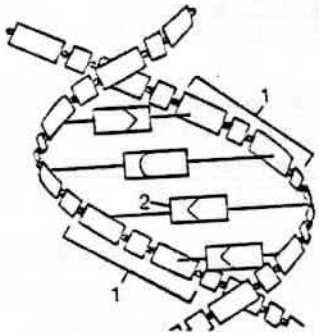
29. DNA contains the instructions for the ____ of amino acids in proteins. a. size b. shape c. sequence d. color

30. Complementary bases in a DNA molecule are held together with weak chemical forces called ___ bonds. a. covalent b. hydrogen c. divergent d. municipal

31. Sex cells are produced by___. a. meiosis b. cyclosis c. mitosis d. cytoplasm

32. Anticodons on tRNA match up with complementary ____ on the mRNA during protwin synthesis. a. nucleotides b. sugar groups c. diploid cells d. codons

Use the diagram below to answer questions 33 and 34.

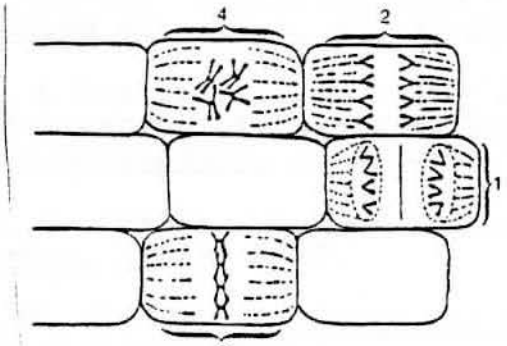


33. The sides of the double helix shown in 1 consist of
a. phosphate and sugar groups b. guanine and phosphate groups c. nitrogen base pairs d. phosphates and nitrogen bases

34. The "rungs" of the double helix shown in 2 consist of
a. sugar groups b. sugar base pairs c. nitrogen base pairs d. phosphate and sugar groups

The numbered structures in the diagram represent plant cells in various stages of mitosis. Use the diagram to answer question 35.

35. Which sequence of numbered cells correctly illustrates the process of mitosis?
a. 1 2 3 4 b. 4 3 2 1 c. 1 3 2 4 d. 3 1 2 4



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