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The effects of tactile/kinesthetic instructional strategies in the biology classroom

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THE EFFECTS OF TACTILE/KINESTHETIC INSTRUCTIONAL STRATEGIES IN THE BIOLOGY CLASSROOM

by
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ABSTRACT

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1998

Dr. Richard Meagher
Biological Sciences

The purpose of this study was to determine whether the addition of tactile/kinesthetic instruction to the biology classroom could significantly increase learning. Various kinds of tactile/kinesthetic lessons were taught to three experimental groups who also received visual and auditory instruction. These tactile/kinesthetic lessons included task cards, task puzzles, manipulatives, total body movement, and large floor games. The control group only received visual and auditory instruction. The subjects were 84 College Biology students from Buena Regional High School, a school in rural South Jersey. The classes varied in gender and race. The same instructor taught all classes and the length of the study was six weeks. The content area used in this study was cellular reproduction. Tests and quizzes were used to measure the learning. Analysis of a pre study chapter test was performed using the t test. No significant differences were found at the 95% level for all class pairings. The t test was also performed on four quizzes and two tests taken during and immediately after the study. This statistical test was performed on all possible class pairings also. Only differences at the 95% level were considered. No differences were found between any of the class pairings. It was concluded that the addition of tactile/kinesthetic instruction to the biology classroom does not increase learning.

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The purpose of this study was to determine whether the addition of tactile/kinesthetic instruction to the biology classroom could significantly increase learning. This learning was measured by the number of correct responses on quizzes and tests. The data was analyzed using the t test. Only differences at the 95% level were considered and no differences were found. It was concluded that tactile/kinesthetic instruction does not increase learning.

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Chapter 1: Introduction

Understanding the process of learning is difficult and unresting. The human brain is necessarily complex and somewhere in the matrix of cells, synapses, and impulses lies the answer to how learning occurs. Students attend school with initial expectations of success. Each student will have their own style of walk and dress as well as their own distinct style of learning (Guild & Garger, 1985). Bernice McCarthy (1991) developed an eight step cycle of instruction that incorporated many learning styles along with right and left brain dominance. She proposed that if teachers followed this eight step cycle, then all students would have the opportunity to learn in the style in which they learn best. Dunn & Dunn (1993) support the work of McCarthy by stating that when teachers use multiple modes of teaching, the students can learn in a style in which they feel comfortable and can also be challenged to learn in other ways.

Young children tend to be highly tactile/kinesthetic in their learning. Many adults will develop other learning styles but some will not (Carbo, 1997; Dunn & Dunn, 1993). Traditionally, many teachers believed that if students could not learn, then the students were not paying attention. Most teachers believed that only those students who could learn by auditory and visual methods, were bright. Most teachers did not know that some children cannot learn directly from an adult (Dunn & Dunn 1993).

It has been found in the past two decades, that many students who do not do well in school, are tactile or kinesthetic learners. Few teachers have used these kinds of activities, and therefore these students have been handicapped. These students fall behind and begin to resent school (Dunn & Dunn 1993). Many gifted students are included in this group (Cropper 1994; Havey & Seeley 1984). More research is needed in specific content areas, such as biology, to determine the importance of this kind of instruction.

At the beginning of the 1900s, the idea of a constant intelligence came into being and the "intelligence quotient" (IQ) was born. It is still used in education today even though the courts have called for modifications of this because of equity issues. A different idea, that all people do not learn the same (and therefore cannot be tested the same), came out of the published work of Carl Jung, *Psychological Types* in 1921. In this work, Jung described four types of learners: feelers, thinkers, sensors, and intuitors. The notion that people take in information differently did not achieve recognition until the 1970s (Learning Styles: Putting Research and Common Sense into Practice 1991).

A recent work in the field of teaching styles, *Teaching and Learning Through Multiple Intelligences* (Campbell, Campbell, & Dickenson, 1996), is based on the work of Howard Gardner. Gardner felt that there were major intelligences: linguistic, logical-mathematical, spatial, bodily-kinesthetic, musical, interpersonal, and intrapersonal. He was

the first theorist to introduce social intelligence and stated that there were probably more intelligences. This book by Campbell, Campbell & Dickenson is written for educators. If offers descriptions and applications of seven kinds of intelligences. One of these intelligences, tactile/kinesthetic, is the topic of this present work.

Accumulating research shows that students who are considered to be academic failures favor the tactile/kinesthetic learning style (Tactile/Kinesthetic Learning). Kinesthetic students learn by using their whole body in learning activities. Tactile students learn by touching and moving objects. Together, they both learn by "doing" (Campbell, Campbell, and Dickenson, 1996). The purpose of this study was to determine whether the implementation of tactile/kinesthetic instruction in the biology classroom could significantly increase learning. This learning was measured by the number of questions correct on four quizzes and two tests. This study was limited to a 84 students in four College Biology classes at a rural South Jersey high school for a period of six weeks. One instructor taught all groups. The content area, cellular reproduction, was chosen based on the sequence of curriculum used during the school year and ease of developing tactile/kinesthetic instruction. The null hypothesis was that there would be no significant difference between the test scores of the experimental groups when paired separately with the control group. The alternate hypothesis was that there would be a significant difference between the test scores of the two groups.

It was assumed that there was no significant difference in the level of achievement between each group before the study began, that the instructor taught each class equally, and that all variables except for the experimental variable of tactile/kinesthetic instruction was the same for both groups.

Many researchers view tactile/kinesthetic learning as the baseline of all learning because many of us remember best what we have actually done. An old Chinese saying exemplifies tactile/kinesthetic learning: "I hear and I forget; I see and I remember, I do and I understand" (Tactile/Kinesthetic Learning, 1997).

Chapter 2: Literature Review

The ability to feel by touching objects and others is one of our many senses. The ability to move is one of our human actions. Both are necessary for meeting our needs for survival in the environment in which we live. Both have implications for the process of learning. An article from *The Philadelphia Inquirer*, Tuesday, October 28, 1997, cites the extreme importance of touching with regards to human development. This information was presented October 27, 1997, in New Orleans at a meeting of the Society for Neuroscience. Harvard University researchers found that Romanian infants raised without being regularly hugged and caressed have abnormally high levels of the stress hormone cortisol, which can have serious effects on learning and memory. The article goes on to state that psychologist Mark Smith at the DuPont Merch Research Labs in Wilmington, Delaware, found that when laboratory animals were deprived of maternal care some of their brain cells committed suicide. Other studies revealed that when a mother licks her pup, this will trigger a chain of biochemical events that inhibit the master stress hormone called CRH. These studies show that touch, or the lack of touch, can have a profound, biochemical effect on the developing brain. The importance of touch, or tactile perception is enormous.

When we are touch or are touched, our skin receptors send electric signals to our Central Nervous System. The CNS interprets these signals and produces sensations where the contact has occurred (Artificial Tactile Perception). Dr. James J. Collins of the Neuromuscular Research Center and the department of biomedical engineering at Boston University, has shown that a certain level of "noise" can increase a person's tactile sensation. These findings have implications in the treatment of people who have experienced a loss of tactile perception due to aging, stroke, etc... ("Noise" Enhances Human Ability to Detect Tactile Sensation). This finding may also have implications for educators when creating a classroom conducive to tactile learning and personalized learning styles.

Touch is an essential element in the mother-infant bond. Kaitz, Lapidot, and Bronner (1992) stated that women can recognize their infants by touch early after birth. It was found in this study that approximately one hour of being with the infant was needed before the mothers could recognize their infants successfully. The birth mothers that were tested did not know that they would be tested until the time of the test. The design of the experiment prevented the other senses - visual, auditory, and olfactory, from interfering with the tactile variable.

Tactile perception arrives very early in the human life form. According to child development expert, Emily Bushnell (1993), tactile perception of volume begins at four months; temperature; hardness and texture begin at six months; weight begins at nine months, and configurational shape begins at twelve months. She also presents a new view regarding motor development in infants. She notes that specific motor activities must be

able to be performed first, in order for given perceptual abilities to emerge. Previous studies had reflected the opposite of this finding. An example of her findings is that certain back and forth hand movements are necessary to determine the texture of an object.

Most young children are tactile and kinesthetic learners and many continue this preference into adulthood (Carbo, 1997; Dunn & Dunn, 1993). Others will strengthen in the auditory realm as they grow older and will be able to function in this style (Dunn & Dunn, 1993). Reading programs for young students need to incorporate holistic methods, active learning, and emotional involvement (Carbo, 1997). Activities should involve movement, manipulatives, games, simulations, and role playing. Carbo states that there is "no single best way" to teach reading. An example of this can be seen in the work of Hodgin and Wooliscroft (1997). Eric was a tactile-kinesthetic learner who was very sensitive to light. He was always in constant motion which had annoyed the other students and his teachers in the past. Eric was allowed to work away from his desk in an area with dim lighting. Eric's work greatly improved and so did his relationship with the other students. This study with Eric came from the Alta Vista Elementary School in Abilene, Texas. Before reading styles had been incorporated into these classrooms at this school, only 50% of the regular student body passed the Texas Assessment of Academic Skills, and none of the special education children passed. After the reading styles strategies and inclusion practices were used in the classrooms, all the regular students passed and approximately 25% of the special education students passed. This school used the work of Marie Carbo and that of Dunn and Dunn to establish their reading style classrooms.

The attributes of tactile/kinesthetic learning is explicit in many more studies. Spelling performance by a special education student improved considerably in an investigation by Murphy and McLaughlin (1990). The visual element was not eliminated but lessened. The tactile, auditory, and kinesthetic elements were emphasized. The student never reached the scores of the regular students, but came very near to them.

Pete Stone(1992) turned problem students of a problem elementary school into successful students of a successful school. Burned-out teachers found teaching more enjoyable and meaningful. This process began by the staff attending learning styles workshops. This snowballed into testing the students on learning styles and then remodeling the classroom environment, school day schedule, and core curriculum. The staff found out amazingly that the problem students were learning and not a problem. Most became mainstreamed and self-esteem rose quickly which lead to even fewer problems. In their student survey of testing styles, it was found out that almost two-thirds of their students were either tactile or kinesthetic learners, compared to only less than one-fourth who were primarily auditory learners.

Blahut and Nicely (1984) inquired into the correlation between tactile learning and two learner attitudes in a secondary school. The two learner attitudes that they studied were: importance of content and pleasurableness of content. Their premise was that students are

more likely to use and want to learn more when they have positive learning experiences. The use of touch and movement make learning more enjoyable. Their results showed a significant difference between the treatment and the control class regarding the importance of content attitude. This result indicates that tactile learning activities have a definite impact on learner attitude. There was no significant difference between the control and treatment class in the pleasurableness of content. They did feel however, that a positive relationship did exist. They also found that the learners in the treated class did better academically on content tests.

Alice Hamachek (1991) expresses her viewpoint on why tactile/kinesthetic learning works the best in education as opposed to the traditional auditory and visual methods which have failed many students. She believes in something called muscle memory. She cites muscle memory as being superior to auditory and visual memory. Her examples include driving a car and riding a bicycle.

The tactile/kinesthetic learning style has also been investigated repeatedly in many studies for many specific groups of students. Incarcerated females were the subject of Croker (1995). These females at the Pocatello Women's Correctional Center were tested for their learning style, brain hemisphericity, and then interviewed for teaching methods that they were exposed to in their education before incarceration. It was found that 21% were right-brain kinesthetic/tactile learners yet 77% identified "reading" as one of the top five methods used while they were being taught. This was at the heart of this research - the discrepancy between what is preferred and what is delivered. It was not suggested by the authors that each individual receive only what is preferred, but that tactile/kinesthetic activities be looked at with greater consideration in educational institutions.

White (1992) analyzed the learning differences among African Americans and Caucasian students. He states that academic achievement is low in the minority community and that cultural differences reflect distinct cognitive styles among these two groups. He acknowledges the difficulty in diagnosing the discrepance in learning styles. Theories include genetic causes and cultural deprivation. He makes it clear that regardless of the cause, this difference still exists. He questions the practice of teaching African Americans in the Caucasian style. He infers that the Caucasian style is visual. He states that African Americans are predominantly auditory and tactile rather than visual. The primary way that African Americans process information is kinesthetically, as indicated by their high motor capabilities.

Kraemer (1996) determined the learning styles of 300 Hispanic English students. It was found that these students prefer auditory and kinesthetic learning methods. Visual learning was not their preferred instructional strategy yet the ESL students depend on reading for learning.

James Wallace (1995) inventoried Filipino students on their learning styles to see

how they matched USA students. The results for this Filipino student population was the following: auditory 8.4%; visual 41.4%; tactile 20.4% and kinesthetic 29.8%. One can see from this data that approximately 50% were tactile/kinesthetic learners. Research on the learning styles of USA students was also reported by Wallace. Rita and Kenneth Dunn in 1989 found that 30% were tactile/kinesthetic learners. Clearly, research indicates that tactile/kinesthetic learning strategies need to be given more consideration in the classroom.

Clara Park (1997) investigated the learning styles of Korean, Mexican, Armenian-American, and Anglo secondary students in the Los Angelos area of California. Four perceptual styles were investigated: visual, auditory, kinesthetic and tactile. Each student completed a questionnaire on his or her learning style preference/s. The Mexican-Americans had a major preference for auditory learning style while the other groups had a minor preference. The Anglo students had a negative preference for visual learning and the others had minor preferences. All groups showed a major preference for kinesthetic learning style. All groups showed a minor preference for tactile learning style. These preferences for kinesthetic and tactile learning existed regardless of ethnicity, sex, and level of academic achievement. Park suggests that educators plan lessons in which students learn by doing.

Cropper (1994) states that in *A Nation at Risk* (1983) more than 50% of the gifted student population do not have a match regarding their testing ability with their achievement in school. Many gifted students drop out of high school and never reach their maximum potential. Harvey and Seeley (1984) investigated the gifted abilities in a population of delinquent youths from the Arapahoe County (Colorado) Juvenile Justice System. They found out that 18 % of those used for the study were gifted. Significant to this population was their difference to nondelinquent gifted youth. This difference was seen in their high abilities in fluid intelligence. Fluid intelligence is problem solving with little dependence on previous learning. The authors of this study concluded that this high fluid intelligence could result in a learning style that differentiates these students from others. Dunn and Dunn (1993) reported that at-risk and drop out students are almost exclusively tactile/kinesthetic learners. Over the past two decades research conducted by the Dunns and others in the USA have shown that when students are taught through their learning style preference, they have increased achievement, improved attitude, and better discipline. They also state that most secondary students are not auditory and cannot remember most of what they heard in an average period. Few teachers know how to introduce new material tactually or kinesthetically, which is the preference of most young or underachieving students.

Dunn and Dunn (1993) began their work on learning styles in 1967 at the New York State Department of Education. Professor Rita Dunn was asked to design and direct a program that would help "educationally disadvantaged" children increase their achievement. By 1990, Doctors Rita and Kenneth Dunn had found twenty-one elements that revealed that learners are affected by the physical environment; their emotions; their sociological preferences; their physiological needs; and their processing modes. Dunn and Dunn explain

that learning style is the way in which each learner focuses, processes and then retains information. They say it is more than whether a person is described as being auditory, visual, kinesthetic, left brained or right brained. It is the interaction of many things, and therefore it is different for everyone. They emphatically state that teachers cannot correctly determine all parts of a students learning style because many parts are not observable. Their recommendation for a reliable and valid assessment is the Dunn, Dunn, and Price *Learning Style Inventory.*

Guild and Garger (1985) simplify the meaning of learning styles and its importance to each individual. Every person has a certain way in which they perceive, think, make judgements, and form values about people and experiences. Two examples they use are that every person has her/his own style of dress and own style of balancing a checkbook. They state that each person is unique and complex, and yet predictable also. Therefore, each person has a distinct learning style, that is used repeatedly when dealing with diverse experiences in life. They say that people are different in four basic functions: cognition (perceive and gain knowledge); conceptualization (form ideas and think); affection (feel and form values); and behavior (act). If people are different, then education has to be about these differences. They also report that boys are not more kinesthetic than girls.

Most schools in the nation now have many computers and use these for both instruction and enrichment. What kind of instructional learning strategy does the computer employ? How do students process information when they are using a computer? Campbell, Campbell, and Dickenson (1996) say that the eye-hand coordination needed for the computer is a kinesthetic activity that makes the students actively involved. Evidence is seen in the popularity of video games. The spatial and logical thinking of video games is the same kind used in math classes. Even though the whole physical body is not used, students may feel as if for example they are actually exploring the inside of a volcano. James Campbell (1996) disagrees with the increasing use of computers in the classroom. He feels that computers are taking away the real tactile experiences of using crayons, scissors, paint, and clay. He goes on to state that with the loss of these very real tactile experiences, the creative development of the child will be stunted.

Bernice McCarthy (1991) developed in 1972 an eight-step cycle of instruction that incorporates various learning styles and brain hemisphericity. Her model was based on the ideas that students learn differently and using this model of diverse strategies can improve teaching and learning. Her model is based on the theories of David Kolb. He saw two major differences in how people learn: how they perceive and how they process. Both are necessary for learning. The McCarthy cycle has eight steps that is to be followed sequentially by the instructor and then repeated. Students will be exposed to both preferred and non-preferred learning strategies. She feels that this is a good balance in that they are both comfortable and challenged in learning. Auditory, visual, tactile and kinesthetic terms are not used in her report. However, other words which mean the same thing are used: doing, watching, and listening.

Campbell, Campbell and Dickenson (1996) list twelve potential traits of students with kinesthetic aptitude: prefer touch and movement; develop coordination and timing; remember by doing; enjoy field trips, games, model building and role playing; show skill in small and large motor development; are sensitive to physical environments; show skill in acting, athletics, dancing and keyboarding; show excellence in balance and grade; can integrate mind and body to perfect physical performances; live by a healthy life style; are interested in careers such as athlete, surgeon, and dancer; and are creative in physical skills such as dance and sports. They point out that every student will not show all of these traits and that some will be stronger than others. In Chapter 3, MOVING TO LEARN: KINESTHETIC LEARNING, various tactile kinesthetic activities are listed and then described. Some of these are: Role Play, Creative Dramatics, Simulations, Task Cards, Task Puzzles, Total Physical Response Games, Generic Review Game, Paper Plate Game and Kinesthetic Flow Charts. Many of these activities were used in this current study.

Chapter 3: Methodology

A total of eighty-four students from Buena Regional High School, Buena, New Jersey, were involved in this study. These students were enrolled in the College Biology course, which is the middle achievement level of biology. Most of these students were in their sophomore year. They were a heterogeneous mixture of gender and race. White was the predominant race (78 %), followed by Black (11 %) and Hispanic (11 %). See Table 3-1 on page 21 and Figure 3-1 on page 23. 57% of the students were female and 43% were male. See Table 3-2 on page 21. Most students lived in rural areas as do most of the students at this high school. Four classes were involved in this study with variation in class size: Class 1 (Period 1) consisted of 23 students; Class 2 (Period 4) consisted of 19 students; Class 3 (Period 6) consisted of 20 students; and Class 4 (Period 9) consisted of 22 students. Periods 1,4, and 6 were chosen as the experimental groups and Period 9 was chosen as the control group. The following account describes the class meeting times and basic instructional style before the study began. Each class meets six, forty minute periods a week, five days a week. Four days of the week consists of one forty minute class and the remaining day consists of one eighty minute class. The instructional style for the four, forty minute classes consists of traditional lecture, note taking, films, and worksheets. The eighty minute class is designated as the laboratory class with active, hands on instruction. Each class has its laboratory on a different day of the week. On the fifth day, no class has a laboratory. A new laboratory cycle begins for the classes on the next day.

Biology (Essenfeld, Gontang, & Moore, 1996) was the textbook for this course and served as a content basis for this study. Supplemental materials for this textbook included worksheets (section review, process skill, study skill, critical thinking), laboratories, and chapter tests. Chapter 7, Cellular Reproduction, was chosen as the specific content area for this study. The chosen variable was tactile/kinesthetic learning. Tactile/kinesthetic learning uses the whole body in movement or parts of the body such as the hands (Campbell, Campbell, & Dickenson, 1996). There are a variety of tactile/kinesthetic activities that can be used and applied to any content area. These activities were researched and ideas for lessons were outlined. The tactile/kinesthetic activities used in this study were total physical response, task cards, task puzzles, paper plate games, and various kinds of manipulatives (Campbell, Campbell & Dickenson). The laboratory periods for all classes including the control remained active and hands on. This was tactile instruction however, but not kinesthetic. The remaining four periods of class time in the experimental group contained the variable of tactile/kinesthetic instruction. In addition to tactile/kinesthetic instruction, the experimental groups were also exposed to visual and auditory instruction. The control group was only exposed to visual and auditory instruction. Visual and auditory instruction included lecture, note taking, films, worksheets, and observation of figures and models. The objectives remained the same for both the experimental and control groups. Quizzes and tests were used to collect the data.

The scores of the New Jersey Statewide Grade 8 Early Warning Test were obtained for all classes involved in the study. This test is given state wide in an effort to find out what students are in need of additional instruction before the Grade 11 High School Proficiency Test. Due to the transient nature of the Buena Regional High School student population, many test scores were not available for the students of this study. Table 3-3 on page 21 displays the number of scores available for each class. Score averages were made for the three sub tests of reading, mathematics and writing. Figure 3-2 on page 24 shows the distribution of these averages. All students had completed Chapter 6 Photosynthesis and Cellular Respiration prior to the planned study. All of their scores were available and the student t-test was performed on these to determine significant differences between the control group and the experimental groups. Only differences at the 95% level were considered to be significant. See Table 3-4 on page 22. All students completed a simple learning style inventory (Learning Styles). See Appendix. Figure 3-3 on page 25 reveals a self-perception rating of their weakest to strongest learning style.

This experiment on instruction lasted approximately six weeks, January 4th through February 13th, 1998. Four quizzes and two tests were used to collect the data. The student t-test was performed on this data to determine significant statistical difference at the 95% level. The quizzes varied in question number from eight to eighteen. The quizzes were teacher made and the questions were matching and multiple choice. The first test on mitosis was teacher made, all multiple choice, and twenty questions in length. The second test which was comprehensive for chapter seven including both mitosis and meiosis, was made by the Addison-Wesley Company and twenty-five questions in length. See Appendix. The following account describes in detail the lessons used for this experiment. Very often the students worked in groups. These groups consisted of three or four students. The purpose of grouping was to share materials, share learning skills, and to practice cooperation with others. These were the same groups that the students worked with during their laboratory class once a week. The control lesson is stated following the experimental lesson. It can be assumed that all elements of the control lesson were the same as the experimental lesson except for what is stated. All handouts, directions, and figures in bold print can be found in Appendix.

DAY 1

Objective *Describe the phases and processes of the cell cycle.*

The chapter was introduced in the auditory/visual style for all of the classes. The students were asked a few questions about what they knew previously about cellular reproduction and were then asked a few questions about the pictures they saw at the beginning of the chapter. They observed some overhead diagrams that outlined the life cycle of the human. Gingerbread shapes were used to represent humans. They were then asked to draw a circle with the letter "A" inside it. Following this, they were instructed to draw two more exactly like this first. The students were asked how much more work it took to

draw the two when compared to the first. This activity concluded that it takes twice as much material and work to make two cells rather than one cell. This ended the introduction to cellular reproduction and now the lesson would concentrate on the phases of the life of the cell called the cell cycle. See **INTRODUCTION TO CHAPTER SEVEN**.

EXPERIMENTAL TACTILE/KINESTHETIC LESSON

The students were told to push their desks together into their groups and then complete a task puzzle on the cell cycle. See **TASK PUZZLE THE CELL CYCLE AND MITOSIS**. Six task puzzles had been made for each ot the six lab groups. After the students completed this puzzle, they were given a handout titled **7.1 THE CELL CYCLE AND MITOSIS**. They were then directed to use the task puzzle to answer the questions on the handout. After this, the correct answers were reviewed and the task puzzles were returned to their bag and returned to the teacher. Homework: Answer the Bio Probe questions on page 108.

CONTROL/AUDITORY LESSON

In place of the task puzzles used in the experimental lesson, the students observed Figure 7.1 on page 107 of their textbook. This figure had been the basis for the making of the task puzzles used in the experimental lesson.

LABORATORY 1

Objective *Locate and identify cells that are in interphase and in the process of dividing by mitosis in prepared onion root slides. Describe the changes and identify the structures that occur in cells undergoing mitosis.*

With the light microscopes, the students observed prepared slides of onion root tips, identified phases of mitosis, labeled diagrams, and answered questions. See **Mitosis 15**.

DAY 2

Objective *Review the cell cycle. Define vocabulary related to the cell cycle: replication, sister chromatids, interphase, mitotsis, and cytokinesis.*

EXPERIMENTAL TACTILE/KINESTHETIC LESSON

The students reviewed the previous lesson by completing the cell cycle task puzzle again. These were then put away. The five vocabulary words in this section of the cell cycle were introduced by having the students complete five task cards on these five words. See

TASK CARDS THE CELL CYCLE AND MITOSIS. Each student was instructed to read each task card as it was completed. The students were then instructed to repeat this activity with the task cards. The task cards were then put away. The students were then given a handout that gave them instructions on how to complete a chromosome replication activity. This activity used beads and pipe cleaners to create replicated chromosomes. See **CHROMOSOME REPLICATION** in Appendix A. Homework: Define five vocabulary words from section 7.1, complete **Process Skills 7-1** and **Section Review 7.1**, and prepare for a quiz on section 7.1 The Cell Cycle and Mitosis.

CONTROL AUDITORY/VISUAL LESSON

The students copied overhead notes of the definitions of interphase, replication, cell division, mitosis, and cytokinesis. The students also listened to teacher explanations of these terms. See **VOCABULARY NOTES**.

DAY 3

Objective *Review the cell cycle. Evaluation with quiz. Student self-assessment of strong and weak learning styles.*

BOTH EXPERIMENTAL AND CONTROL LESSON

Homework was checked and reviewed. The students took **QUIZ 7.1 THE CELL CYCLE AND MITOSIS**. After the quiz, each student completed **LEARNING STYLES**.

DAY 4

Objective *Sequence correctly the phases of the cell cycle. Describe the events of interphase, mitosis, and cytokinesis. Identify all structures of these events.*

BOTH EXPERIMENTAL AND CONTROL LESSON

The students wrote the phases of the cell cycle in their notebook: interphase, prophase, metaphase, anaphase, telophase, and cytokinesis. Each student was then asked to think of a six word sentence whose first letter of each word was the same sequence as these events of the cell. The example given was Ivan Punched Melissa At The Circus. Memory devices made from last years students were read to the class. See **Memory Devices For Cell Division and Cytokinesis**. Some students were able to contribute their own memory devices and a list was started for the College Biology classes of 1998. See **MEMORY DEVICES FOR MITOTIC CELL DIVISION AND CYTOKINESIS**

COLLEGE BIOLOGY 1997-1998.

The students then began to make mitosis study cards. Directions and materials were passed out. See **7.2 MITOTIC CELL DIVISION AND CYTOKINESIS 110 - 112.**

LABORATORY 2

Objective *Review the phases of prophase, metaphase, anaphase and telophase.*

The students worked cooperatively to create one mobile which consisted of two sides yet showed four phases of mitosis. This was accomplished through accordion folding and alternating picture strips. The greatest challenge in this lab was to color the chromosomes and cell structures the same for all four phases. This was needed to show that it is one cell going through these changes, and not four different cells. See **MULTIPLE MONTAGE MITOSIS MOBILE** and **Multiple Montage Mobile 45469-00**. See also **SUPPLIES**.

DAY 5 AND 6

Two additional periods were needed to complete the mitosis cards from DAY 4.

DAY 7

Objective *Review the phases of mitosis.*

EXPERIMENTAL TACTILE/KINESTHETIC LESSON

This was a kinesthetic lesson using total physical response. The students moved into their group and then took out their mitosis cards for reference. Each group was assigned one phase of the cell cycle. Their assignment was to design a movement in which they would show an event/s of the phase using all of their bodies in movement. There would be no speaking during the movement. After each group performed, the audience was asked to identify the phase that had been assigned to them, all structures that they represented with their bodies, and the event of the phase that they showed in their movement. See **MOVING WITH MITOSIS**.

CONTROL AUDITORY/VISUAL LESSON

The students saw a fifteen minute film titled MITOSIS, copyright 1980, Encyclopaedia Britannica Education Corporation. After a brief discussion of the film, the students were asked to put their mitosis cards on their desks. They were then asked questions about the figures that they had drawn on them. See **MITOSIS CARDS AND**

QUESTIONS. The students recorded their answers and then correct answers were given and discussed.

DAY 8

Objective *Review the phases of mitosis.*

EXPERIMENTAL TACTILE/KINESTHETIC LESSON

The students manipulated beads, plastic cylinders, yarn, and magnets to simulate the events of mitosis. They worked with their group. After each phase was completed, each student recorded this in a drawing. They were not permitted to move to the next phase until their drawing had been completed and approved. See **STUDENT STUDY SHEET CHROMOSOME SIMULATION CLASS ACTIVITY KIT ACTIVITY: MITOSIS** and **ANALYSIS SHEET CHROMOSOME SIMULATION** and **TEACHER'S MANUAL CHROMOSOME SIMULATION CLASS ACTIVITY KIT**. See also **SUPPLIES**. HOMEWORK: Complete **Section Review 7.2** and prepare for a quiz on section 7.2

CONTROL AUDITORY/VISUAL LESSON

The students observed, but did not manipulate, three dimensional models of mitosis. Each group completed a question and answer sheet on their observation of these models. The answers were reviewed before the end of class. See **MITOSIS VISUAL MODELS**.

DAY 9

Objective *Review the phases of mitosis. Evaluate with quiz. Prepare for the next lab on mitosis.*

BOTH EXPERIMENTAL AND CONTROL LESSON

Homework was checked and reviewed. The students took **QUIZ 7.2 MITOTIC CELL DIVISION AND CYTOKINESIS**. After the quiz, the students colored mitosis diagrams in preparation for their next lab titled **MITOSIS ORNAMENTS**. See **PREPARATION FOR MITOSIS ORNAMENTS**.

DAY 10

Objective *Identify types of asexual reproduction, identify factors that are needed for normal growth and repair, and compare the growth of cancer cells to normal*

cell growth.

BOTH EXPERIMENTAL AND CONTROL LESSON

The students were asked what would happen if people continued to grow larger as they aged. Class discussion followed. The students looked at textbook pictures of regeneration, budding, fragmentation, vegetative reproduction, and cancer in their textbook. The students were asked about their previous knowledge regarding these topics. The students were instructed to write an outline for this section on the control of mitosis. See **Study Skills 7-1**. After it was completed, they compared their outline to the teacher's outline. How outlines can be used and why they are important was discussed with the students. Homework: Define eight vocabulary from section 7.3, answer Bio Probe questions on page 115, complete **Section Review 7.3**, and prepare for a quiz on 7.3.

LABORATORY 3

Objective *Review the structures and events of the phases of mitosis.*

The students used their mitosis coloring pages that they had completed previously to guide them in making mitosis models made of dough. See **MITOSIS ORNAMENTS**.

DAY 11

Objective *Review the control of mitosis, section 7.3. Evaluate with a quiz.*

EXPERIMENTAL TACTILE/KINESTHETIC LESSON

After the homework was checked and reviewed, the students practiced the control of mitosis by completing a task puzzle with their group. See **TASK PUZZLE CONTROL OF MITOSIS**. The students were instructed to use their outline and defined vocabulary words from this section to help them to complete this puzzle. After the task puzzles were completed and put away, the students took **QUIZ 7.3 CONTROL OF MITOSIS**.

CONTROL AUDITORY/VISUAL LESSON

The students practiced the content by taking turns asking each group member questions about the control of mitosis, using their outline and defined vocabulary.

DAY 12

Objective *Review the cell cycle, interphase, mitotic cell division, and cytokinesis.*

EXPERIMENTAL TACTILE/KINESTHETIC LESSON

This was a kinesthetic lesson in which the students moved their body to go to the answer. This is called a paper plate game. The desks were rearranged and pushed to the back of the classroom allowing three aisles for three teams to line up and stand. The students formed three teams based on the number (1,2 or 3) that had been assigned to each previously. Each team formed a line at the back of the classroom in one of the aisles. Three students, one from each team, was chosen to keep score for each of the teams. They were given a sheet of paper, a pencil, and a seat at the opposite side of the classroom from each team. Six paper plates, labeled with I for Interphase, P for Prophase, M for metaphase, A for anaphase, T for telophase, and C for cytokinesis were placed on the floor between each team and their score keeper. The rules of the game consisted of no talking, rotation of the players, answer quickly by placing your foot on the paper plate that best answers the given statement, and no changing your answer after it has been first chosen. Points were given for correct answers and there was no deduction for wrong answers. A total of twenty-three statements were given by the teacher. There was time for a second round using the same statements. See **REVIEW OF INTERPHASE, MITOSIS, AND CYTOKINESIS** for the list of statements used in the game. At the end, the total score of each team was announced by each score keeper. The desks were returned to the original position. Homework: **REVIEW OF INTERPHASE, MITOSIS, AND CYTOKINESIS** and prepare for a test on this to be given the next day.

CONTROL AUDITORY/VISUAL LESSON

Each group completed the work used in the paper plate game, except it was in the form of a worksheet. After it was completed, the correct answers were given and a volunteer from each group scored their own work. The total score of each team was announced. The papers were collected and the same paper was handed out individually for homework like the experimental lesson.

DAY 13

Objective *Review the cell cycle, mitosis, and control of mitosis. Evaluate with a test.*

BOTH EXPERIMENTAL AND CONTROL LESSON

Homework was checked and reviewed. The test was given. See **TEST CELL CYCLE, MITOSIS, CYTOKINESIS, AND CONTROL OF MITOSIS**.

DAY 14

Objective *Identify and describe homologous chromosomes, diploid cells, haploid cells, gametes, fertilization, sexual reproduction, zygote, male meiosis and female meiosis. Describe the life cycle of a diploid organism.*

EXPERIMENTAL TACTILE/KINESTHETIC LESSON

The students manipulated paper chromosomes to simulate the life cycle of an imaginary creature called the Reebop. After male and female meiosis of the parents, and then fertilization, the zygote's chromosomes were decoded and an order form was completed by each group for one Baby Reebop. See **MARSHMALLOW MEIOSIS**.

CONTROL AUDITORY/VISUAL LESSON

The students saw the film MEIOSIS (second edition) 1980 by the Encyclopaedia Educational Corporation. The running time was fifteen minutes. During the film, the students completed questions about its content. This was reviewed at the end of class. See **Questions for MEIOSIS.**

DAY 15

Objective *Describe the role of meiosis in producing variation in populations. Explain the value of variation in the evolution of a population.*

EXPERIMENTAL TACTILE/KINESTHETIC LESSON

This lesson was a continuation of **MARSHMALLOW MEIOSIS**. Each group received the materials needed to make their Reebop baby. Each baby was made. The parents were heterozygous for all seven traits and therefore all of the babies were different from each other and from the parents. The babies were placed together in a pretend nursery in front of the parents. The students observed the variety. Each group completed a handout titled **OBSERVATION - ANALYSIS - CONCLUSION**. Homework: Answer Bio Probe questions on pages 117 and 120. Define the ten vocabulary words from section 7.4 and 7.6. Prepare for a quiz on these two sections.

CONTROL AUDITORY/VISUAL LESSON

The students saw a second film called MEIOSIS: The Key to Genetic Diversity by Human Relations Media. The running time was twenty-six minutes. The students completed questions during the film about its content. See **Questions for MEIOSIS: The**

Key to Genetic Diversity. This film had a pretend organism called a Windpog that was used to explain variation and its importance in a population.

LABORATORY 4

Objective *Learn what a karyotype is and prepare a karyotype for a normal person.*

The students prepared a karyotype of a normal human by cutting, matching, and then glueing paper chromosomes according to size and shape. Questions were then answered about their work. See **A Chromosome Study 21** and **Karyotype**.

DAY 16

Objective *Review meiosis, chromosome number, and importance of meiosis in evolution.*

BOTH EXPERIMENTAL AND CONTROL LESSON

The students completed two content review worksheets: **Section Review 7.4** and **Section Review 7.6**. Homework reminder was given by the teacher's substitute: Answer Bio Probe questions on pages 117 and 120, define the ten vocabulary from these sections, and prepare for a quiz on sections 7.4 and 7.6 which will be given the next day.

DAY 17

Objective *Review previous day's work and homework due.*

BOTH EXPERIMENTAL AND CONTROL LESSON

The work from the day before and homework due was checked and reviewed.

DAY 18

Objective *Review mitosis. Evaluate with a quiz.*

BOTH EXPERIMENTAL AND CONTROL LESSON

The students took **QUIZ 7.4 MEIOSIS AND SEXUAL REPRODUCTION AND 7.6 MEIOSIS AND EVOLUTION**. After the quiz, the students reformed their lab groups

and received their dried mitosis ornaments from a previous laboratory. They were given a two page handout to complete as a group. See **MITOSIS ORNAMENTS EVALUATION**.

DAY 19

Objective *Compare mitosis to meiosis.*

EXPERIMENTAL TACTILE/KINESTHETIC LESSON

The students compared mitosis to meiosis by completing a handout titled **Comparing Mitosis and Meiosis 17**. The students manipulated pieces of yarn which represented chromosomes to simulate these cellular processes. Part A was about mitosis and Part B was about meiosis. At the end of the activity, there were questions to answer and tables to complete. The work of the students was reviewed at the end of class.

CONTROL AUDITORY/VISUAL LESSON

The same objective was accomplished by the teacher moving the chromosomes (yarn) on the overhead and having the students observe this movement.

DAY 20

Objective *Review cellular reproduction in preparation for the comprehensive test on chapter 7.*

EXPERIMENTAL TACTILE/KINESTHETIC LESSON

The students played a second paper plate game that was very similar to the first. The paper plates from the first game were used and new ones were made also. A total of 77 statements in four categories were used in this review. See **REVIEW OF CHAPTER 7 CELLULAR REPRODUCTION**. Homework: Answer the chapter review on pages 122 and 123.

CONTROL AUDITORY/VISUAL LESSON

This was also a very similar activity to the previous control lesson which was done in place of the paper plate game. The same statements were used as above, each group completed one worksheet, and total scores were announced at the end of class.

LABORATORY 5

Objective *Describe the events and structures of the phases of meiosis I.*

The students built a manipulative called a meiosis hexaflexagon. This paper manipulative consists of four sides, with each side consisting of three separate diamonds. When the three diamonds come together, a picture is created. See **MEIOSIS HEXAFLEXAGON** and **Manipulative Hexaflexagon 45108**. See also **SUPPLIES**.

DAY 21

Objective *Review the events and structures of the phases of meiosis I.*

EXPERIMENTAL TACTILE/KINESTHETIC LESSON

Homework was checked and reviewed. The students used their meiosis hexaflexagon to complete **OBSERVATION AND ANALYSIS**. Homework: Complete **Section Review 7.5**, **Critical Thinking Diagram Worksheet 7-1**, and prepare for the Chapter 7 test on Cellular Reproduction.

CONTROL AUDITORY/VISUAL LESSON

The students used diagrams from section 7.5 of their textbook to answer the same items from the worksheet above. The items were given orally by the teacher and not in a worksheet.

DAY 22

Objective *Evaluate knowledge of Chapter 7 Cellular Reproduction.*

BOTH EXPERIMENTAL AND CONTROL LESSON

Homework was checked and reviewed. The students took the test. See **Chapter 7 Test A**.

Table 3-1

Summary of Percentage of White, Black, and Hispanic Students

	P1EXP	P4EXP	P6EXP	P9CON	TOTAL
White	82	68	80	82	78
Black	9	21	10	4	11
Hispanic	9	11	10	14	11

Table 3-2

Summary of Percentage of Male and Female Students

	P1EXP	P4EXP	P6EXP	P9CON	TOTAL
Male	39	42	50	41	57
Female	61	58	50	59	43

Table 3-3

Number of Students Tested by the New Jersey Statewide Testing System Grade 8 Early Warning Test

	P1EXP	P4EXP	P6EXP	P9CON	TOTAL
Number of Students	23	19	20	22	84
Tested Students	8	12	13	18	51
Percent Tested	35	64	65	82	61

Table 3-4

Summary of t Test Calculations for Test Scores of Chapter 6 Cellular Respiration and Photosynthesis

	t Calculated	Degrees of Freedom
P9 CON:P1 EXP	0.239832	43
P9 CON:P4 EXP	0.909276	39
P9 CON:P6 EXP	0.007218	40
P1 EXP:P4 EXP	0.245831	40
P1 EXP:P6 EXP	0.079770	41
P4 EXP:P6 EXP	0.006562	37

NOTE: Only differences at the 95% level were considered to be significant. All t calculations were less than t critical. See Tabe 4-2 on page 31. These indicate no significant differences between all groups in the study.

Figure 3-1
Percentage Totals of White, Black, and Hispanic Students

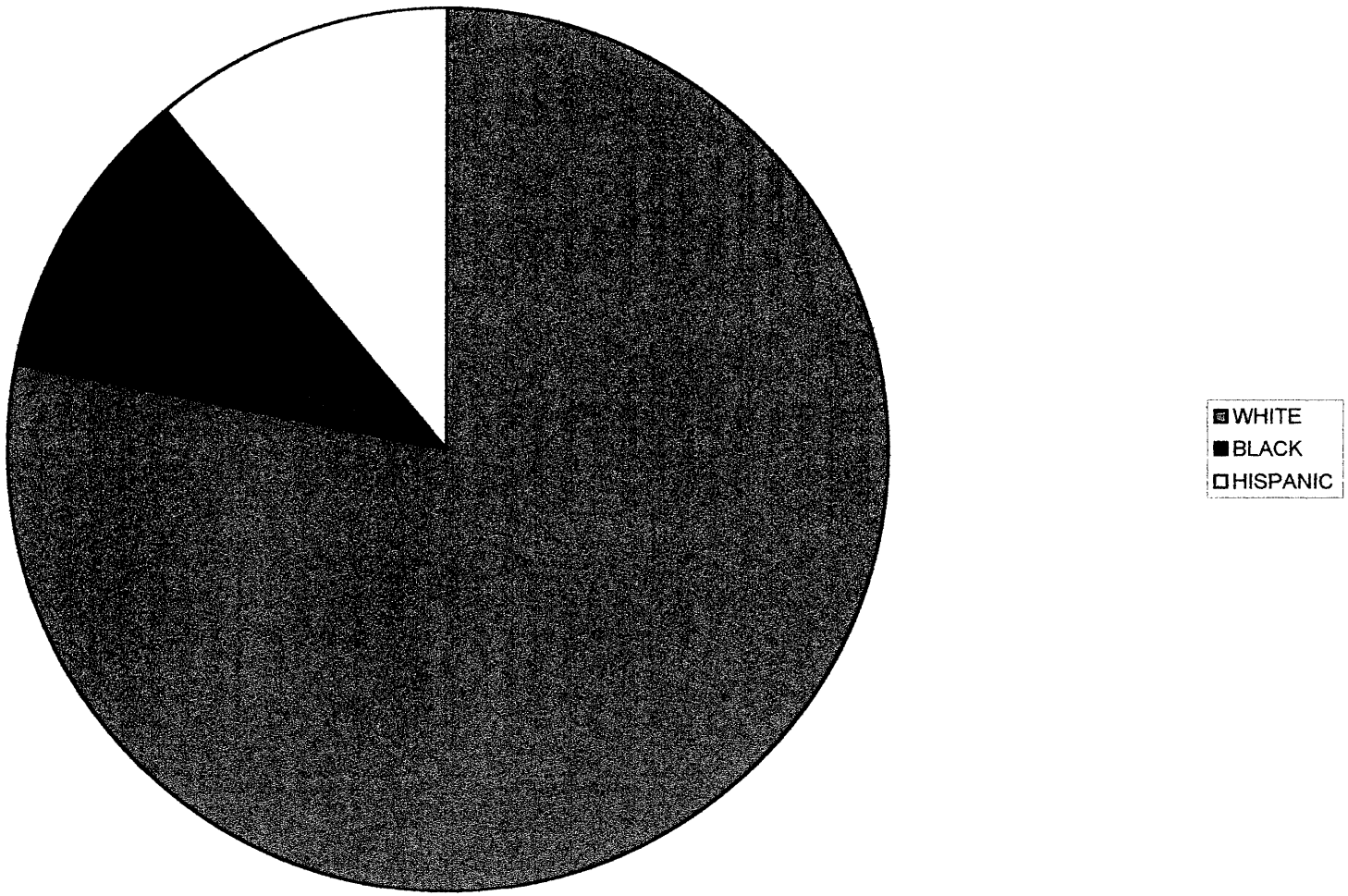


Figure 3-2
Distribution of Score Averages of the New Jersey Statewide Testing System Grade 8 Early Warning Test

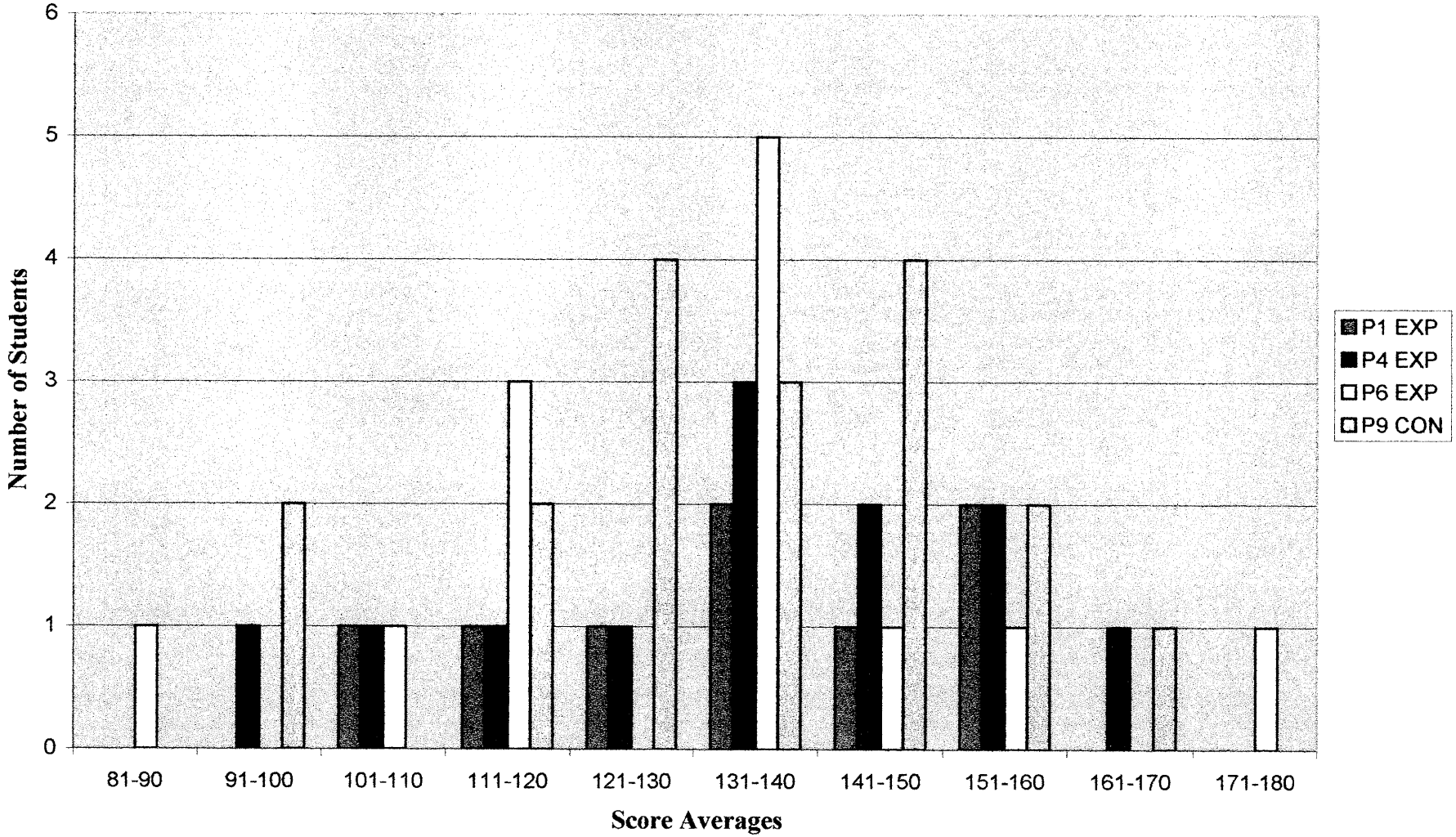
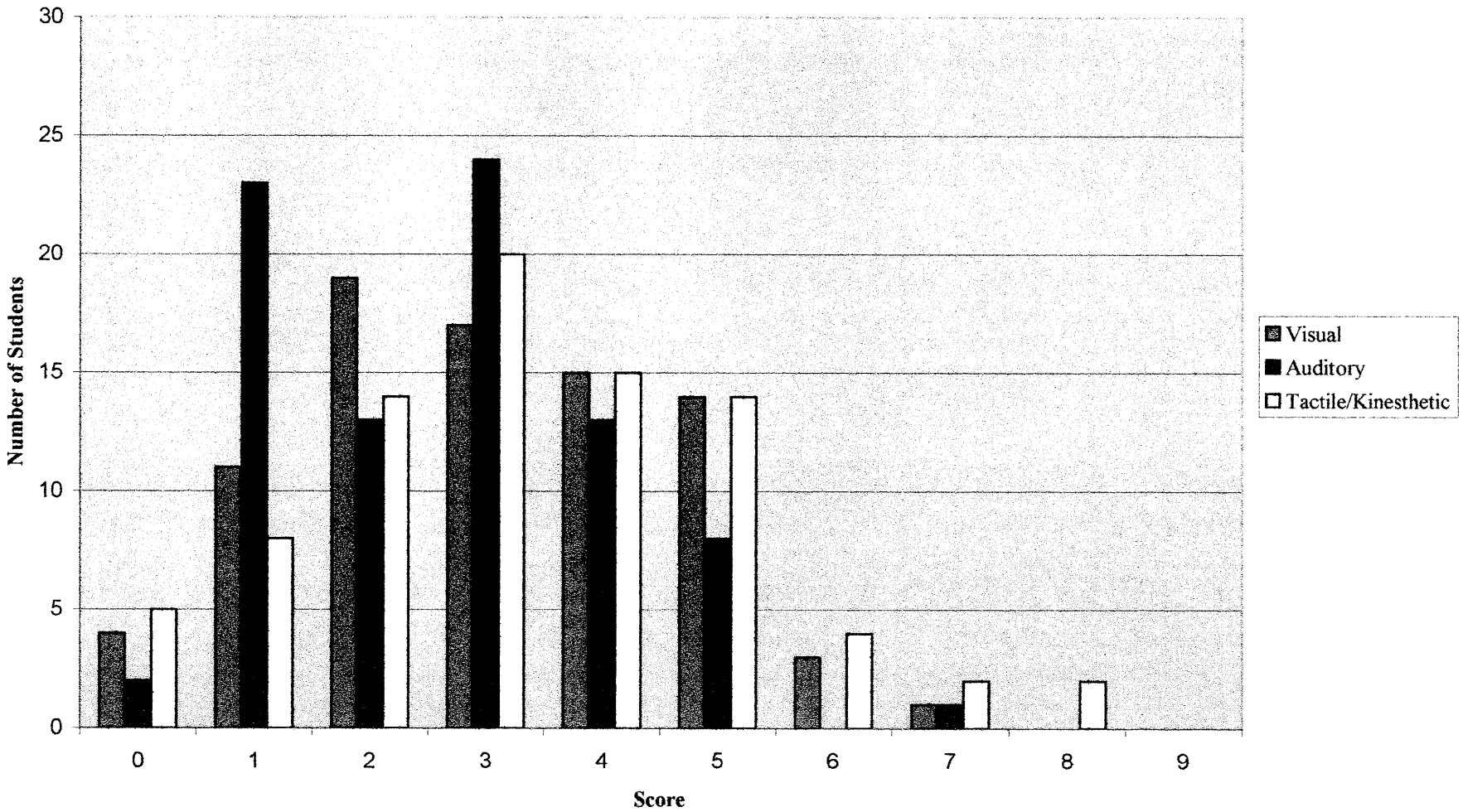


Figure 3-3
Summary of Student Self-Assessment Scores For Learning Styles
Weakest (0) Strongest (9)



Chapter 4: Data Analysis

The raw scores of four quizzes and two tests were recorded for each class. See Table 4-1 on page 27. Six class pairings were determined to be P9 CONTROL : P1 EXPERIMENTAL, P9 CONTROL : P4 EXPERIMENTAL, P9 CONTROL : P6 EXPERIMENTAL, P1 EXPERIMENTAL : P4 EXPERIMENTAL, P1 EXPERIMENTAL : P6 EXPERIMENTAL, and P4 EXPERIMENTAL : P6 EXPERIMENTAL. The null hypothesis was that there would be no significant differences at the 95% level between the control group, which received no tactile/kinesthetic instruction and the experimental groups which did receive tactile/kinesthetic instruction. The instrument used to determine whether the null hypothesis could be rejected was the t test. The t test is a statistical test limited to normal distributions of data which are independent of each other (Ambrose & Ambrose, 1987). T test calculations were made for each quiz and test for every class pairing. Microsoft Excel 7.0 was the software program used for all statistical calculations. The t test results can be seen on Table 4-3 on page 32. The mean and standard deviation were also determined for every class pairing of every quiz and test. See Table 4-4 on page 33 and Figure 4-2 on page 35. The degrees of freedom were also determined for each class pairing. Degrees of freedom are necessary to complete the t test. The degrees of freedom were calculated by adding the two sample sizes and then subtracting two. Once t calculated and degrees of freedom were determined, reference was made to a table of critical t values. See Table 4-2 on page 31. The critical t values in the table are set at the 0.5 alpha level.

The results indicate that there were no significant differences at the 95% level (alpha 0.5) except for P9 CON : P6 EXP, Test 1. Therefore, the null hypothesis was not rejected. However, it was the control group that had the higher test scores, not the experimental group. Analysis of the determined means, see Figure 4-2 on page 35, show that the control group had a higher mean for each quiz and test except for Test 2 when P1 EXP had the higher mean. Analysis of the means for a test taken before the study, see Figure 4-1 on page 34, show that the control group (P 9), had the highest means also. However, there were no significant differences at the 95% level for all class pairings for this last unit covered before the study. See Table 3-4 on page 22. Analysis of the standard deviation summary for all class pairings in the study show that the control group (P 9) had the least standard deviation five out of six testing times. See Figure 4-3 on page 36.

Table 4-1

Raw Scores of Experimental Data

P9 CON	**Quiz 1**	**Quiz 2**	**Quiz 3**	**Quiz 4**	**Test 1**	**Test 2**
Student	10 questions	18 questions	8 questions	10 questions	20 questions	25 questions
1	10	16	8	10	18	19
2	6	12	8	10	14	20
3	4	9	8	10	13	18
4	9	4	8	10	15	18
5	6	9	4	10	14	13
6	10	13	8	8	17	19
7	10	12	8	8	16	21
8	10	15	5	8	18	21
9	9	12	4	6	15	19
10	7	11	8	9	16	21
11	6	10	8	10	12	21
12	9	16	8	8	20	23
13	10	17	6	8	18	16
14	10	18	6	10	20	18
15	10	17	8	10	18	24
16	10	12	3	6	20	21
17	9	12	6	6	18	23
18	10	12	8	10	15	22
19	10	12	8	10	14	22
20	10	16	8	10	20	21
21	7	13	6	8	15	18
22	7	14	8	8	15	18

Table 4-1 continued

Raw Scores of Experimental Data

P1 EXP	**Quiz 1**	**Quiz 2**	**Quiz 3**	**Quiz 4**	**Test 1**	**Test 2**
Student	10 questions	18 questions	8 questions	10 questions	20 questions	25 questions
1	9	12	6	8	11	16
2	6	8	6	8	11	17
3	6	13	6	8	15	18
4	6	12	8	8	10	19
5	9	14	8	6	12	23
6	10	17	8	8	16	22
7	8	17	6	8	19	24
8	8	10	6	10	12	21
9	10	12	6	8	13	18
10	6	16	8	10	17	21
11	6	5	6	8	13	13
12	9	9	8	8	16	22
13	7	13	6	10	12	23
14	5	7	2	6	12	14
15	5	16	8	10	18	23
16	10	13	8	6	18	23
17	9	15	8	8	17	20
18	2	11	8	8	17	19
19	3	6	3	6	13	14
20	10	16	8	10	19	24
21	6	5	3	10	14	16
22	10	13	8	10	20	22
23	7	11	5	8	17	23

Table 4-1 continued

Raw Scores of Experimental Data

P4 EXP	**Quiz 1**	**Quiz 2**	**Quiz 3**	**Quiz 4**	**Test 1**	**Test 2**
Student	10 questions	18 questions	8 questions	10 questions	20 questions	25 questions
1	6	8	8	8	11	15
2	8	10	5	8	16	18
3	4	9	8	10	11	19
4	5	11	4	4	8	10
5	7	10	2	10	15	19
6	10	12	6	8	11	18
7	6	15	8	10	15	20
8	7	13	8	10	18	14
9	4	7	8	8	17	19
10	9	11	8	3	16	14
11	9	3	6	10	11	14
12	10	13	6	10	20	20
13	8	13	8	6	16	14
14	6	10	4	10	11	21
15	10	18	8	10	19	20
16	5	7	4	10	13	17
17	7	11	8	8	13	14
18	7	9	8	8	11	16
19	10	4	6	2	8	15

Table 4-1 continued

Raw Scores of Experimental Data

P6 EXP	**Quiz 1**	**Quiz 2**	**Quiz 3**	**Quiz 4**	**Test 1**	**Test 2**
Student	10 questions	18 questions	8 questions	10 questions	20 questions	25 questions
1	8	10	6	10	11	20
2	9	11	6	7	12	16
3	7	10	6	10	12	18
4	9	14	8	10	14	19
5	8	10	8	5	11	18
6	9	7	8	8	12	15
7	7	11	4	10	11	15
8	3	9	3	6	11	18
9	7	2	5	7	8	13
10	9	16	8	10	20	20
11	6	10	6	8	10	15
12	3	5	5	2	11	10
13	5	8	4	10	9	16
14	10	17	8	10	20	20
15	6	3	2	4	11	10
16	10	9	3	0	10	15
17	8	11	6	10	14	21
18	8	11	8	8	12	18
19	6	9	8	10	14	16
20	10	14	8	4	17	20

Table 4-2

Table of Critical Values of t For The t Test at The .05 Alpha Level

degrees of freedom	t critical
1	12.706
2	4.303
3	3.182
4	2.776
5	2.571
6	2.447
7	2.365
8	2.306
9	2.262
10	2.228
11	2.201
12	2.179
13	2.160
14	2.145
15	2.131
16	2.120
17	2.110
18	2.101
19	2.093
20	2.086
21	2.080
22	2.074
23	2.069
24	2.064
25	2.060
26	2.056
27	2.052
28	2.048
29	2.045
30	2.042
40	2.021
60	2.000

Adapted from J.P. Guilford. *Fundamental Statistics in Psychology and Education.* McGraw-Hill Book Company. New York. 1956.

Copied from Ambrose, Harrison S. & Ambrose, Katharine Peckham. *A Handbook of Biological Investigation. Fourth Edition.* Hunter Textbooks Inc., Winston-Salem, North Carolina. Page 90.

Table 4-3

Summary of t Test Calculations For Experimental Data

Class Pairings	t Calculated						Degrees of Freedom
	Quiz 1	Quiz 2	Quiz 3	Quiz 4	Test 1	Test 2	
P9 CON : P1 EXP	0.03197	0.363431	0.476611	0.210101	0.060516	0.754214	43
P9 CON : P4 EXP	0.027647	0.024688	0.498445	0.251554	0.005909	0.001245	39
P9 CON: P6 EXP	0.046402	0.012536	0.141843	0.074706	7.17E-05	0.000829	40
P1 EXP : P4 EXP	0.997315	0.173278	0.993709	0.738252	0.247575	0.003348	40
P1 EXP : P6 EXP	0.837476	0.100007	0.417788	0.258224	0.016973	0.002005	41
P4 EXP : P6 EXP	0.836599	0.762527	0.453174	0.508631	0.282527	0.899708	37

Table 4-4

Summary of Mean and Standard Deviation
For Experimental Data

Mean

	Quiz 1	Quiz 2	Quiz 3	Quiz 4	Test 1	Test 2
P9 CON	8.67	12.76	6.86	8.81	16.48	19.90
P1 EXP	7.26	11.78	6.48	8.26	14.87	20.22
P4 EXP	7.26	10.21	6.47	8.05	13.68	16.78
P6 EXP	7.40	9.85	6.00	7.45	12.50	16.65

Standard Deviation

	Quiz 1	Quiz 2	Quiz 3	Quiz 4	Test 1	Test 2
P9 CON	1.85	3.32	1.65	1.47	2.46	2.57
P1 EXP	2.30	3.72	1.83	1.39	3.00	3.83
P4 EXP	2.02	3.58	1.90	2.55	3.54	3.02
P6 EXP	2.09	3.80	2.00	3.05	3.24	3.17

Table 4-5

Summary of Mean and Standard Deviation For Pre Study Test Scores of Chapter 6 Photosynthesis and Respiration

	Mean	Standard Deviation
P9 CON	17.73	3.04
P1 EXP	16.61	3.24
P4 EXP	17.63	2.14
P6 EXP	14.61	4.08

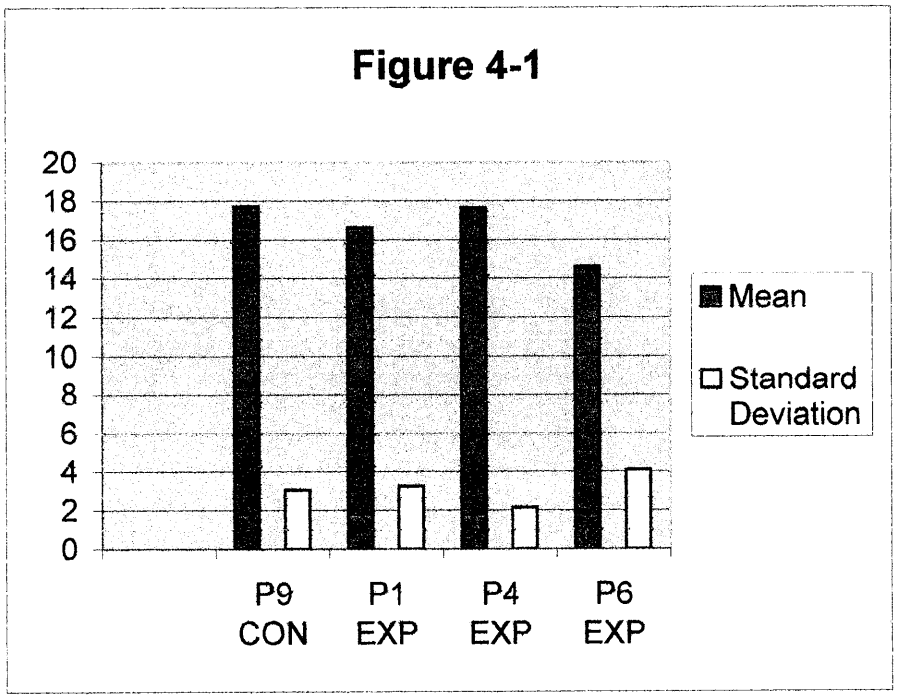


Figure 4-2 Summary of Means For Experimental Data

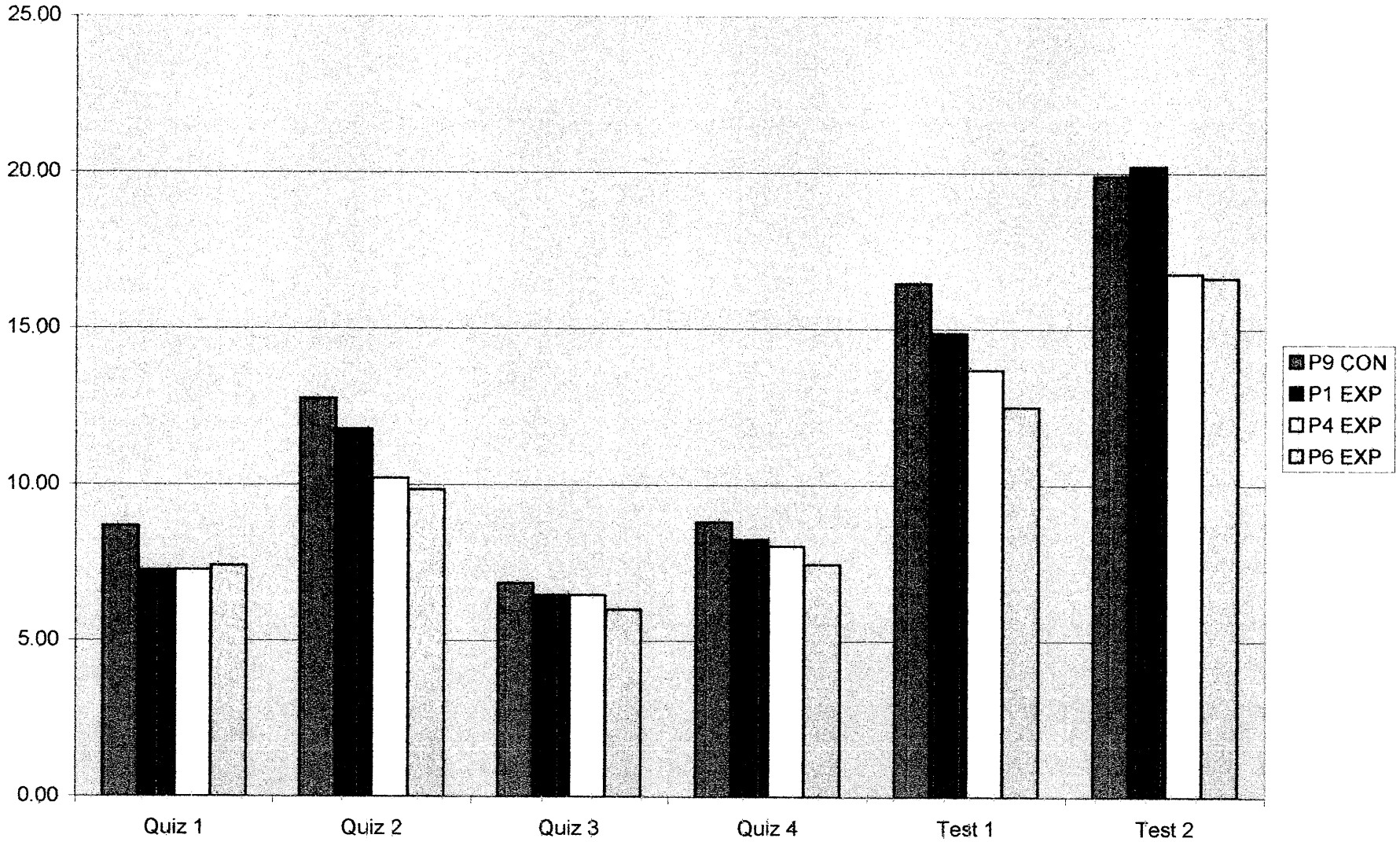
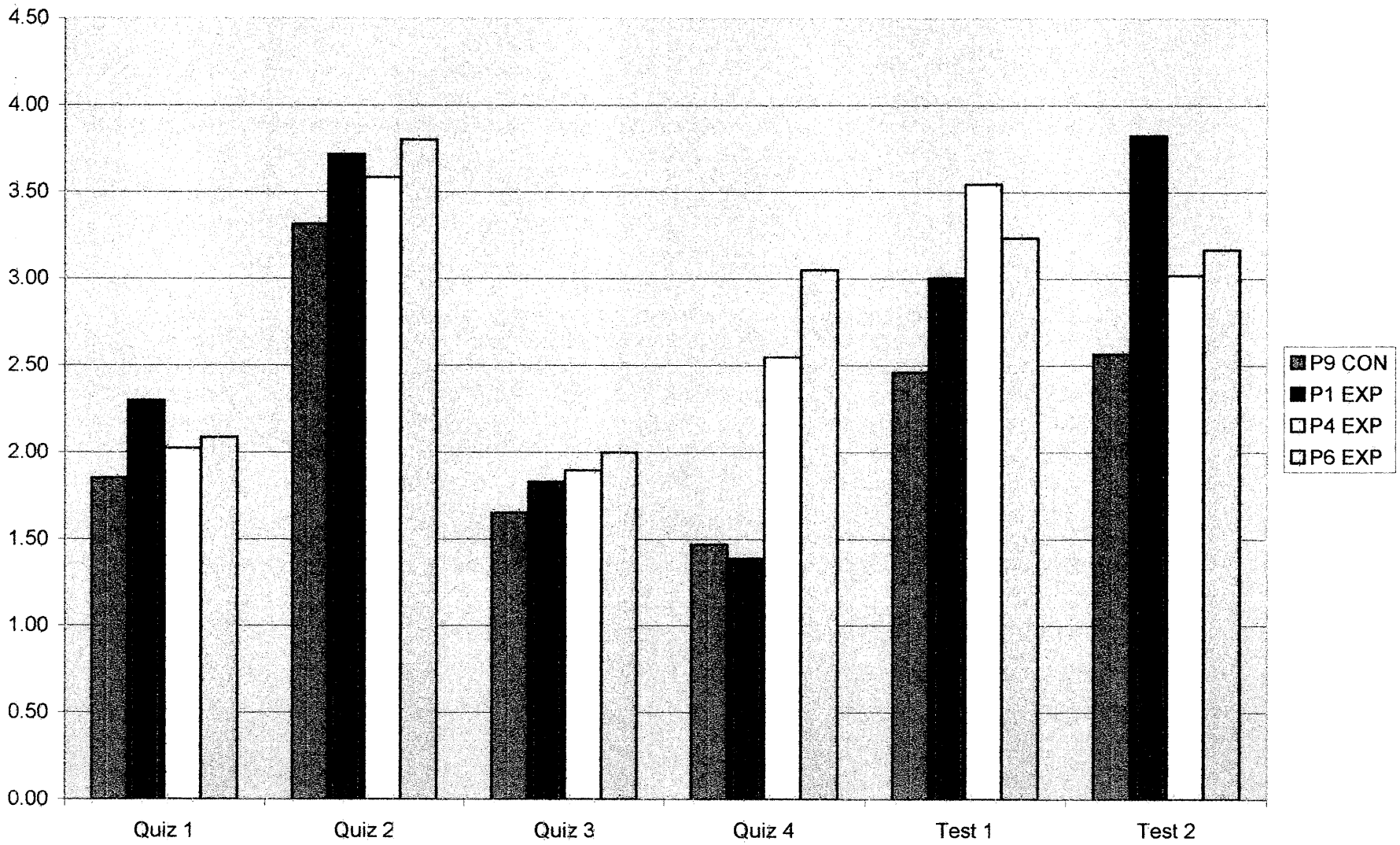


Figure 4-3 Summary of Standard Deviations For Experimental Data



Chapter 5: Summary and Discussion

Tactile/kinesthetic instruction is one of many styles of teaching and one of many ways in which students learn. Research indicates that tactile/kinesthetic intelligence is the baseline of the learning process because most children as well as many adults learn this way (Carbo, 1997; Dunn & Dunn, 1993). We all remember best what we have actually done, rather than what we have seen or heard. Touch is also extremely important in the mother-infant bond and in child development (Kaitz, Lapidot & Bonner, 1992; Study shows how neglect warps the brain, 1997). Four classes of College Biology students at Buena Regional High School were used in this study. One class was chosen as a control group and the other three were used as the experimental groups. It was assumed that there were no significant differences among the four groups. This was determined by a t test calculation on a pre study chapter that showed no significant differences at the 95% level. A chapter on mitosis and meiosis was chosen as the content area. All groups received instruction visually and auditorily but the experimental groups had in addition tactile/kinesthetic instruction. Data was collected by means of four quizzes and two tests. The t test was performed on six class pairings. All results showed no significant differences at the 95% level except for P9 CON : P6 EXP, Test 1. However, it was the control group that had the higher test score. Analysis of the means showed that the control group scored highest for all quizzes and tests except for Test 2 when P1 EXPERIMENTAL scored the highest. Analysis of the means for the pre study test showed that the control group (P 9) also had the highest means.

This study indicates that the addition of tactile/kinesthetic instruction to strategies in the biology classroom does not increase test score results. It was assumed that all classes were similar and according to the pre-study analysis of test results there were no significant differences among the classes. It is necessary to acknowledge possible errors of the instructor and of the instruction. It is also necessary to acknowledge the limitations of the study. Tactile/kinesthetic instruction used in this study, was new to the instructor. Materials as well as detailed instructions on how to use these materials were many.

Repeated experiments in this field are needed to determine the effectiveness of tactile/kinesthetic instruction in the biology classroom. Application of this study to various age groups is recommended.

References

Artificial Tactile Perception. 9/24/97 12:42 PM http://bioing2.unipv.it/tactile.htm

Ambrose, Harrison W. & Ambrose, Katharine Peckham Ambrose (1987). *A Handbook of Biological Investigation.* Winston-Salem, North Carolina: Hunter Textbooks, Inc.

Blahut, John (February 1984). Tactile Activities and Learning Attitudes. *Social Education,* 48, 153-158.

Bushnell, Emily W. & Boudreau, J. Paul (August 1993). Motor Development and the Mind: The Potential Role of Motor Abilities as a Determinant of Aspects of Perceptual Development. *Child Development*, 64, 1005-1021.

Campbell, James P. (April/May 1996). Some Cautions About Visual Learning and Religous Education. *Momentum*, 27, 29-30.

Campbell, Linda, Campbell, Bruce & Dickenson, Dee (1996). *Teaching and Learning Through Multiple Intelligences.* Needham Heights, Massachusetts: Allyn & Bacon.

Carbo, Marie. (March 1997). Reading styles times twenty. *Educational Leadership*, 54, 38 - 42.

Croker, Robert E., Bobell, John LVV & Wilson, Ruth A. (1995). Learning Style, Brain Modality, and Teaching Preferences of Incarcerated Females at the Pocatello Women's Correctional Center. A Research Project presented to the American Vocational Association Annual Conference, Denver, Colorado, December 4, 1995. Research Funded by the Idaho Commission on Women's Programs, Boise, Idaho.

Cropper, Carolyn. (September/October 1994). Teaching for Different Learning Styles. *Gifted Child Today*, 17, 36-39.

Dunn, Rita, & Dunn, Kenneth (1993). *Teaching Secondary Students Through Their Individualized Learning Styles.* Reston, VA : Reston Publishing Company.

Essenfeld, Bernice E., Gontang, Carol R., & Moore, Randy (1996). *Biology.* New York, New York : Addison-Wesley Publishing Company, Inc.

Guild, Pat Burke & Garger, Stephen (1985). *Marching to Difference Drummers.* Alexandria, VA: Association for Supervision and Curriculum Development.

Hamachek, Alice L. (1991). Enhancing Comprehension Through the Development of

Strategies for Reading, Learning, and Remembering. Teacher Education and Professional Development, Central Michigan University, Mt. Pleasant, Michigan.

Harvey, S. & Seeley, K. (1984). An Investigation of the Relationships Among Intellectual and Creative Abilities, Extracurricular Activities, Achievement, and Giftedness in a Delinquent Population. *Gifted Child Quarterly*, 28, 73-79.

Hodgin, June & Wooliscroft, Caaren. (March 1997). Eric learns to read: learning styles at work. *Educational Leadership*, 54, 6, p43(3) Internet. 10/25/97, Association for Supervision and Curriculum Development

Kaitz, Marsha, Lapidot, Pnina & Bronner, Ruth (January 1992). Women Can Recognize Their Infants by Touch. *Developmental Psychology*, 28, 35-39.

Kraemer, Barbara (1996). Meeting the Needs of Nontraditional Students: Retention and Transfer Studies. Paper presented at the Annual Meeting of the North Central Association (101st, Chicago, IL, March 23-26, 1996).

Learning Styles: Putting Research and Common Sense into Practice (1991). American Association of School Administrators, 1801 North Moore Street, Arlington, VA, 22209, 56 pages.

McCarthy, Bernice (1991). Learning Styles and Schools: Marking It Happen. Excel, Inc.

Murphy, Erroleen & McLaughlin, T.F. (Fall 1990). The Effects of Tactile and Kinesthetic Learning in Improving Spelling Performance of a Special Education Student. *Reading Improvement*, 27, 207-211.

"Noise" Enhances Human Ability to Detect Tactile Sensation 9/24/97 12:39 PM http://www.eurekalerf.org/E-lert/current/public_releases/deposit/stimulus.html

Oram, Raymond F. (1989). *Biology Living Systems*. Columbus, Ohio : Merrill Publishing Company.

Park, Clara C. (January 1997). Learning Style Preferences of Korean, Mexican, Armenian-American, and Anglo Students in Secondary Schools. *NASSP Bulletin*, 81, 585, 103-111.

Rose, Colin. LEARNING STYLES (1987). 9/30/97 12:45 PM http://www.chaminade.org/inspire/learnstl.htm

Soderberg, Patti. (November 1992). Marshmallow Meiosis. *The Science Teacher*, 28 - 31.

Stone, Pete (November 1992). How We Turned Around a Problem School. *Principal*, 72, 34-36

Study shows how neglect warps the brain. (1997, October 28). *The Philadelphia Inquirer*

"Tactile/Kinesthetic Learning" 9/24/97 7:15 PM
http://volcano.und.nodak.edu/vwdocs/msh/llc/is/tkl.html

Wallace, James (Spring 1995). Accomodating Elementary Student's Learning Styles. *Reading Improvement*, 32, 38-41.

White, Stephen Earl (1992). Factors That Contribute to Learning Difference Among African American and Caucasian Students. Debut Paper. Tuskegee University, Tuskegee, Alabama.

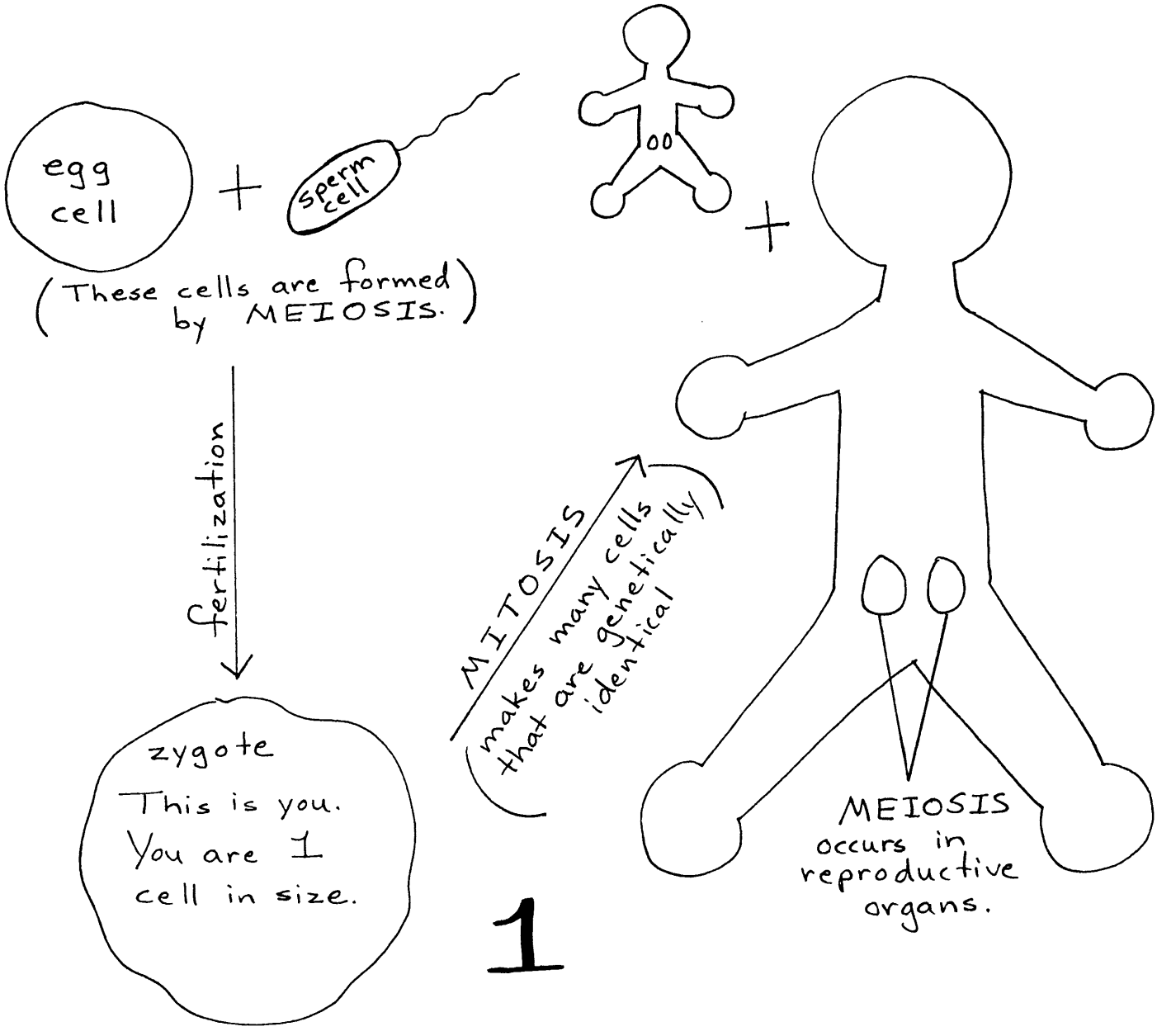
Appendix

INTRODUCTION TO CHAPTER SEVEN

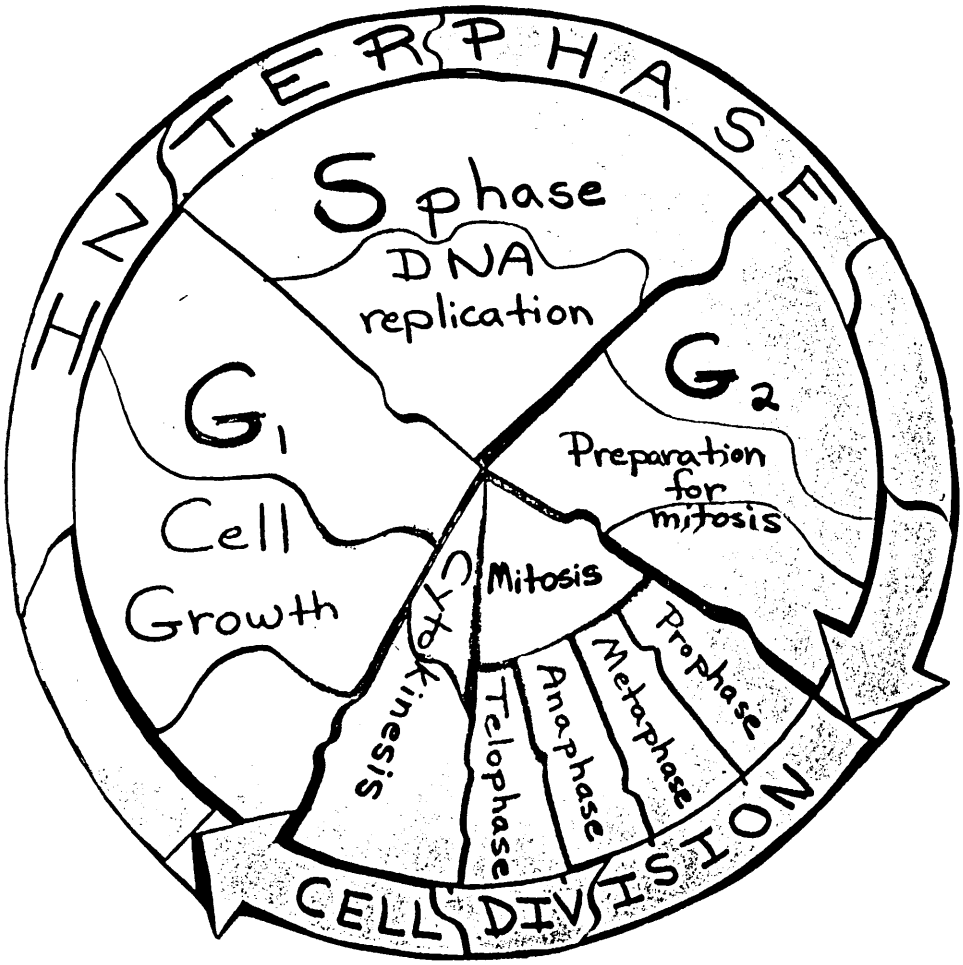
TEACHER: Look at the photographs of the Venus Flytraps and of Sea Anemones on page 106. The Venus Flytraps are genetically identical because they resulted from mitotic cell cell division. They were grown from tissue culture. The Sea Anemones, from colonies, are also genetically identical because they were grown from mitotic cell division.

In your Bio Journal, list ways that you differ from a single-celled organism. How did you become trillions of cells from one cell? (Check student responses.)

TEACHER: This chapter is about two kinds of cellular reproduction: mitosis and meiosis. The following diagram shows how these two kinds of cellular reproduction are connected in the life cycle of the human. You may copy these down into your Bio Journal or just look and listen.



TASK PUZZLE THE CELL CYCLE AND MITOSIS



This task puzzle was made from oaktag paper. Approximate size was 24 X 24 inches. A variety of colors were using in the print.

7.1 THE CELL CYCLE AND MITOSIS

1. The cell cycle consists of interphase and _____.

AND

2. The cell cycle consists of interphase and _____ and _____.

3. The longest phase of the cell cycle is _____.

4. During interphase, the cell _____, _____, and _____.

5. Mitosis consists _____, _____, _____, and _____.

6. This process, _____, follows mitosis.

7. Cell division consists of _____ and _____.

Mitosis

15

A single fertilized human egg cell will divide to form two cells. These two cells will each divide into two cells. In time, millions of cells are produced. The division of nuclear material in which each new cell obtains the same number of chromosomes and the same nuclear code as the original cell is called mitosis. Mitosis occurs in four phases. There is an interphase between each mitosis.

In this investigation, you will

(a) locate cells in prepared onion root slides that are in the process of dividing by mitosis.
(b) identify cells in interphase and in each of the four stages of mitosis in the onion root tips by comparing them with diagrams.
(c) study the changes which occur in a cell as it undergoes mitosis.

Materials

microscope
prepared slides of onion root tip *(Allium)*, longitudinal section

Procedure

• Locate with a microscope the region of rapidly dividing cells on the prepared slide of onion root tip as shown in Figure 15-1. After locating the cells under low power, switch to high power.

• Locate cells that appear to be in the various stages of mitosis. Use Figure 15-2 as a guide.

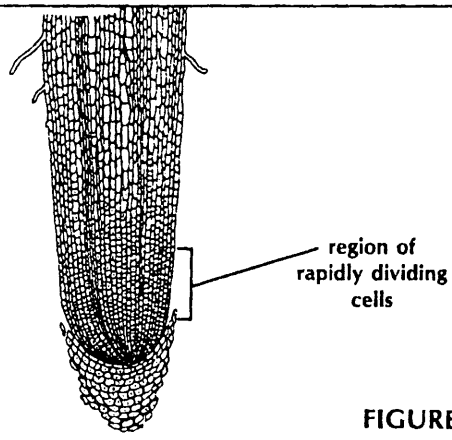


FIGURE 15-1

• Identify and label the following stages of mitosis by using the brief description provided. Write the correct stage name on the lines provided in Figure 15-2.

(a) *Interphase*—cell contains easily seen nucleus and nucleolus—chromosomes appear as fine dots within nucleus

(b) *Prophase*—cell nucleus enlarged—nucleolus no longer visible—chromosomes appear as short strands within nucleus

(c) *Metaphase*—chromosomes long and thin strands—chromosomes lined up along cell center and look like "spider on a mirror"

(d) *Anaphase*—two sets of separate chromosomes can be seen—look as if they are being pulled apart from one another

(e) *Telophase*—chromosomes appear at opposite ends of cell—middle of cell has line across center that divides it almost into two new cells

(f) *Daughter cells*—appear as cells in interphase but smaller and side by side—actually start of new interphase

4

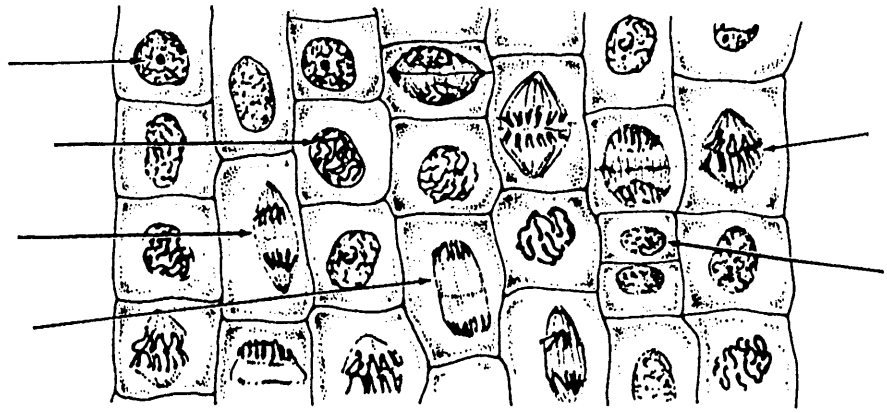


FIGURE 15-2

• Answer the following questions about each of the phases of mitosis.

FIGURE 15-3

INTERPHASE

Interphase

• Locate cells resembling Figure 15-3. Answer questions 1-3 while observing these cells.

1. Describe the contents of a nucleus during interphase. _____

2. Are a nucleolus and nuclear membrane present in the cell? _____

3. Are distinct rod-shaped structures called chromosomes easily observed in the nucleus at this time? _____

• Use your text for reference while answering questions 4-6.

4. Are chromosomes present in cells during interphase? _____

5. What term is used to describe nuclear contents during interphase? _____

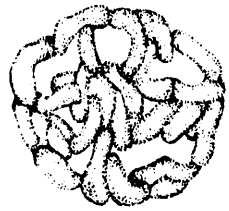
6. (a) What important event occurs to chromosomes during interphase? _____

_____

(b) What other important events occur during interphase? _____

_____

FIGURE 15-4



PROPHASE

Prophase

• Locate cells resembling Figure 15-4. Answer questions 7 and 8 while observing these cells.

7. Are chromosomes now visible during prophase? _____

8. Describe the changes that have occurred to the nucleolus and nuclear membrane from interphase to prophase. _____

_____

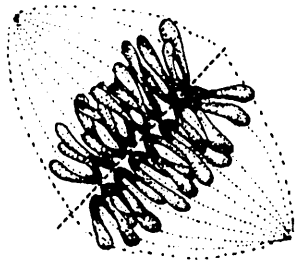
• Use your text for reference while answering question 9.

9. Explain why chromosomes can now be observed but were not observable during interphase. _____

_____

5

FIGURE 15-5



METAPHASE

Metaphase

• Locate cells resembling Figure 15-5. Answer questions 10 and 11 while observing these cells.

10. Describe where the chromosomes are now located in relation to the cell. _____

_____

11. Can evidence of chromosome duplication (replication) now be observed? _____

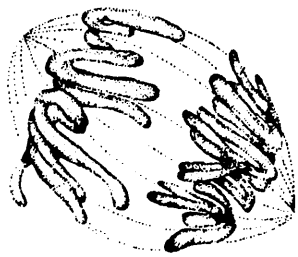
• Use your text for reference while answering questions 12 and 13.

12. What are the fibers called that become visible during this phase? _____

13. What term is used to describe the structure at which each fiber attaches to a chromosome?

_____

FIGURE 15-6



ANAPHASE

Anaphase

• Locate cells resembling Figure 15-6. Answer questions 14 and 15 while observing these cells.

14. In metaphase, chromosome pairs were lined up along the cell's center. Describe what is occurring to each chromosome pair during anaphase. _____

15. Toward what area of the cell are the chromosomes being directed? _____

• Use your text for reference while answering question 16.

16. What structure is responsible for the movement of chromosomes during this phase?

_____

Telophase

• Locate cells resembling Figure 15-7. Answer question 17 while observing these cells.

17. What cell parts begin to reappear during this phase? (See question 8.) _____

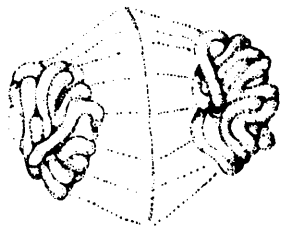
_____

18. Describe the location of the chromosomes now compared to where they were during metaphase. _____

_____

_____

FIGURE 15-7



TELOPHASE

FIGURE 15-8

DAUGHTER CELLS

Daughter Cells

• Locate cells resembling Figure 15-8. Answer questions 19 and 20 while observing these cells.

19. How many cells have now formed from an original cell? _____

20. Explain how the number of chromosomes found in each daughter cell compares to the number found in the original cell before mitosis. (HINT: Read introduction.) _____

_____

6

Analysis

1. The term "mitosis" comes from the Greek word meaning "thread." Explain why this word may be helpful in describing this process of nuclear division. _____

_____

2. Explain how the process of mitosis helps an organism to grow in size. _____

_____

3. Complete Figure 15-8 to show the structures visible during each stage of mitosis. Draw in and/or label the structures listed below on the appropriate diagram. Be sure to label each animal cell with the correct mitosis stage name.
   (a) *Interphase:* draw and label *nuclear membrane, nucleolus, chromatin, centriole.*
   (b) *Prophase:* label *disappearing nuclear membrane, disappearing nucleolus, original chromosomes* (shaded), *chromosome copies* (unshaded).
   (c) *Metaphase:* draw in the two chromosome pairs as they would appear during metaphase. Label *chromosomes, spindle fibers.*
   (d) *Anaphase:* draw in the two chromosome pairs as they separate in anaphase. Label *centromeres.*
   (e) *Telophase:* label *reforming nuclear membrane, reforming nucleolus, pinching in of cell membrane.*
   (f) *Interphase:* draw in and label *nucleus, nucleolus, nuclear membrane,* and *chromatin* in each cell.

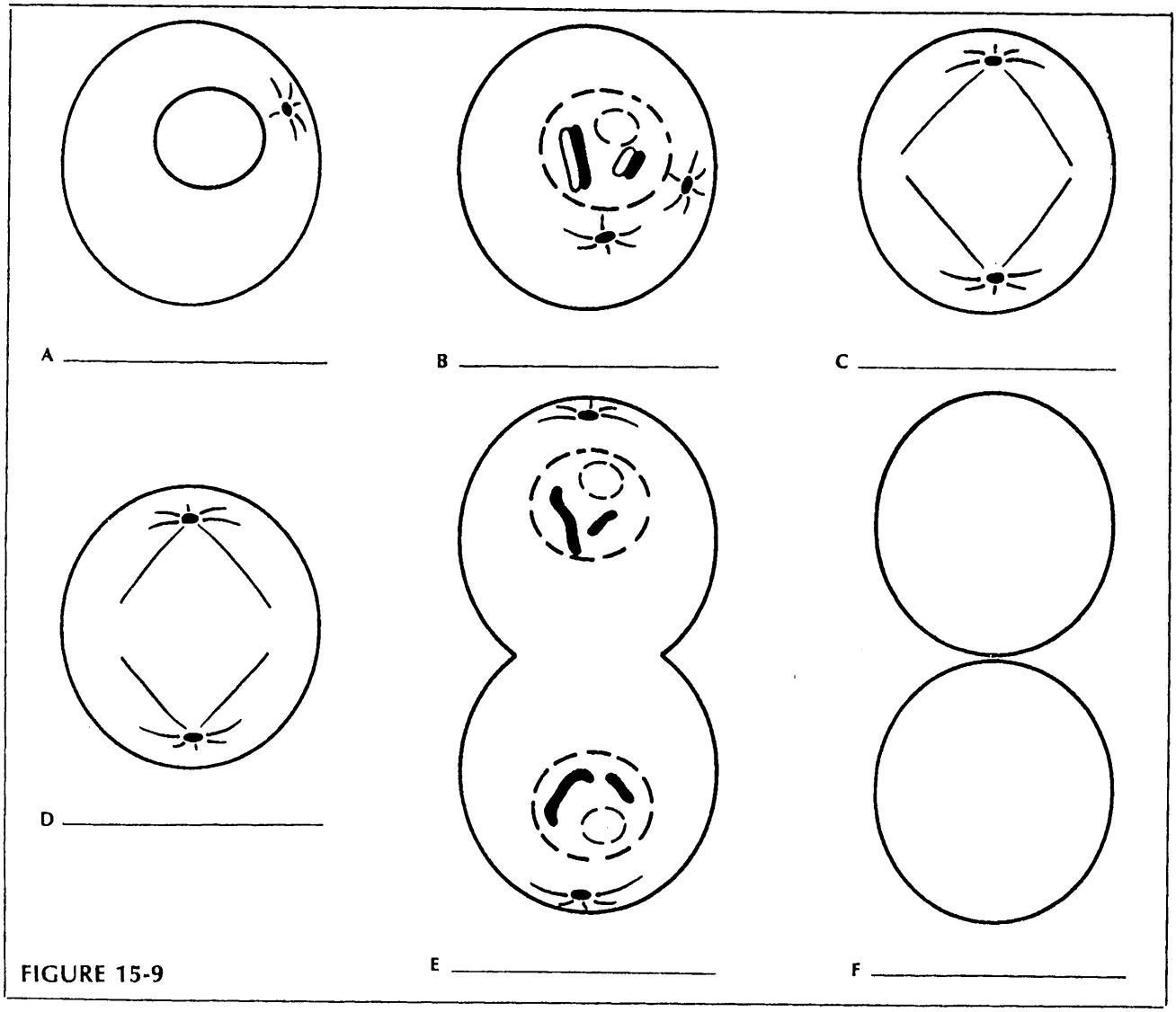


FIGURE 15-9

7

mitosis

series of phases in cell division during which the nucleus of a cell divides into 2 nuclei with identical genetic material

replication

process of copying genetic material

results in two identical copies of a chromosome

cytokinesis

cytoplasm of the cell divides into 2 new cells, called daughter cells

sister chromatids

identical copies of each chromosome that result from replication

interphase

the portion of the cell cycle between divisions

These task cards were made from 5 X 7 inch index cards.

All vocabulary terms were printed in black. The definitions were printed in a variety of colors.

CHROMOSOME REPLICATION

Go to the teacher's desk and get a cell model with unreplicated chromosomes. Take this back to your group.

Using Figure 7.2 at the top of page 108 of your textbook as a guide, decide as a group what materials you need to replicate these chromosomes.

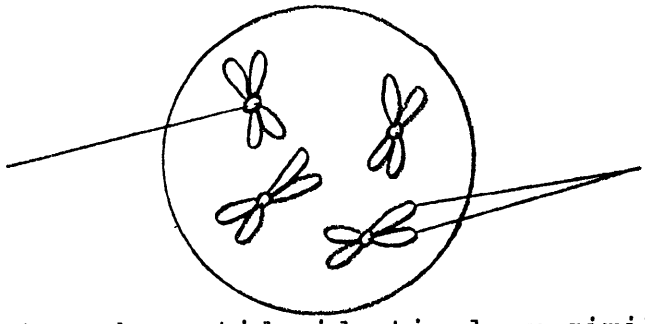
Once you have decided, go get these materials at the teacher's desk and then take them back to your group. **Replicate the chromosomes in your cell model.**

Answer these questions below.

1. How many chromosomes were in your original cell?

2. How many chromosomes are in the cell now?

3. Label the centromere and sister chromatids in the figure below.



4. Are the sister chromatids identical or similar to each other?

The answers to these questions will be reviewed in class.

After the review, return your chromosomes to their unreplicated state, and then return all materials to the teacher's desk in the same place where you originally obtained them.

Name _____ Class _____ Date _____

Process Skills Worksheet 7-1

Organization Data in a Graph

Graphs, like tables, provide a compact way to organize and show information. One of the most common graphs is the pie graph or circle graph. This type of graph is used to illustrate objects or events as parts of a whole. The parts are indicated as either fractions or percentages.

Read the following information concerning the stages of cell division. Then record the information in the form of percentages in a pie graph.

The duration of the individual phases of the complete cell cycle vary from one type of cell to another. The cells of one kind of animal have a cell cycle of about 24 hours. The G_1 phase, or period of cell growth, lasts about 10 hours. The S phase, where DNA replication occurs, lasts about 8 hours. The G_2 phase, when the cell prepares for mitosis, lasts for about 5 hours. Collectively, the G_1, S, and G_2 phases are called interphase. Following interphase, the M phase, or mitosis occurs. This phase lasts for 30 minutes.

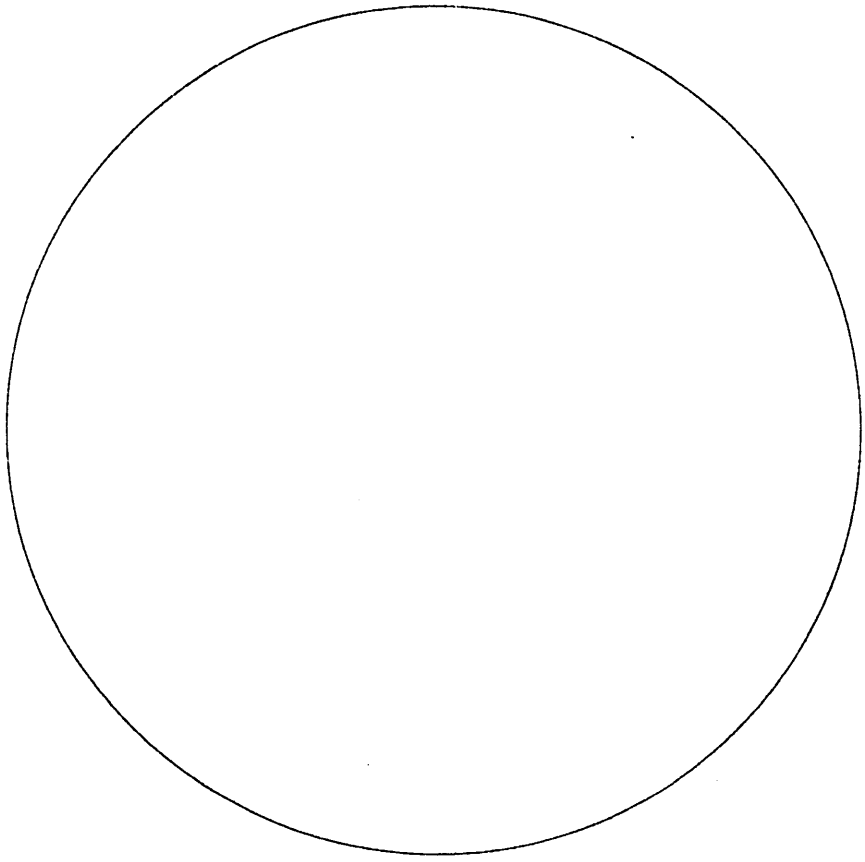


Figure 1 Phases of the Cell Cycle

10

Name _____ Class _____ Date _____

Section Review 7.1

Complete the following.

1. What is interphase? _____

2. Why is it incorrect to call interphase a resting phase? _____

3. Describe what happens during each of the following phases of interphase.

a. G_1 _____

b. S _____

c. G_2 _____

4. What occurs during replication? _____

5. What are sister chromatids? _____

6. During which phase of interphase does a cell copy its chromosomes? _____

7. Explain the difference between the process of mitosis and the process of cytokinesis. _____

8. How do cells that do not undergo cytokinesis differ in appearance from cells that do undergo cytokinesis?

9. In what type of cells does mitosis occur, eukaryotes or prokaryotes? _____

10. What is the name of the cells that result from mitosis? _____

11. What processes make up the cell cycle? _____

12. Why is mitosis important? _____

11

VOCABULARY NOTES

INTERPHASE is the portion of the cell cycle between divisions. The phases of interphase are G1, S, and G2. During G1 the number of organelles and amount of cytoplasm increases; during S the chromosomes replicate; during G2 the cell makes organelles and substances it needs for cell division.

REPLICATION is the process of copying genetic material. It results in two identical copies of a chromosome called sister chromatids. Look at Figure 7.2 on page 108. Observe what happens when replication occurs. Copy this figure into your Bio Journal.

Answer these questions by observing Figure 7.2.

1. How many chromosomes are in the original cell?
2. How many chromosomes are in the new cell?
3. Are the sister chromatids identical or similar to each other?

CELL DIVISION is the part of the cell cycle that consists of mitosis and cytokinesis.

MITOSIS is a series of phases during which the nucleus of a cell divides into two nuclei with identical genetic material. It only occurs in eukaryotes.

CYTOKINESIS is the division of the cytoplasm into two new cells, called daughter cells. During this process, each daughter cell receives a nucleus. The daughter cell nuclei are identical to the parent cell nucleus.

QUIZ 7.1 THE CELL CYCLE AND MITOSIS

DIRECTIONS: Number your answer sheet 1 - 10. Record the best answer for each question below.

VOCABULARY

1. series of phases in cell division during which the nucleus of a cell divides into two nuclei

2. the process of copying genetic material, results in two identical copies of a chromosome

3. the cytoplasm of the cell divides into two new cells called daughter cells

4. the portion of the cell cycle between divisions

5. the identical copies of each chromosome that result from replication

VOCABULARY BANK

replication sister chromatids mitosis

cytokinesis interphase

MULTIPLE CHOICE

6. The cell cycle includes interphase, mitosis, and

   A. meiosis.
   B. replication.
   C. cytolysis.
   D. cytokinesis.

7. During the G1 phase of interphase, the cell

   A. grows.
   B. replicates.
   C. reproduces.
   D. condenses.

8. Mitosis consists of prophase, metaphase, anaphase, and

   A. telophase.
   B. cytokinase.
   C. chromoatase.
   D. replicase.

9. DNA replication occurs during

A. prophase.
B. interphase.
C. telophase.
D. metaphase.

10. After replication, each chromosome consists of

A. 2 similar, but different chromatids.
B. 2 identical sister chromatids.
C. 1 similar and circular strand of DNA.
D. 2 centromeres only.

LEARNING STYLES

This chart helps you determine your learning style; read the word in the left column and then answer the questions in the successive three columns to see how you respond to each situation. Your answers may fall into all three columns, but one column will likely contain the most answers. The dominant column indicates your primary learning style.

When you..	Visual	Auditory	Kinesthetic & Tactile
Spell	Do you try to see the word?	Do you sound out the word or use a phonetic approach?	Do you write the word down to find if it feels right?
Talk	Do you sparingly but dislike listening for too long? Do you favor words such as *see, picture*, and *imagine*?	Do you enjoy listening but are impatient to talk? Do you use words such as *hear, tune*, and *think*?	Do you gesture and use expressive movements? Do you use words such as *feel, touch*, and *hold*?
Concentrate	Do you become distracted by untidiness or movement?	Do you become distracted by sounds or noises?	Do you become distracted by activity around you?
Meet someone again	Do you forget names but remember faces or remember where you met?	Do you forget faces but remember names or remember what you talked about?	Do you remember best what you did together?
Contact people on business	Do you prefer direct, face-to-face, personal meetings?	Do you prefer the telephone?	Do you talk with them while walking or participating in an activity?
Read	Do you like descriptive scenes or pause to imagine the actions?	Do you enjoy dialog and conversation or hear the characters talk?	Do you prefer action stories or are not a keen reader?
Do something new at work	Do you like to see demonstrations, diagrams, slides, or posters?	Do you prefer verbal instructions or talking about it with someone else?	Do you prefer to jump right in and try it?
Put something together	Do you like at the directions and the picture?		Do you ignore the directions and figure it out as you go along?
Need help with a computer application	Do you seek out pictures or diagrams?	Do you call the help desk, ask a neighbor, or growl at the computer?	Do you keep trying to do it or try it on another computer?

Adapted from Colin Rose(1987). Accelerated Learning.

Memory Devices for Mitotic Cell Division and Cytokinesis

Ian Passed Me A Toy Car. Dennis Steudle

In Philadelphia My Aunt Tracy Cried. Ryan Satterfield

In Phys Ed Marcus Acts Too Cool. Chimere Williams

Is Pat Making Any Telephone Calls? Carrie Merlock

I Picked Many Apples Today Cheerfully. Jerry Errickson

Intelligent People Can Memorize All This Correctly. Olivia Koziel

I Pulled My Automatic Trailer Closer. Erica Lamond

I Punched My Aunt To Canada. Richard Giovinazzi

Inevitably Perfect Magnificently Attractive Totally Conceited Dinean Robinson

I Put My Answers Too Close. Darnelle Radford

Ingrid Passed Money At The Church. Mark Hughes

I Played Music At The Concert. Frank Comparri

I Punched M A T Cole. Allison Blizzard

I Piled Mine And Tina's Clothes. Michelle Spaschak

I Pushed Mike Across The Cafetera. Dolores Palmer

I Put My Aunt Through College. Zaira Landrau

Indians Put Matches Around The Cabin. Joann Young

I Phoned Melanie About Tom Cruise. Tina Marchesano

I Passed Matt At The Car Wash. Alycia Levari

Can Tiny Animals Make Purple Ink? (Read backwards.) Dolores Palmer

A Chromosome Viewpoint of Mitosis

by Jennifer Thompson

Here I am, a little scrawny thread just sitting in a nucleus. Oh no! The nuclear membrane is fading away. But hey! I'm getting bigger! Now I feel like I've got a siamese twin. Here I am again hanging out in the center of a cell with these spindle fibers all around me. I'm disappointed my twin left me and is on the opposite side of the cell. Now I'm all by myself again but now I am in another cell. Where did that come from?

MEMORY DEVICES FOR MITOTIC CELL DIVISION AND CYTOKINESIS

COLLEGE BIOLOGY 1997 - 1998

I Pinched Melissa At The Courthouse	John Dreyer
I Put My Apple To Cook I Punched Megan At The Cinema	Natalie Lebron
I Picture Myself At the Caribbean	Mike Giercyk
In Puertorico Men Are Tremendously Cute	Karina Burgos
I Placed Mike Across The Couch	Jaclyn Myers
In Pat's Motorcycle Annie Took Candy	Deena Epps
I Promised My Aunt The Candy	Harold Mas
I Propose My Analogy to Cindy	Caitlin Boyle
I Propose My Affection to Caitlin	Justin Scott
I Predict My Aunt's Telephone Calls	Tim Sage
I Punched My Aunt Til Christmas	Irena Burgos
I Pushed My Anger Toward Carl In Paradise Me And Tanisha Collided	Virgil Phillips
In Popeye My Arm Turned Closer	Bryan Satterfield
Ill People Make A Terrible Cough	Veronica Shurig
I Punched Malitza At The Cafeteria	Noyra Mas
In Prison My Aunt Turned Cuckoo	Crystal Rodriquez
Irena Punched Melissa At The Carnival	Lauren Cudney

7.2 MITOTIC CELL DIVISION AND CYTOKINESIS PP. 110-112

Materials Needed Per Student

two handouts with figures titled same as above
eight - 3 X 5 index cards
scissor

Materials Needed Per Group

glue
colored pencils (six colors needed)

DIRECTIONS FOR LABELING

Figure 1

Label the centrioles, nucleolus, chromatin, nucleoplasm, nuclear membrane, cytoplasm, and cell membrane. Color the chromatin two different, bright, contrasting colors. Color the cytoplasm a light color. Color the nucleoplasm a light color. Color the centrioles. Color the nucleolus. **Use these same colors for all of the remaining figures.**

Figure 2

Label the centrioles, centromeres, spindle fibers, chromosomes, sister chromatids, nucleoplasm, nuclear membrane, cytoplasm and cell membrane. Choose the same colors for the chromosomes as you did with Figure 1. Color the large pair with one color, making one a solid pattern and the other a striped pattern. Color the small pair with the other color, one solid and one striped also. Color the cytoplasm, nucleoplasm, and centrioles with the same colors that you used with Figure 1.

Figure 3

Label the same structures that you did for Figure 2, except for the nuclear membrane and the nucleoplasm. Color the remaining structures.

Figure 4

Label and color the same as for Figures 2 and 3. Note that the sister chromatids have separated. **The colors of chromosomes for Figure 4 should be done in the same order as was done for Figure 3.**

Figure 5

Label the centrioles, centromeres, nucleoplasm, nuclear membrane, cytoplasm and chromosomes. Color all the structures that you did in the previous figure and also color the nucleoplasm (nuclear membrane) that is reappearing. Note that one of each kind of chromosome should be in each forming daughter cell. The colors and size of the chromosomes should match the previous figure.

Figure 6

Label the chromosomes and nuclear membrane. Label the cleavage furrow. Color all structures to match the previous figures.

Figure 7

Label the cell wall, cell membrane, cytoplasm, nuclear membrane, and chromosomes. Label the cell plate and daughter cells.

DIRECTIONS FOR CUTTING AND GLUEING

Cut out each figure along the solid, rectangular lines and glue it to the blank side of a 3 X 5 index card. Write your name on the title card.

DIRECTIONS FOR THE LINED SIDE OF THE INDEX CARD

On the back of each card, write boldly the title for each figure at the top of the card. Use these titles listed below.

Figure 1	INTERPHASE
Figure 2	PROPHASE
Figure 3	METAPHASE
Figure 4	ANAPHASE
Figure 5	TELOPHASE
Figure 6	CYTOKINESIS IN ANIMAL CELLS
Figure 7	CYTOKINESIS IN PLANT CELLS

On the remaining lines, write a description of each figure, using pages 110 - 112 of your textbook. Use these cards to study mitosis and cytokinesis.

18b

7.2 Mitotic Cell Division and Cytokinesis

pp. 110-112

Figure 1

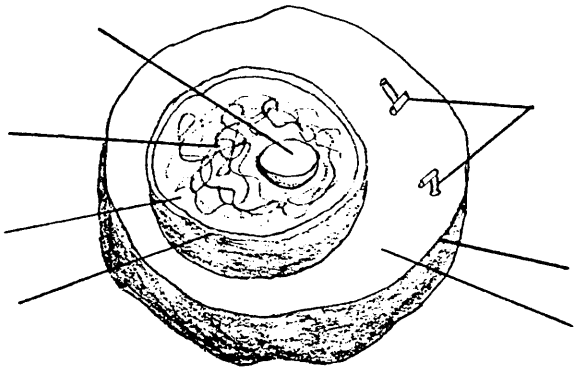
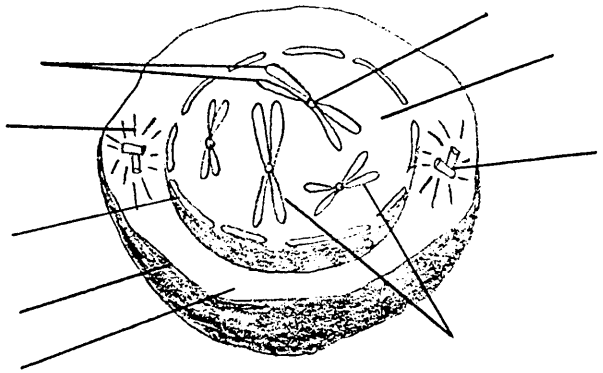


Figure 2



19

Figure 3

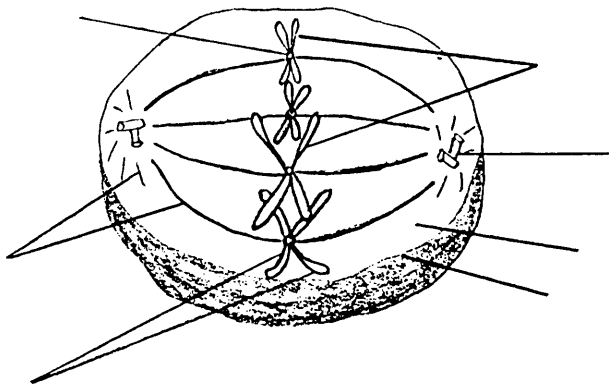


Figure 4

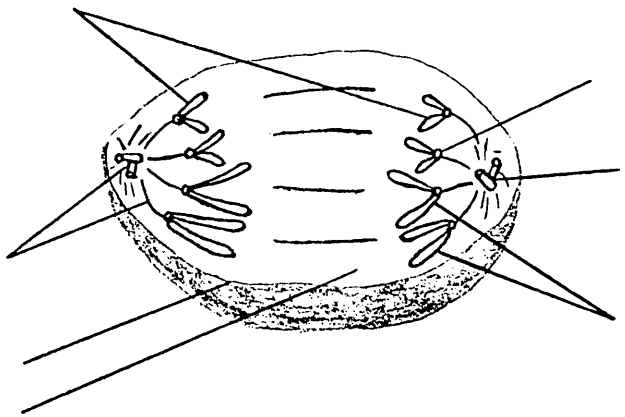


Figure 5

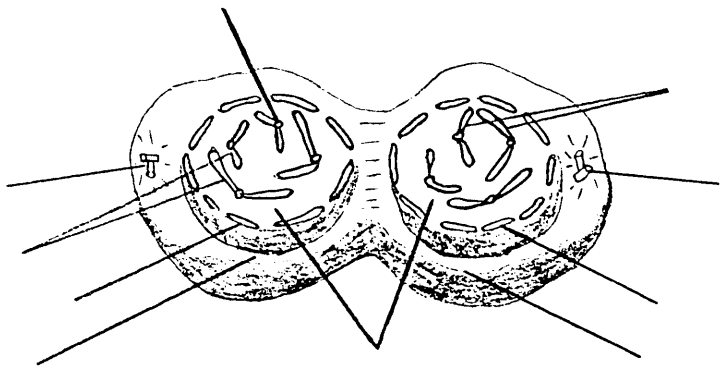


Figure 6

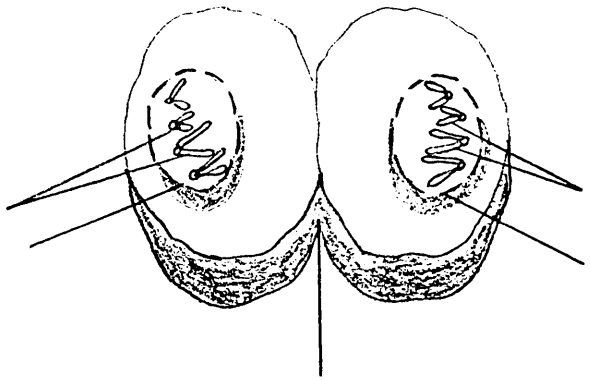


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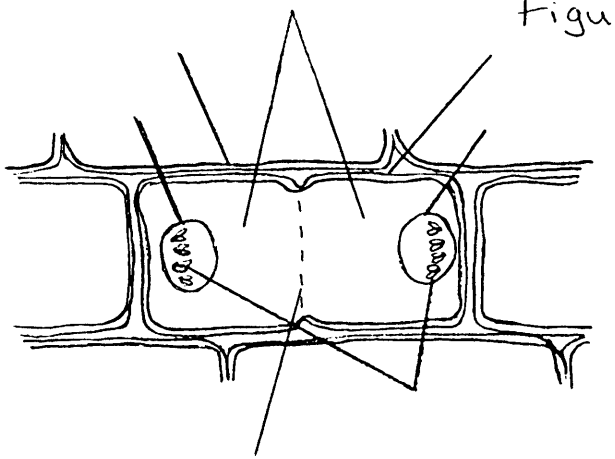
Figure 7



Title Card

7.2 Mitotic Cell Division and Cytokinesis pp. 110-112

Name _____

MULTIPLE MONTAGE MITOSIS MOBILE

1. Obtain four pieces of drawing paper provided by your teacher. Hold them vertically and cut one inch off the top of all of them and cut one inch off the side of two of them only. You will then have two smaller pieces and two larger pieces.

2. The smaller papers will be used for the drawings of interphase(a) and metaphase(c). The larger papers will be used for the drawings of prophase(b)and anaphase(d).

3. Make pencil drawings of interphase, prophase, metaphase, and anaphase using pages 110-111 of your textbook. As a group decide on colors for the following cell parts.

cell membrane_____
cytoplasm_____
nuclear membrane_____
nucleoplasm_____
chromatin and chromosomes_____and_____
(choose two contrasting colors, ex. orange and purple
nucleolus_____
centrioles_____

4. Outline your drawings in brown or black and color your drawings in using the colors that you have decided upon. See classroom sample. The chromosomes in metaphase and anaphase should be lined up to match. Remember that this is the same cell. Prophase, Metaphse, and Anaphase should have one large pair of chromosomes and one small pair of chromosome. Each pair should be assigned a different color. One member of each pair should be striped (or polka dotted!) and the other member of the pair should be colored in solid. The chromatin of interphase should have both colors in it.

5. After your drawings are completed, make one inch vertical lines on all of your drawings using a pencil and a ruler.

6. Number your strips at the top right corner like the following:

interphase 1a - 8a
prophase 1b - 9b
metaphase 1c - 8c
anaphase 1d - 9d

7. Ask for a piece of accordion paper from your teacher. Fold it on the dotted lines very carefully. This takes some time. Do not rush your work.

8. Hold this accordion paper vertically. Number the blank side in the upper right corner of each fold - 1b, 1a, 2b, 2a, 3b, 3a etc... starting at the left and working to the right. On the lined side of the paper, repeat numbering as above except use - 1d, 1c, 2d, 2c, 3d, 3c etc...

9. Cut strips a and b (interphase and prophase). Glue to their matching positions on the blank side. Use the hole puncher to punch holes.

10. Cut strips c and d (metaphase and anaphase). Glue to their matching positions on the lined side. Use the hole puncher to repunch the holes.

11. Obtain two wooden dowels from your teacher. Insert them into the holes. Use a twisting motion.

12. Obtain two feet of fishing line. Attach these to the ends of the top dowel. Use a dot of glue on each to secure the knot.

13. At the bottom of your multiple montage mitosis mobile, write your names. Hand this to your teacher for display in the classroom or possibly the high school library!!!

Multiple Montage Mobile

45469-00

CONTENTS

ITEM	QUANTITY	DESCRIPTION
1	62	Wooden dowels
2	1 pkg.	Patterns, 11" x 17", 31/ pkg.
3	1 pkg.	Paper clips, 100/pkg.
4	1	Fishing line, 25 yards
5	10	White glue, small containers
6	1	Hole punch

Additional materials needed:
Pictures for each montage (discarded calendars, magazine covers, original drawings, construction paper collages and photographs are all excellent sources for pictures)
Scissors
Rulers

SUGGESTIONS FOR USE

The multiple-montage mobile is a hands-on project which helps illustrate a variety of scientific principles and phenomena. Coupled with "writing to learn" strategies, the mobile can be used to illustrate:

- phases of mitosis (prophase, metaphase, anaphase, telophase)
- links in a food chain (producer, primary, secondary, tertiary consumer)
- stages of insect metamorphosis (egg, larva, pupa, adult)
- types of protective coloration (camouflage, Batesian mimicry, Mullerian mimicry, warning coloration)
- ecological relationships (predation, parasitism, commensalism, mutualism)
- developmental stages in a particular life cycle
- seasonal changes of appearance in plants or animals
- phases of matter.....and a myriad of other topics.

The following example illustrates how the multiple montage mobile can be implemented in a lesson cycle. After introducing the various biomes, the types of communities that inhabit them (food chains), and the concept of their carrying capacities (ecological pyramids), the teacher plans a lesson to reinforce the concepts and to achieve closure in a graphic way. The teacher then prepares a stack of index cards with the names of various plants and animals to represent the different biomes and trophic levels. Each student chooses a card and researches information about his organism, including:

a. the biome in which it is found
b. the niche (trophic level) that it fills
c. three other organisms that would complete the food chain
and
d. a pyramid of numbers/biomass/energy.

Any (or all) of these items could then be graphically depicted in a multiple montage mobile. Other suggested mobile illustrations could include pictures of the types of organisms (animals, vegetation, etc.) found in each student's particular biome, or the various types of geographical biomes (for example, grasslands, deserts, forests, and tundras). Students (and teachers) are encouraged to use their imaginations in determining what items might be included in the mobile, and in creating those items, where appropriate.

The information in the student report, combined with the choice of pictures in the mobile, provide a written and illustrated annotation that the teacher can grade, while the construction of the mobile provides the student with a hands-on activity that is memorable and fun.

CONSTRUCTING THE MULTIPLE MONTAGE MOBILE

1. Assemble the following materials for each mobile:
   - 1 pattern
   - 2 wooden dowels
   - 4 pictures for each montage
   - fishing line*
   - glue*
   - paper clip(s)
   - hole punch*
   - scissors*
   - ruler*

* - These items may need to be shared amongst classmates.

Note: The mobile can be shortened by cutting off unnecessary folds from the pattern, or lengthened by taping a second pattern to the first. In either case, you will need to adjust the length of the dowels, the size of the photos, and the number of vertical strips for each mobile, accordingly.

2. Use the back of a pair of scissors to score the pattern along the dotted lines. Do not cut deeply into the pattern; instead, just crease it so that it will bend more readily.

3. Starting at either end, fold the pattern along the scored lines in opposite directions to create a pleated sheet (fanfold form).

4. Prepare two of the pictures that will comprise the mobile in the following manner:
   a. Trim each picture to a uniform size (about 8 inches wide x 10 inches high).
   b. Cut each picture into vertical strips that are 1 inch wide.
   c. Line up the strips in the correct order for each picture.
   d. Clearly write your name in the bottom right corner of the last strip of the last picture.

5. Attach the pictures to the **blank side** (the side with no printing) of the pleated sheet in the following manner:
   a. Glue the strips from one picture on every other fold of the sheet.
   b. Glue the strips from the second picture on the alternate folds.

6. Turn the pleated sheet over and punch holes through the circles printed on the pattern.

7. With the **printed side** of the pleated sheet showing (that is, the side that you just punched the holes in), repeat steps 4 and 5 with the remaining two pictures.

8. Turn the pleated sheet over, and repunch the holes through the pattern, in exactly the same places that you punched out in step 6.

9. Thread the wooden dowels through the holes in the pleated sheet to hold the folds at approximately a 45 degree angle. If necessary, knot a small piece of fishing line around each end of both dowels to help secure the folds of the mobile in place.

10. Suspend the mobile with a length of fishing line tied at the midpoint of one of the wooden dowels. If necessary, the paper clips can be bent and used as hooks for hanging.

Roger Robison
MacArthur High School
San Antonio, Texas

Science Kit® & Boreal® Laboratories
Tonawanda, NY/San Luis Obispo, CA 1-800-828-7777
St. Catharines, Ontario, Canada 1-800-387-9393

SUPPLIES

Chromosome Simulation Class Activity Kit 63852 $99.00 Science Kit & Boreal Laboratories

MITOSIS : MANIPULATIVE MODEL 45108 $19.95 Science Kit & Boreal Laboratories

MULTIPLE MONTAGE MOBILES 45469 $19.95 Science Kit & Boreal Laboratories

Science Kit & Boreal Laboratories
777 East Park Drive
Tonawanda, NY 14150 - 6782
1 - 800 - 828 - 7777

MOVING WITH MITOSIS

Group Assignment_____

Pull out your **Mitosis Study Card** that matches the assignment given above. Study the labeled figure on the front of the card and read the back which has all of the events that occur during this phase.

Decide as a group how you can use your **OWN BODIES** to show one or more events that occur during this phase. **Be creative without losing the integrity of the phase!** Practice these movements in an empty space in the classroom.

You may also use other materials that are available in the classroom such as yarn, chairs, desks, other students, etc... These can be used to represent structures observed during this phase.

You will be asked to perform these **MITOSIS MOVEMENTS** in front of the class before the end of the period. You do not need to introduce or narrate your body movements because...

After your performance, the audience will be asked to: 1 - identify your movement to an event in mitosis, 2 - identify structures that were represented, 3 - name the phase that was your assignment.

You may be asked to repeat your **MOVING MITOSIS** again for the audience after your first performance.

MAKE THIS A MEMORABLE EXPERIENCE FOR YOU AND THE AUDIENCE!

MITOSIS CARDS AND QUESTIONS

Directions: Lay your Mitosis Cards on your desk with the picture side up. Answer the following questions using these cards. If you do not know the answer by looking at the pictures, turn your card over and use the information on the back.

1. How many chromosomes are in the parent cell? Do all parent cells have this same amount of chromosomes?

2. How many chromosomes are in each of the daughter cells?

3. How many pairs of chromosomes are there?

4. What disappears during prophase?

5. What reappears during telophase?

6. How do the chromosomes position themselves during metaphase?

7. What happens to the sister chromatids during anaphase?

8. What do the centrioles begin to produce during prophase?

9. During anaphase what pulls the chromosomes to the opposite poles of the cell?

10. How many daughter cells are formed?

11. In animal cells, what forms as the last event between the two daughter cells?

12. In plant cells, what forms as the last event between the daughter cells?

13. Are the chromosome pairs identical or similar?

14. Are the sister chromatids identical or similar?

15. **Why** are the chromosomes in pairs? Explain your answer.

CHROMOSOME SIMULATION CLASS ACTIVITY KIT

OBJECTIVE

This kit will make it easier for your students to understand the cell cycle and the processes of cell division. Mitosis and meiosis can be graphically demonstrated using strands of pop-it beads with magnetic centromeres.

This Kit Contains:

600	Red pop-it beads
600	Yellow pop-it beads
30	Blue pop-it beads
60	Magnetic centromeres (30 red, 30 yellow)
60	Plastic tubular centrioles
1	Spool of thread
1	Roll of cellophane tape
1	Teacher's Manual
1	Student Study Sheet (copymaster)
2	Student Analysis Sheet (copymasters)

Needed but not Supplied:

Pencils, colored pencils, scissors

PREPARATION FOR USE

Students should work in pairs. Have each pair of students obtain 40 red and 40 yellow pop-it beads, 2 red and 2 yellow centromeres, 4 centrioles, and about 8' of thread. Students should clear the tops of their desks or work areas. The entire desk top can represent the boundaries of the cell, or students can use large sheets of scrap paper upon which cell boundaries can be drawn.

CELL CYCLE

The cell cycle describes the growth and development of actively dividing cells. Although this division is a continuous process, it has distinct stages that we will examine in the exercises that follow. The two types of nuclear cell division are mitosis and meiosis. Mitosis results in two daughter cells with nuclei that are identical to each other and to the parent cell. Growth and development of the individual organism from a fertilized egg, maintenance and repair of the body, including regeneration, and asexual reproduction are all the result of mitotic cell division.

Meiosis differs in the formation of daughter cells with half the chromosome number of the parent cell. Sex cells — gametes and spores — are the result of meiotic cell division.

Let's look at mitosis first.

ACTIVITY: MITOSIS

Use your analysis sheet to diagram each stage as you simulate the events that occur.

Interphase:

WHAT'S HAPPENING: After cell division takes place, the cell enters the longest stage of the cell cycle. This is called interphase. During this stage, the cell is preparing for the next division. Distinct chromosomes are not visible. DNA exists in an uncoiled state and the chromosome material appears as granular matter, called chromatin, within the nucleus. **TO SIMULATE:** Your pop-it beads represent the DNA in the chromatin material. Assemble a strand of red beads and a strand of yellow beads to represent a homologous pair of chromosomes. Seven beads on each side of the centromere

Science Kit & Boreal Laboratories 28

are the chromosome arms. Now draw an imaginary line to represent the nuclear membrane, and place the red and yellow bead strands in the center of this area. Remember that these distinct chromosomes would not be visible at this stage. DNA replication would now occur to produce an identical duplicate of each chromosome. Assemble a second strand of red and yellow beads. Each half of the duplicated chromosome is called a chromatid. Join the two chromatids at the centromeres to form paired sister chromatids. The centrioles also replicate: put four of the plastic cylinders just outside your nuclear membrane.

Prophase:

WHAT HAPPENS: Chromatin condenses within the nucleus and chromosomes and chromatids become visible. Centrioles migrate to opposite sides (poles) of the nucleus and spindle fibres begin to form. As the spindle fibres appear, the nuclear membrane and nucleoli disappear. The spindle fibres attach to the centromere region of each chromatid. **TO SIMULATE:** Separate your two pairs of centrioles, and move them to opposite sides of the nuclear membrane. Tape down one centriole of each pair, just inside the nuclear membrane, pointing toward the center of the nucleus. Separate the two paired strands of beads (homologous chromosomes). Tie one end of a piece of thread to the centromere. Do this for each of the four chromatids in your nucleus. Insert the other end of the thread from each sister chromatid through the opposite taped centriole. A thread from one red and one yellow centromere should go through each centriole. The threads represent the spindle fibres.

Metaphase:

WHAT HAPPENS: Chromosomes line up in the middle of the nucleus at metaphase. The centromere regions of sister chromatids are attached by spindle fibres to the opposite centrioles. **TO SIMULATE:** Center your chromosomes between the centrioles to demonstrate this stage.

Anaphase:

WHAT HAPPENS: The chromatids of each chromosome separate at the centromeres and move to the opposite poles, forming daughter chromosomes. **TO SIMULATE:** Pull on the threads to separate the centromeres. Note that the arms of the chromosomes trail the centromeres to the poles.

Telophase:

WHAT HAPPENS: The spindle apparatus disappears. Nucleoli and the nuclear membranes reappear to form two separate nuclei; one for each daughter cell. The chromosomes once again become diffuse chromatin. **TO SIMULATE:** Remove the thread. Move one red and one yellow strand to the centriole it was drawn to during anaphase. These are your daughter cells. Each contains one red and one yellow chromosome, exactly like the ones you began the exercise with.

MITOSIS WITH TWO PAIRS OF HOMOLOGOUS CHROMOSOMES

Now that you're familiar with mitosis, you can work with a second pair of students to combine your resources and repeat the process with 4 chromosomes. Shorten two strands (one red and one yellow) to 6 beads on a side. After simulating mitosis, you should again have two identical daughter cells, each with one long, and one short, red and yellow strands (chromosomes).

ACTIVITY: MEIOSIS

Diagram all stages of meiosis in the following exercise, as you do them. Use color pencils to show homologous chromosomes.

Sexual reproduction requires a reduction in the chromosome number of the parent cell (diploid or 2N) to half (haploid or N) in the gamete or sex cell. This type of cell division, resulting in half the chromosome number, is called meiosis. When two haploid gametes (egg and sperm) combine during fertilization, the diploid chromosome number is restored. Thus sexual reproduction provides the mechanism to produce genetic variation, when the genes of two different individuals combine. Meiosis consists of two nuclear divisions (meiosis I and II). This results in the formation of four daughter cells, each of which has only half the number of chromosomes of the parent.

STUDENT STUDY SHEET

CHROMOSOME SIMULATION

Meiosis I — Interphase:

WHAT HAPPENS: DNA synthesis occurs, resulting in the formation of paired chromatids. The centrioles also replicate during interphase. TO SIMULATE: Draw an imaginary line around your work area to represent the nuclear membrane. Place one strand of red and one strand of yellow beads in the center — but remember that distinct chromosomes aren't yet visible at this stage. Put two plastic centrioles at right angles to each other, near the chromosomes. DNA synthesis occurs — make two more strands identical to the first, and join them at the centromeres. You now have paired chromatids (called dyads). Replicate the centriole by placing another pair near the first.

Prophase I:

WHAT HAPPENS: A process called synapsing occurs — homologous chromosomes move close together and pair up along their entire length. A tetrad, consisting of 4 chromatids, is formed. Centrioles migrate to the opposite poles, and the nuclear membrane breaks down. TO SIMULATE: Align your homologous chromosomes and entwine them at the center of your cell. Separate the centrioles and move them to opposite sides of the nucleus. QUESTION: Did this occur during mitosis?

Metaphase I:

WHAT HAPPENS: Chromosomes disentangle and become aligned in the center of the cell in homologous pairs. TO SIMULATE: Position your paired strands in the center of the cell, at right angles to the centrioles. We won't use threads this time to simulate spindle fibres — imaginary lines will do. QUESTION: How does this metaphase differ from mitosis?

Anaphase I:

WHAT HAPPENS: The homologous chromosomes separate and are drawn to opposite sides of the cell. TO SIMULATE: Move your strands toward their respective centrioles. They're being drawn by the spindle fibres.

Telophase I:

WHAT HAPPENS: Cell division may occur at this time, resulting in two daughter cells still containing paired chromatids. Centrioles will duplicate at this time. TO SIMULATE: Move each paired strand to its centriole. Duplicate each centriole. Draw an imaginary line around each daughter cell.

Meiosis II:

A second division must now occur to separate the chromatids in the daughter cells formed by this first division. This will reduce the amount of DNA in each resulting daughter cell to one strand per chromosome — one-half the original. Only one homologue from each chromosome pair will be present in each daughter cell following meiosis II.

Interphase II:

WHAT HAPPENS: DNA replication does not occur during the interphase between stages of meiosis. This stage is often called interkinesis. TO SIMULATE: Your daughter cells remain as you left them following telophase I.

Prophase II:

WHAT HAPPENS: The centrioles move to opposite poles of the two daughter cells. The chromosomes appear to shorten and thicken. TO SIMULATE: Move the duplicated centrioles to opposite sides of each daughter cell and tape them down to your desk. Place your strands between the centrioles. QUESTION: What are the differences between prophase I and II? How do they differ from prophase in mitosis?

Metaphase II:

WHAT HAPPENS: All of the chromosomes line up, single file, in the center of the cell. TO SIMULATE: Line up the strands so they are centered between the centrioles. QUESTION: How is this different from metaphase I — and from mitosis?

Anaphase II:

WHAT HAPPENS: The chromatids of each chromosome separate and are drawn to the opposite poles of each cell. Each chromatid, with a well-defined centromere, is now a chromosome. TO SIMULATE: Separate the chromatids at their centromeres and pull them toward their respective centrioles. QUESTION: How is this different from anaphase of mitosis?

Student Study Sheet

Chromosome Simulation

Telophase II:

WHAT HAPPENS: Cell division is completed and four daughter cells are formed. Each has half the chromosome number of the parent cell. A nuclear membrane forms, and one pair of centrioles remain outside the nuclear membrane. **TO SIMULATE:** Place each chromosome strand near its respective centriole. Draw imaginary lines around each cell. **QUESTION:** How many cells have been formed in meiosis? in mitosis? Compare the resultant chromosome number in the daughter cells formed by each type of cell division.

Activity

Compare the stages of meiosis with your drawings of mitosis. This will be a useful reference to you to help understand the differences.

Segregation of Alleles:

Homologous chromosomes in diploid organisms insure that there are a pair of genes for each trait. These genes are found at the same position (locus) on each homologous chromosome. Each of these two genes is called an allele. If the genes for a particular trait are identical, the organism's genotype is homozygous. If the genes yield different expressions for the same trait (as in wrinkled or smooth coats in pea seeds), the organism's genotype is heterozygous. In meiosis, the alleles separate on homologous chromosomes and are said to be segregated. This is Mendel's first law: alleles segregate in meiosis. **TO SIMULATE:** Exchange one red bead for one yellow bead at a point on one of the yellow chromosome strands. This allele is R. Exchange a red bead for a yellow bead at the same locus on the red strand. This homologue is r. Follow the exercise on meiosis to demonstrate that the alleles for a given trait segregate and that each is found in a different sex cell at the completion of meiosis. Diagram your results on the analysis sheet provided.

Independent Assortment:

Mendel's second law states that alleles on unlinked genes assort independently. If alleles for trait R are found on one set of chromosomes, and for trait B on another, then the alleles for traits R and B assort independently. Heterozygous parents RrBb can produce gametes with genotypes RB, Rb, rB, and rb, depending upon the arrangement of chromosomes at metaphase I. **TO SIMULATE:** You'll combine resources with a second pair of students. Remove 3 beads from one arm of four of your strands — two yellow and two red. One homologous pair (one red dyad and one yellow dyad) will have arms of equal length, and another homologous pair will have short arms on one side of the centromere, long arms on the other. Be sure to retain proper orientation. The allele R is designated by the red bead in one arm of the longer yellow chromosome (it's homologue, r, is the yellow bead at the same locus on the longer red chromosome). Replace one yellow bead with a blue bead on the long arm of the shorter chromosome. This is allele B. It's homologue, b, is a red bead at the same locus on the homologous red chromosome. There are two ways that the homologous chromosomes are aligned in metaphase I, depending on which side you align the red and yellow homologues. Diagram both these possibilities. Indicate the alleles on each chromosome. Follow each possibility through the stages of meiosis and diagram your results for each stage. Use color pencils to show the chromosomes and label your alleles.

Crossing Over:

Crossing over results when an exchange occurs between portions of the arms of homologous chromosomes. This results in a redistribution of genetic material following meiosis. Crossing over occurs during prophase I of meiosis I, when synapsed homologous chromosomes entwine. **TO SIMULATE:** You may simulate crossing over by exchanging the last 3 beads between one arm of single red and yellow chromatid strands. Arrange your chromosome strands as in prophase I. They're synapsed — close together and intertwined. Pop off the last 3 beads of 1 red and 1 yellow chromatid and exchange them. Proceed through the remaining stages of meiosis and diagram your results. **QUESTIONS:** How are your results different from your first diagrams of meiosis? What would happen to the independently assorting alleles if crossover occurred? Explain how this can account for greater genetic variation. Explain how the results may not be beneficial to the resulting offspring. In some circumstances, the results may be beneficial; explain.

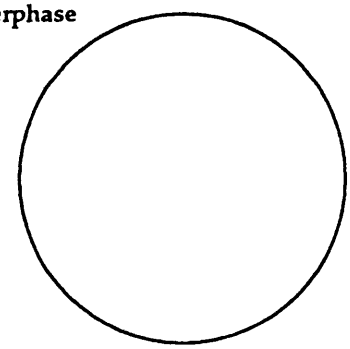
250-1362

Analysis Sheet

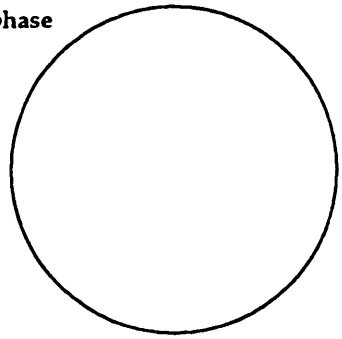
Chromosome Simulation

Name: _____ **Date:** _____

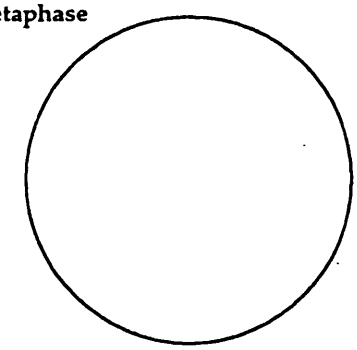
Interphase



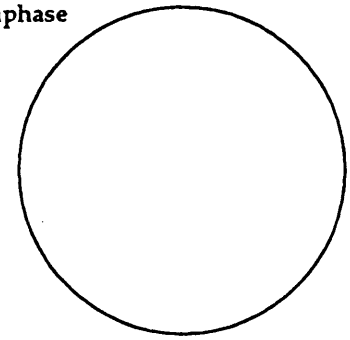
Prophase



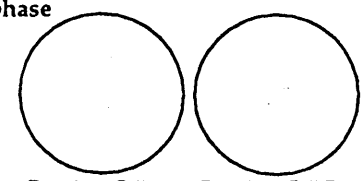
Metaphase



Anaphase



Telophase



Daughter Cell A Daughter Cell B

Mitosis

32

CHROMOSOME SIMULATION CLASS ACTIVITY KIT

OBJECTIVE

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Students should work in pairs. Have each pair of students obtain 40 red and 40 yellow pop-it beads, 2 red and 2 yellow centromeres, 4 centrioles, and about 8' of thread. Students should clear the tops of their desks or work areas. The entire desk top can represent the boundaries of the cell, or students can use large sheets of scrap paper upon which cell boundaries can be drawn.

CELL CYCLE

The cell cycle describes the growth and development of actively dividing cells. Although this division is a continuous process, it has distinct stages that we will examine in the exercises that follow. The two types of nuclear cell division are mitosis and meiosis. Mitosis results in two daughter cells with nuclei that are identical to each other and to the parent cell. Growth and development of the individual organism from a fertilized egg, maintenance and repair of the body, including regeneration, and asexual reproduction are all the result of mitotic cell division.

Meiosis differs in the formation of daughter cells with half the chromosome number of the parent cell. Sex cells — gametes and spores — are the result of meiotic cell division.

Let's look at mitosis first.

ACTIVITY: MITOSIS

Use your analysis sheet to diagram each stage as you simulate the events that occur.

Interphase:

WHAT'S HAPPENING: After cell division takes place, the cell enters the longest stage of the cell cycle. This is called interphase. During this stage, the cell is preparing for the next division. Distinct chromosomes are not visible. DNA exists in an uncoiled state and the chromosome material appears as granular matter, called chromatin, within the nucleus. TO SIMULATE: Your pop-it beads represent the DNA in the chromatin material. Assemble a strand of red beads and a strand of yellow beads to represent a homologous pair of

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chromosomes. Seven beads on each side of the centromere are the chromosome arms. Now draw an imaginary line to represent the nuclear membrane, and place the red and yellow bead strands in the center of this area. Remember that these distinct chromosomes would not be visible at this stage. DNA replication would now occur to produce an identical duplicate of each chromosome. Assemble a second strand of red and yellow beads. Each half of the duplicated chromosome is called a chromatid. Join the two chromatids at the centromeres to form paired sister chromatids. The centrioles also replicate: put four of the plastic cylinders just outside your nuclear membrane.

Prophase:

WHAT HAPPENS: Chromatin condenses within the nucleus and chromosomes and chromatids become visible. Centrioles migrate to opposite sides (poles) of the nucleus and spindle fibres begin to form. As the spindle fibres appear, the nuclear membrane and nucleoli disappear. The spindle fibres attach to the centromere region of each chromatid. TO SIMULATE: Separate your two pairs of centrioles, and move them to opposite sides of the nuclear membrane. Tape down one centriole of each pair, just inside the nuclear membrane, pointing toward the center of the nucleus. Separate the two paired strands of beads (homologous chromosomes). Tie one end of a piece of thread to the centromere. Do this for each of the four chromatids in your nucleus. Insert the other end of the thread from each sister chromatid through the opposite taped centriole. A thread from one red and one yellow centromere should go through each centriole. The threads represent the spindle fibres.

Metaphase:

WHAT HAPPENS: Chromosomes line up in the middle of the nucleus at metaphase. The centromere regions of sister chromatids are attached by spindle fibres to the opposite centrioles. TO SIMULATE: Center your chromosomes between the centrioles to demonstrate this stage.

Anaphase:

WHAT HAPPENS: The chromatids of each chromosome separate at the centromeres and move to the opposite poles, forming daughter chromosomes. TO SIMULATE: Pull on the threads to separate the centromeres. Note that the arms of the chromosomes trail the centromeres to the poles.

Telophase:

WHAT HAPPENS: The spindle apparatus disappears. Nucleoli and the nuclear membranes reappear to form two separate nuclei; one for each daughter cell. The chromosomes once again become diffuse chromatin. TO SIMULATE: Remove the thread. Move one red and one yellow strand to the centriole it was drawn to during anaphase. These are your daughter cells. Each contains one red and one yellow chromosome, exactly like the ones you began the exercise with.

MITOSIS WITH TWO PAIRS OF HOMOLOGOUS CHROMOSOMES

Now that you're familiar with mitosis, you can work with a second pair of students to combine your resources and repeat the process with 4 chromosomes. Shorten two strands (one red and one yellow) to 6 beads on a side. After simulating mitosis, you should again have two identical daughter cells, each with one long, and one short, red and yellow strands (chromosomes).

ACTIVITY: MEIOSIS

Diagram all stages of meiosis in the following exercise, as you do them. Use color pencils to show homologous chromosomes.

Sexual reproduction requires a reduction in the chromosome number of the parent cell (diploid or 2N) to half (haploid or N) in the gamete or sex cell. This type of cell division, resulting in half the chromosome number, is called meiosis. When two haploid gametes (egg and sperm) combine during fertilization, the diploid chromosome number is restored. Thus sexual reproduction provides the mechanism to produce genetic variation, when the genes of two different individuals combine. Meiosis consists of two nuclear divisions (meiosis I and II). This results in the formation of four daughter cells, each of which has only half the number of chromosomes of the parent.

Meiosis I — Interphase:

WHAT HAPPENS: DNA synthesis occurs, resulting in the formation of paired chromatids. The centrioles also replicate during interphase. TO SIMULATE: Draw an imaginary line around your work area to represent the nuclear membrane. Place one strand of red and one strand of yellow beads in the center — but remember that distinct chromosomes aren't yet visible at this stage. Put two plastic centrioles at right angles to each other, near the chromosomes. DNA synthesis occurs — make two more strands identical to the first, and join them at the centromeres. You now have paired chromatids (called dyads). Replicate the centriole by placing another pair near the first.

Prophase I:

WHAT HAPPENS: A process called synapsing occurs — homologous chromosomes move close together and pair up along their entire length. A tetrad, consisting of 4 chromatids, is formed. Centrioles migrate to the opposite poles, and the nuclear membrane breaks down. TO SIMULATE: Align your homologous chromosomes and entwine them at the center of your cell. Separate the centrioles and move them to opposite sides of the nucleus. QUESTION: Did this occur during mitosis?

Metaphase I:

WHAT HAPPENS: Chromosomes disentangle and become aligned in the center of the cell in homologous pairs. TO SIMULATE: Position your paired strands in the center of the cell, at right angles to the centrioles. We won't use threads this time to simulate spindle fibres — imaginary lines will do. QUESTION: How does this metaphase differ from mitosis?

Anaphase I:

WHAT HAPPENS: The homologous chromosomes separate and are drawn to opposite sides of the cell. TO SIMULATE: Move your strands toward their respective centrioles. They're being drawn by the spindle fibres.

Telophase I:

WHAT HAPPENS: Cell division occurs at this time, resulting in two daughter cells still containing paired chromatids. Centrioles will duplicate at this time. TO SIMULATE: Move each paired strand to its centriole. Duplicate each centriole. Draw an imaginary line around each daughter cell.

Meiosis II:

A second division must now occur to separate the chromatid in the daughter cells formed by this first division. This will reduce the amount of DNA in each resulting daughter cell to one strand per chromosome — one-half the original. Only one homologue from each chromosome pair will be present in each daughter cell following meiosis II.

Interphase II:

WHAT HAPPENS: DNA replication does not occur during the interphase between stages of meiosis. This stage is often called interkinesis. TO SIMULATE: Your daughter cells remain as you left them following telophase I.

Prophase II:

WHAT HAPPENS: The centrioles move to opposite poles of the two daughter cells. The chromosomes appear to shorten and thicken. TO SIMULATE: Move the duplicated centrioles to opposite sides of each daughter cell and tape them down to your desk. Place your strands between the centrioles. QUESTION: What are the differences between prophase I and II? How do they differ from prophase in mitosis?

Metaphase II:

WHAT HAPPENS: All of the chromosomes line up, single file, in the center of the cell. TO SIMULATE: Line up the strands so they are centered between the centrioles. QUESTION: How is this different from metaphase I — and from mitosis?

Anaphase II:

WHAT HAPPENS: The chromatids of each chromosome separate and are drawn to the opposite poles of each cell. Each chromatid, with a well-defined centromere, is now a chromosome. TO SIMULATE: Separate the chromatids at their centromeres and pull them toward their respective centrioles. QUESTION: How is this different from anaphase of mitosis?

Telophase II:

WHAT HAPPENS: Cell division is completed and four daughter cells are formed. Each has half the chromosome number of the parent cell. A nuclear membrane forms, and one pair of centrioles remain outside the nuclear membrane. TO SIMULATE: Place each chromosome strand near its respective centriole. Draw imaginary lines around each cell. QUESTION: How many cells have been formed in meiosis? in mitosis? Compare the resultant chromosome number in the daughter cells formed by each type of cell division.

ACTIVITY

Compare the stages of meiosis with your drawings of mitosis. This will be a useful reference to you to help understand the differences.

Segregation of Alleles:

Homologous chromosomes in diploid organisms insure that there are a pair of genes for each trait. These genes are found at the same position (locus) on each homologous chromosome. Each of these two genes is called an allele. If the genes for a particular trait are identical, the organism's genotype is homozygous. If the genes yield different expressions for the same trait (as in wrinkled or smooth coats in pea seeds), the organism's genotype is heterozygous. In meiosis, the alleles separate on homologous chromosomes and are said to be segregated. This is Mendel's first law: alleles segregate in meiosis. TO SIMULATE: Exchange one red bead for one yellow bead at a point on one of the yellow chromosome strands. This allele is R. Exchange a red bead for a yellow bead at the same locus on the red strand. This homologue is r. Follow the exercise on meiosis to demonstrate that the alleles for a given trait segregate and that each is found in a different sex cell at the completion of meiosis. Diagram your results on the analysis sheet provided.

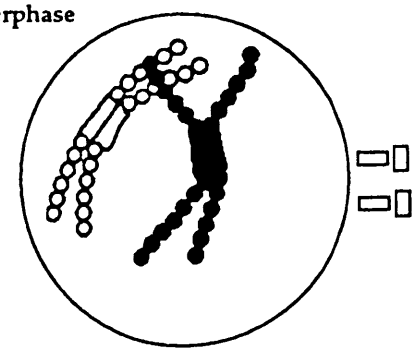
Independent Assortment:

Mendel's second law states that alleles on unlinked genes assort independently. If alleles for trait R are found on one set of chromosomes, and for trait B on another, then the alleles for traits R and B assort independently. Heterozygous parents RrBb can produce gametes with genotypes RB, Rb, rB, and rb, depending upon the arrangement of chromosomes at metaphase I. TO SIMULATE: You'll combine resources with a second pair of students. Remove 3 beads from one arm of four of your strands — two yellow and two red. One homologous pair (one red dyad and one yellow dyad) will have arms of equal length, and another homologous pair will have short arms on one side of the centromere, long arms on the other. Be sure to retain proper orientation. The allele R is designated by the red bead in one arm of the longer yellow chromosome (it's homologue, r, is the yellow bead at the same locus on the longer red chromosome). Replace one yellow bead with a blue bead on the long arm of the shorter chromosome. This is allele B. It's homologue, b, is a red bead at the same locus on the homologous red chromosome. There are two ways that the homologous chromosomes are aligned in metaphase I, depending on which side you align the red and yellow homologues. Diagram both these possibilities. Indicate the alleles on each chromosome. Follow each possibility through the stages of meiosis and diagram your results for each stage. Use color pencils to show the chromosomes and label your alleles.

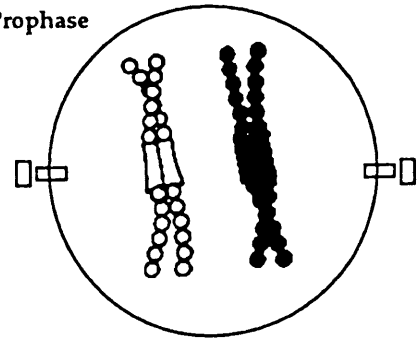
Crossing Over:

Crossing over results when an exchange occurs between portions of the arms of homologous chromosomes. This results in a redistribution of genetic material following meiosis. Crossing over occurs during prophase I of meiosis I, when synapsed homologous chromosomes entwine. TO SIMULATE: You may simulate crossing over by exchanging the last 3 beads between one arm of single red and yellow chromatid strands. Arrange your chromosome strands as in prophase I. They're synapsed — close together and intertwined. Pop off the last 3 beads of 1 red and 1 yellow chromatid and exchange them. Proceed through the remaining stages of meiosis and diagram your results. QUESTIONS: How are your results different from your first diagrams of meiosis? What would happen to the independently assorting alleles if crossover occurred? Explain how this can account for greater genetic variation. Explain how the results may not be beneficial to the resulting offspring. In some circumstances, the results may be beneficial; explain.

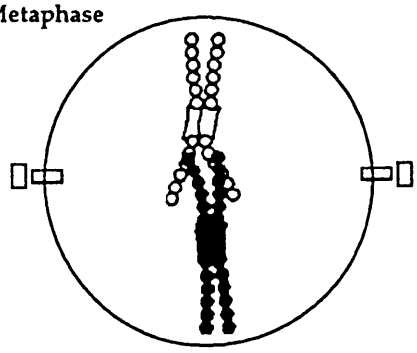
Interphase



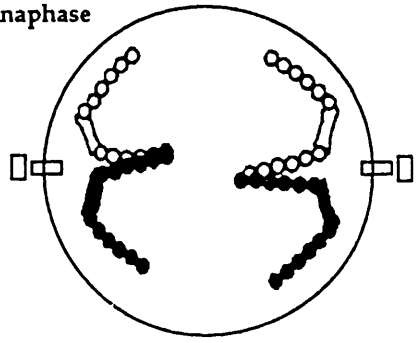
Prophase



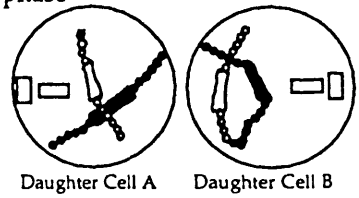
Metaphase



Anaphase



Telophase



Daughter Cell A Daughter Cell B

Mitosis

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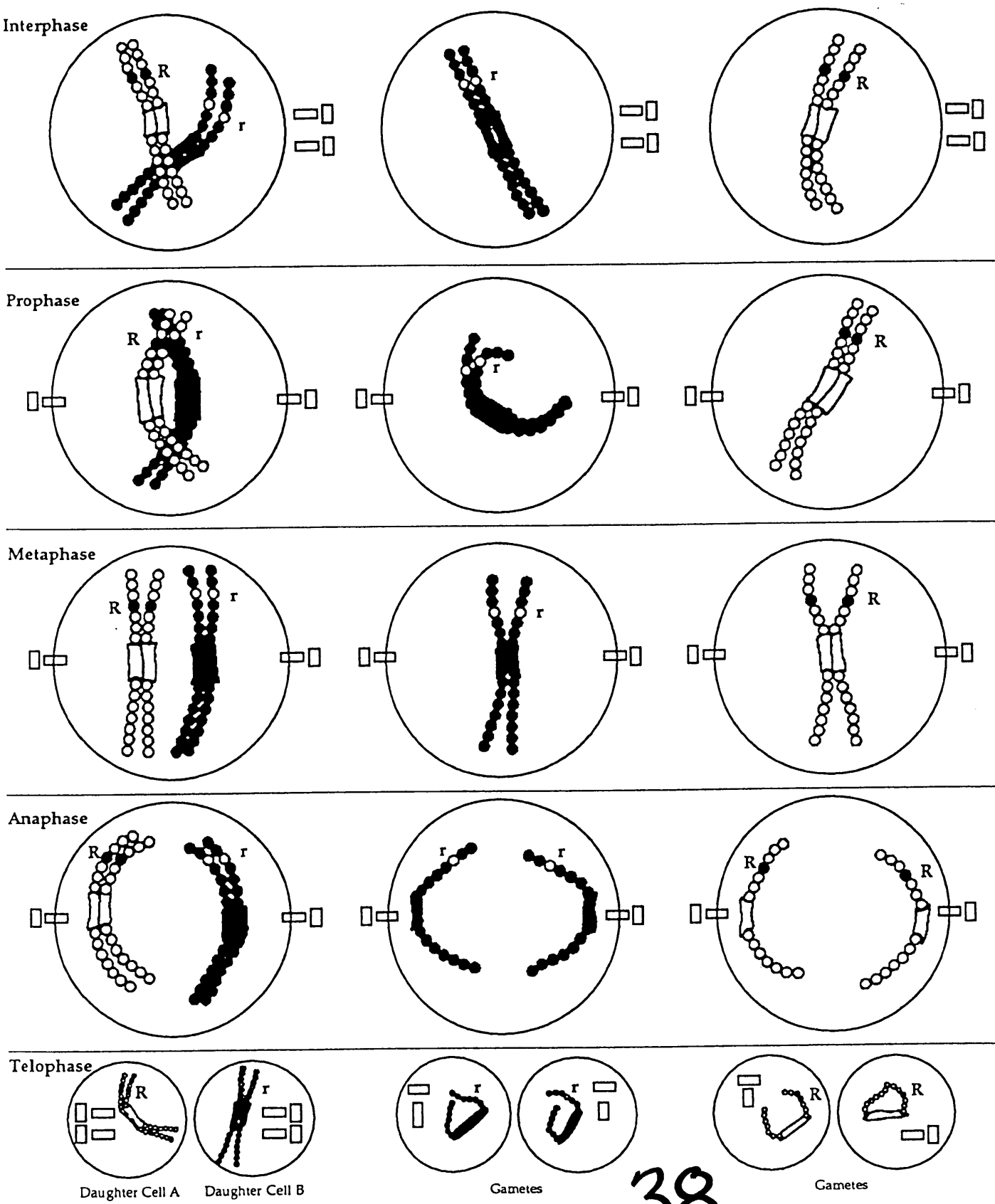
CHROMOSOME SIMULATION

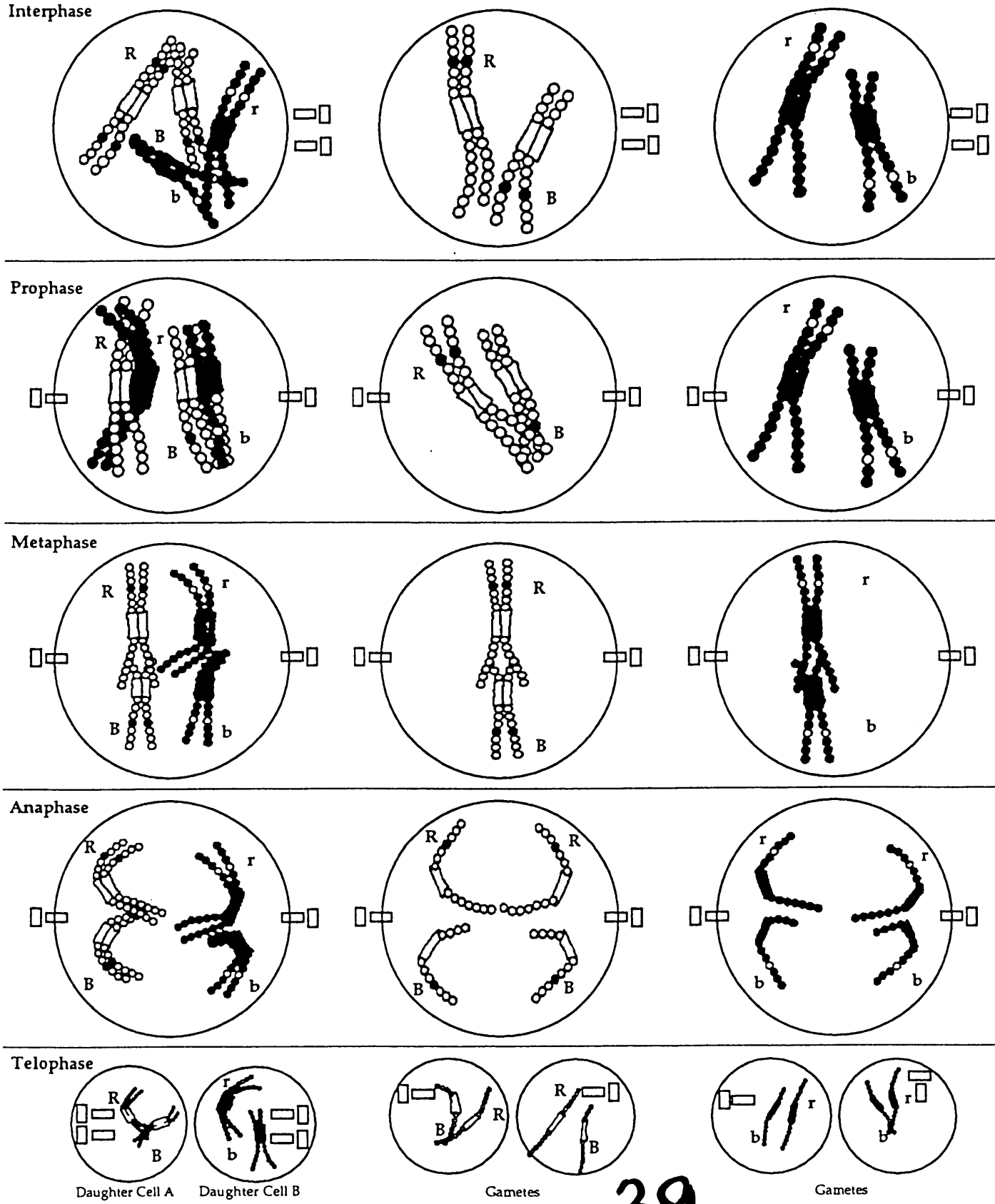
SHOWING: *SEGREGATION*



TEACHER'S MANUAL

CHROMOSOME SIMULATION

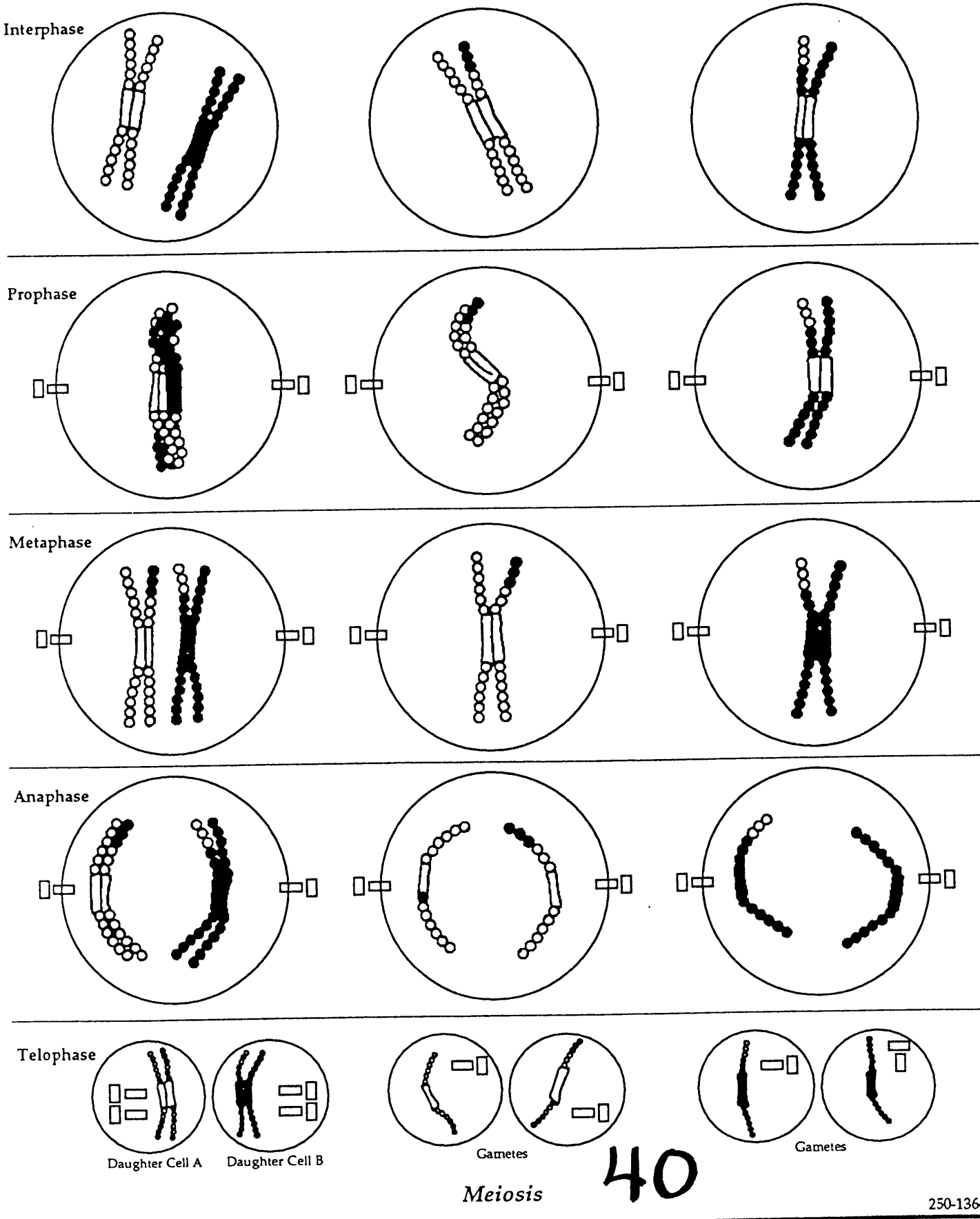
SHOWING: *INDEPENDENT ASSORTMENT*



TEACHER'S MANUAL

CHROMOSOME SIMULATION

SHOWING: *CROSSING OVER*



Name _____ Class _____ Date _____

Section Review

7.2

Use the diagram to complete the following.

a. _____ **b.** _____ **c.** _____ **d.** _____

1. Label each diagram to identify the phase of mitosis shown.

2. Beginning with prophase, identify the corrrect sequence of events in mitosis by writing the letter of each phase in the correct order. _____

3. During which phase of mitosis does cytokinesis begin? _____

4. a. Label the spindle fibers in the part of the diagram that shows metaphase.

b. Label the centromere in the part of the diagram that shows anaphase.

5. During which phase of mitosis are the sister chromatids separated? _____

_____

6. Which diagram shows interphase? _____

7. Use the diagrams to describe the changes that occur in a cell during each phase of mitosis listed.

a. prophase _____

_____

_____

b. metaphase _____

_____

_____

c. anaphase _____

_____

_____

d. telophase _____

_____

_____

8. How does cytokinesis in plant cells differ from cytokinesis in animal cells? _____

_____

_____

_____

_____

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MITOSIS VISUAL MODELS

Directions: Draw the structures of each model on the handout titled Analysis Sheet. After the drawing is completed, answer the questions below using your observations of these three dimensional models.

EARLY INTERPHASE 1

1. How many strands of chromatin are present?

2. Has the DNA replicated?

3. Are the nucleus and nucleolus present?

4. Does each strand of chromatin have a centromere?

LATE INTERPHASE 2

5. Has the DNA replicated?

6. What are the centrioles producing?

7. Are the nucleus and nucleolus present?

EARLY PROPHASE 3 AND LATE EARLY PROPHASE 4

8. What disappears during this phase as evidence by the difference between models 3 and 4?

9. What has happened to the chromatin from models 1 and 2 and what are these structures now called?

10. How many chromosomes are present?

11. Are sister chromatids present?

METAPHASE 5

12. Where are the chromosomes in the cell?

13. What structures are the spindle fibers attached to?

EARLY PROPHASE 6 AND LATE ANAPHASE 7

14. What has happened to the sister chromatids?

15. What structure is making this occur?

16. What is happening in Late Anaphase that is not seen in Early Anaphase?

TELOPHASE 8

17. How many chromosomes will be in each daughter cell?

18. What structures have reappeared?

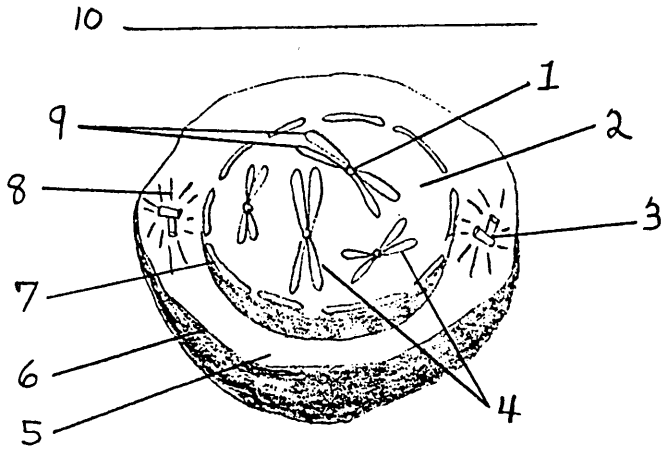
19. What change has occurred to the chromosomes?

20. How many cells will there be after cytokinesis is completed?

QUIZ 7.2 MITOTIC CELL DIVISION AND CYTOKINESIS

DIRECTIONS: Number your answer sheet 1 - 18. Record the best answer for each question below.

Correctly label the mitotic figure below.



LABELING WORD BANK
(Note that there are more words than what you need!)

centriole cytoplasm centromere sister chromatids

chromosome nuclear membrane nucleoplasm spindle fiber

cell membrane nucleolus telophase metaphase

interphase anaphase prophase

Correctly identify the phase which best matches each statement below. Use T for telophase, M for metaphase, P for prophase, I for interphase, A for anaphase, and C for cytokinesis. They may be used more than once.

11. The chromosomes are moved to the center of the cell by the spindle fibers attached to the centromeres.

12. The nucleolus and nuclear envelope disappear.

13. The centromeres of each chromosome are pulled by the spindle fibers toward the ends of the cell.

14. The cell membrane begins to pinch the cell in two as cytokinesis begins.

15. The chromosomes replicate and the cytoplasm increases as the cell prepares to divide.

16. The two sister chromatids of each chromosome are attached to spindle fibers radiating from opposite ends of the cell.

17. The cytoplasm of a cell and its organelles separate into two daughter cells.

18. The sister chromatids condense to become thicker and visible when viewed through the microscope.

MITOSIS ORNAMENTS

This activity is a group review of the features of the phases of mitosis and the cell cycle. Each group will construct a series of models representing these phases. Work cooperatively and courteously. Grades will be determined on a basis of participation, cooperation, completion and accurate representation of features.

Materials: flour, salt, water, gloves, bowl or bin, cookie cutter, rolling pin, food dye (various colors), elmer's glue water diluted solution, large brush, box for holding completed ornaments, string, hot glue, and hot glue gun

The models will be prepared with a Baker's Clay recipe which follows below:

Baker's Clay (for each lab group)

3 ½ cups of flour
7/8 cup of salt
1 1/4 cups of water

Using your hands, mix the above ingredients together in a bowl, or lab bin. After it is the consistency of a soft, but firm dough, set 1/3 aside for food coloring.

Take the 1/3 dough that has been set aside and shape it into six balls. With your finger, indent each ball on the top. Add one or two drops of food dye to each ball, and blend it into each ball with your hands. Each ball will be a different color. The colors to be created are: purple, orange, green, pink, blue, and yellow. You will end up with six balls of six different colors.

Roll the remaining dough out on your table until it is approximately ½ inch thick. If the dough is too sticky, lightly flour your table before rolling it out. Use whatever is available in the lab room to roll out your dough. Using a plastic cup, cut out nine *cookies*. Two of the *cookies* should be blended together at one edge. This ornament will represent telophase. Two

separate but identical *cookies* will be used for cytokinesis (daughter cells) and all of the other ornaments will be represented by one *cookie.*
The models that will be created will represent the following phase:

INTERPHASE
PROPHASE
METAPHASE
EARLY ANAPHASE
LATE ANAPHASE
TELOPHASE
CYTOKINESIS

Use the coloring pages that you have already completed to help complete this activity.

Create these structures below from the colored dough balls. Place these on the appropriate phase *cookie* after you have coated them with a water diluted solution of Elmer's glue.

nuclear membrane	purple
nucleolus	orange
centromere	yellow
chromatin & chromosomes (four)	green
centriole	pink
spindle fiber	blue

After you have attached the structures, apply a second coat of diluted Elmer's glue.

The models need a week to dry. After they are dry, a string will be attached to the back with hot glue for hanging. After their display in the high school library or in the classroom, each group member will be able to take two ornaments home.

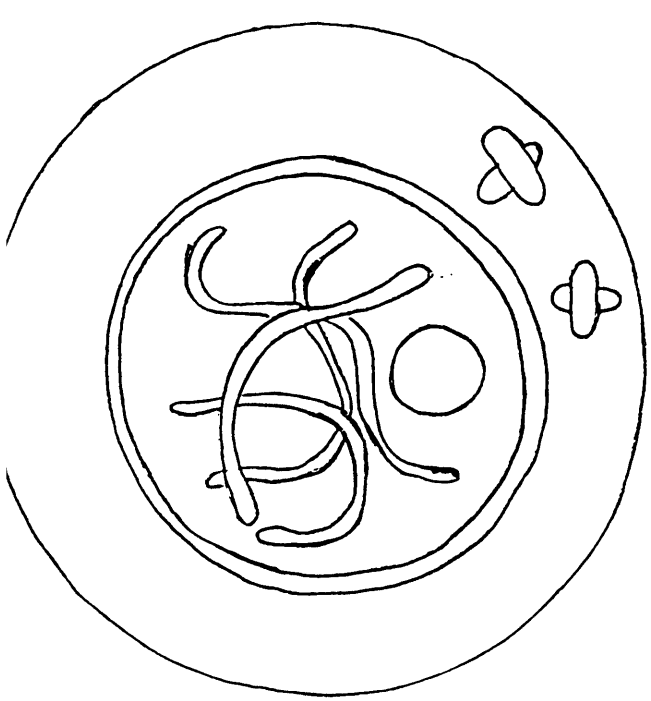
PREPARATION FOR MITOSIS ORNAMENTS

COLOR THESE FIGURES USING THE COLORS LISTED BELOW. USE YOUR MITOSIS CARDS TO HELP YOU IDENTITY THESE STRUCTURES.

NUCLEAR MEMBRANE	PURPLE
NUCLEOLI	ORANGE
CENTROMERES	YELLOW
CHROMATIN & CHROMOSOMES	GREEN
CENTRIOLES	PINK
SPINDLE FIBERS	BLUE

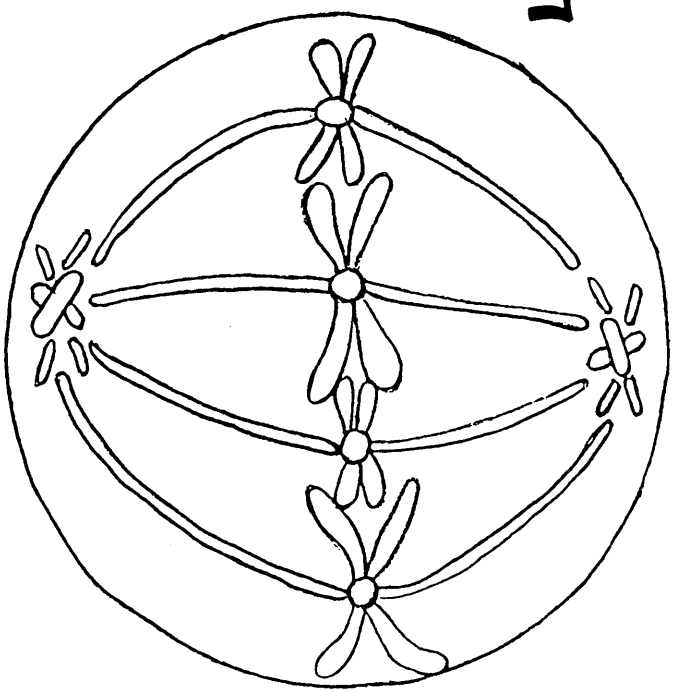
USE THESE COMPLETED FIGURES TO HELP YOU WITH THE ACTIVITY TITLED MITOSIS ORNAMENTS.

H8

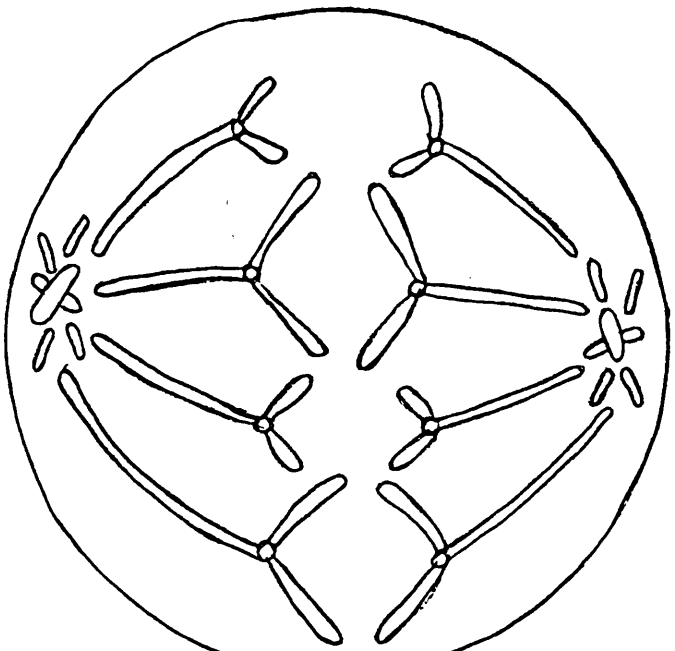


Interphase

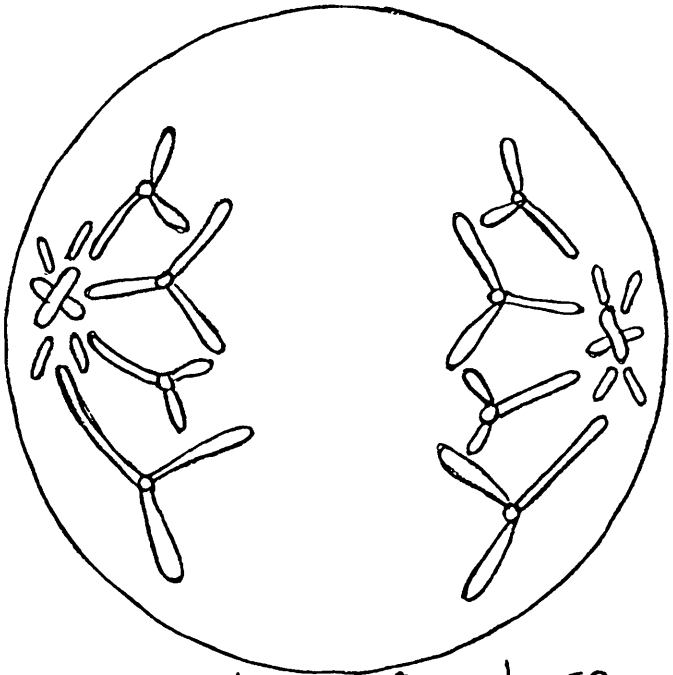
Prophase



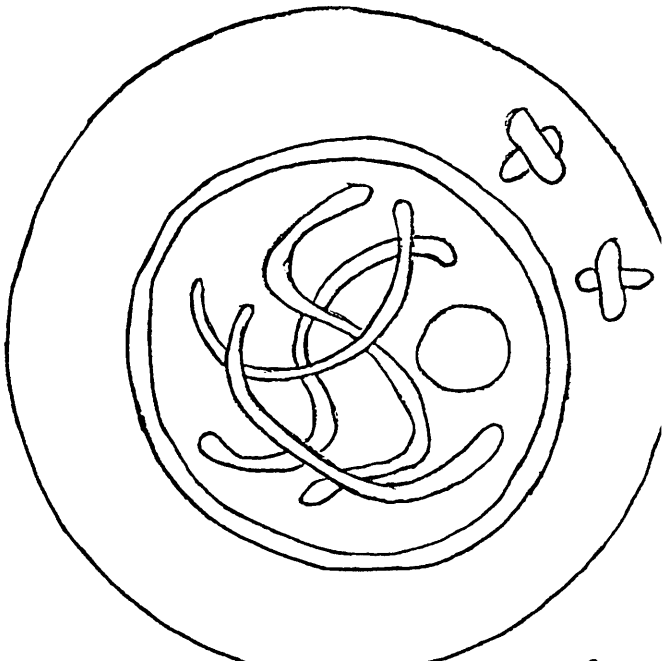
Metaphase



Early Anaphase

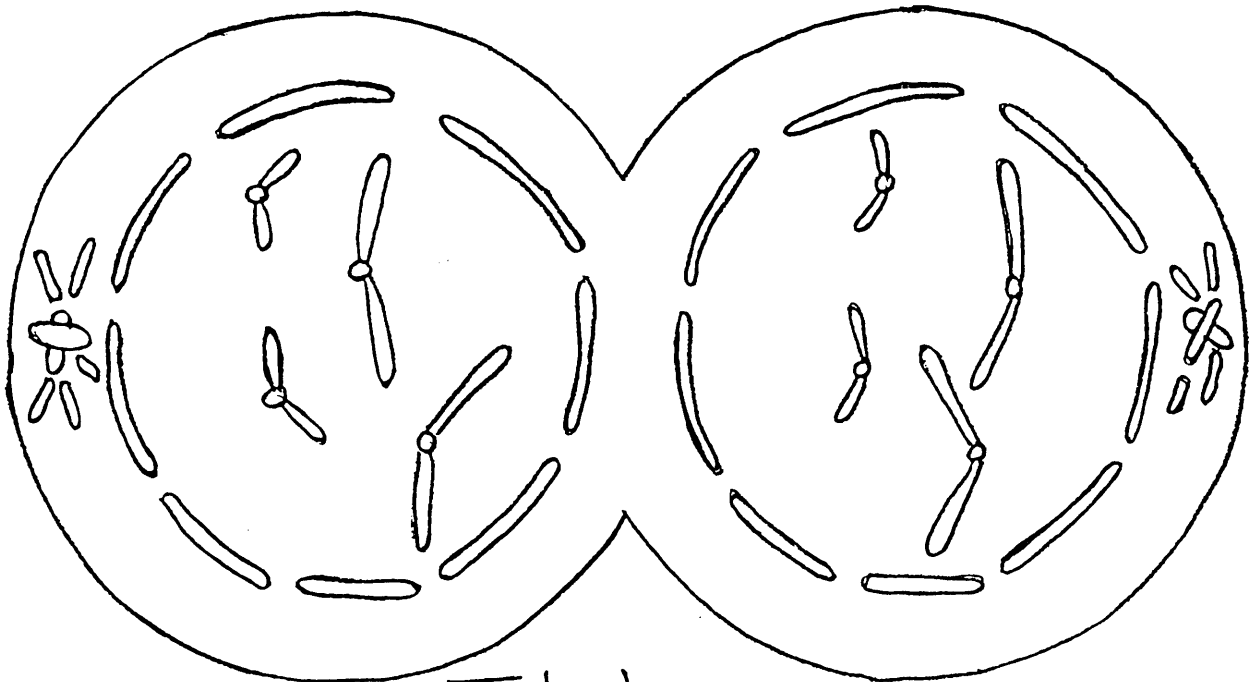


Late Anaphase

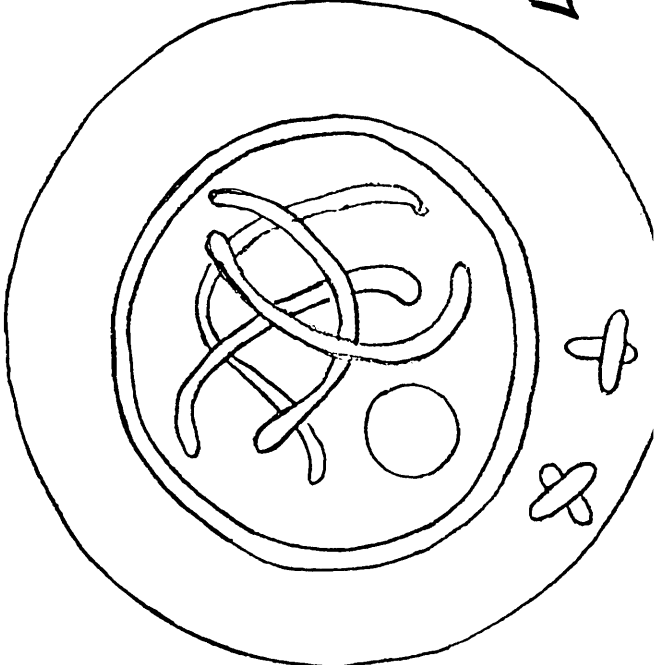


Cytokinesis (daughter cell)

4h



Telophase



Cytokinesis (daughter cell)

Name _____ Class _____ Date _____

Study Skills Worksheet 7-1

Making an Outline

An outline is a general description or summary of the main topics of a subject. When you make an outline, follow these guidelines. First, number the major topics of the outline using Roman numerals. Second, divide each major topic into at least two subtopics. Label these subtopics using capital letters. When necessary, break down subtopics into smaller topics. Number these topics using Arabic numbers, such as 1., 2., and 3. Make the heads for these subtopics as brief as possible.

Read Section 7.3, Control of Mitosis. Use the above guidelines to make an outline of the major topics and subtopics of the section. Write your outline in the space provided.

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Name _____ Class _____ Date _____

Section Review

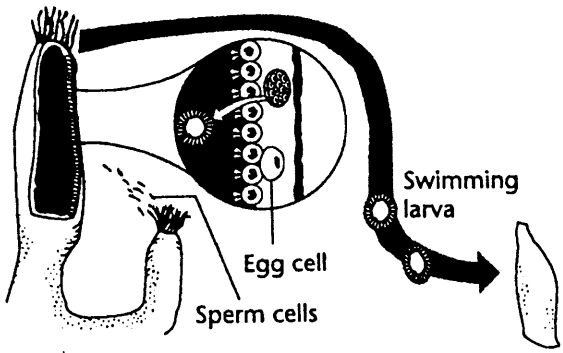
7.3

PART A *Match each term in Column B with its description in Column A. Write the letter of the correct term in the space provided.*

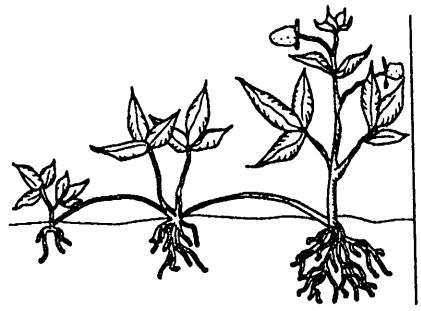
Column A		Column B
_____	**1.** reproduction in which one parent produces offspring by cell division	**a.** tumor
_____	**2.** chemicals that stimulate the division and differentiation of new cells during growth	**b.** asexual reproduction
_____	**3.** changes that take place in cells as they develop	**c.** fragmentation
_____	**4.** reproduction in which a new organism may develop from separated pieces of the parent organism	**d.** vegetative reproduction
_____	**5.** plant reproduction involving the growth of a new plant from the stems, roots, or leaves of an existing plant	**e.** cancer
_____	**6.** uncontrolled growth of abnormal, malignant cells	**f.** differentiation
_____	**7.** mass of abnormal cells that can be malignant or benign	**g.** growth factors
_____	**8.** process of growing back lost body parts	**h.** regeneration

PART B *Study the diagrams. Label each diagram as an example of* ***budding, sexual reproduction, regeneration,*** or ***vegetative reproduction.***

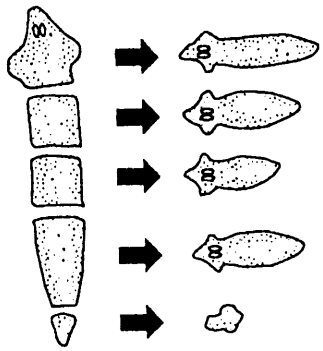
1. _____



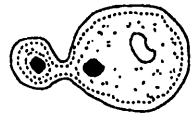
2. _____



3. _____



4. _____



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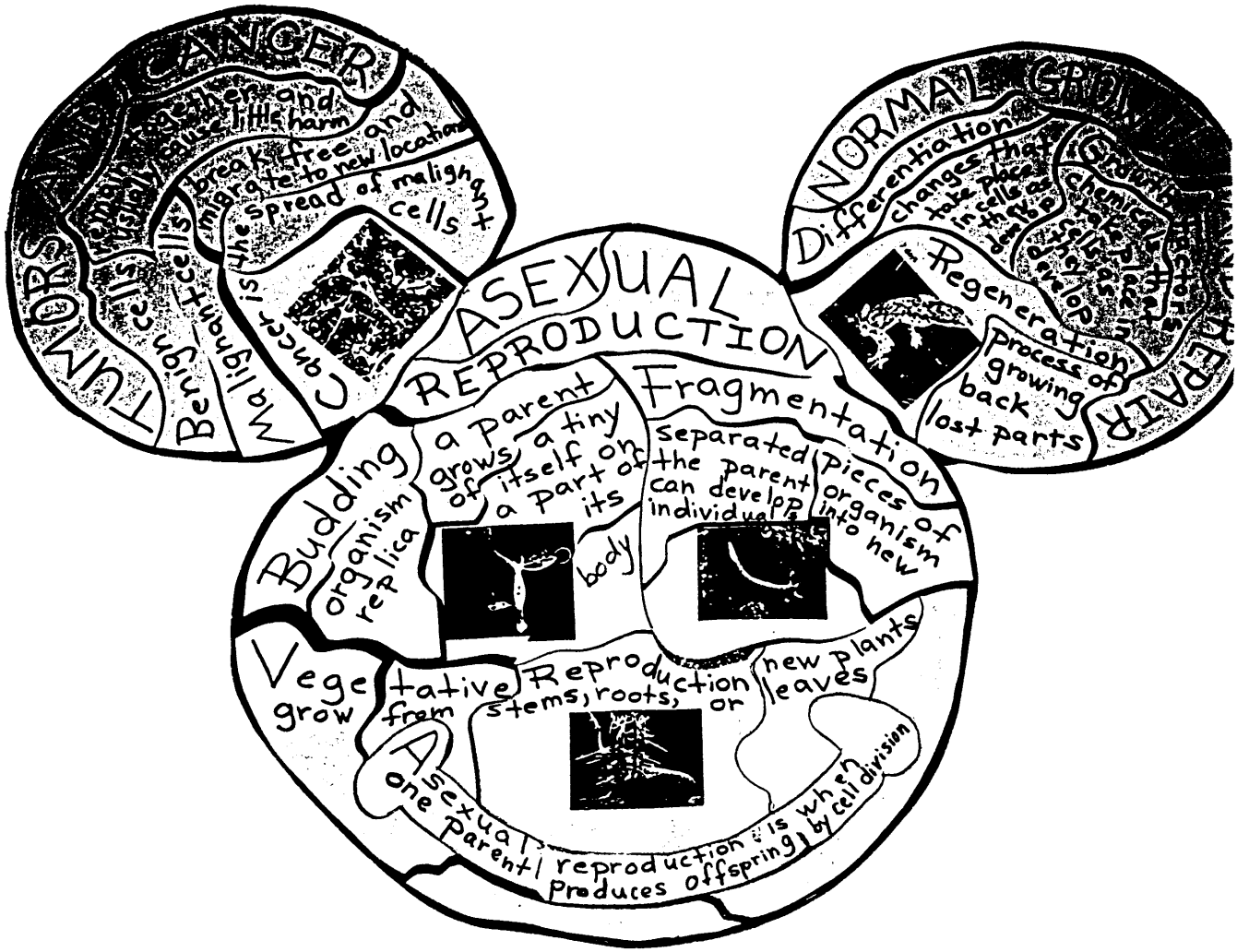
TASK PUZZLE CONTROL OF MITOSIS



This task puzzle was made from oaktag paper. Approximate size was 36 X 24 inches. A variety of colors were used in the print. The pictures were photocopied from the textbook and then enlarged and glued on to the puzzle.

QUIZ 7.3 Control of Mitosis

DIRECTIONS: Number your answer sheet 1 - 8. Choose the best term from the vocabulary bank for each definition below and then write this term on your answer sheet.

1. separated pieces of the parent organism can develop into new individuals

2. process of growing back lost body parts

3. a parent organism produces offspring by growing a tiny replica of itself on some part of its body

4. one parent produces offspring by cell division

5. new plants grow from the stems, roots, or leaves of an existing plant

6. spread of malignant cells to new locations

7. changes that take place in cells as they develop

8. chemicals that stimulate the division and differentiation of new cells during growth

VOCABULARY BANK

asexual reproduction fragmentation growth factors

cancer differentiation budding regeneration

vegetative reproduction

REVIEW OF INTERPHASE, MITOSIS, AND CYTOKINESIS

DIRECTIONS: Write the first letter of the correct phase that matches each statement below: **I** for interphase, **P** for prophase, **M** for metaphase, **A** for anaphase, **T** for telophase, and **C** for cytokinesis.

1. Cell grows

2. Nucleolus and nuclear envelope disappear

3. Chromosomes replicate

4. Sister chromatids condense to become thick and visible when viewed through a microscope

5. Cytoplasm increases

6. Chromosomes cannot be seen

7. Completes the process of cell division

8. Cell membrane begins to pinch the cell in two as cytokinesis begins

9. New nuclei form around the chromosomes at each end of the cell

10. Cleavage furrow forms in animal cells

11. Sister chromatids are separated from each other

12. Microtubules that make-up spindle fibers begin to assemble

13. Centromeres of each chromosome are pulled by the spindle fibers toward the ends of the cell

14. Cell plate forms in plant cells

15. Cytoplasm and organelles are separated into two daughter cells

16. G1, S, and G2

17. Sister chromatids are first present

18. Mitosis is complete

19. Two sister chromatids of each chromosome are attached to spindle fibers radiating from opposite ends of the cell

20. Chromosomes are thin and tangled

21. Longest phase of the cell cycle

22. Chromosomes are moved to the center of the cell

23. Number of organelles increases

TEST CELL CYCLE, MITOSIS, CYTOKINESIS, CONTROL OF MITOSIS

DIRECTIONS: Number your answer sheet 1 - 20. Choose the **BEST ANSWER** for each question below and then record the letter of the **BEST ANSWER** on your answer sheet.

1. The cytoplasm of a cell and its organelles separate into two daughter cells during

   A. metaphase.
   B. cytokinesis.
   C. anaphase.
   D. prophase.

2. The cell cycle includes interphase, mitosis, and

   A. meiosis.
   B. replication.
   C. cytolysis.
   D. cytokinesis.

3. After replication, each chromosome consists of

   A. 2 similar, but different chromatids.
   B. 2 identical sister chromatids.
   C. 1 similar and circular strand of DNA.
   D. 2 centromeres only.

4. This process of copying genetic material, results in 2 identical copies of a chromosome:

   A. replication
   B. recondensation
   C. telophase
   D. cytokinesis

5. The cell membrane begins to pinch the cell in two as cytokinesis begins during

   A. metaphase
   B. telophase
   C. interphase
   D. prophase

6. One parent producing offspring by cell division is called

A. sexual reproduction.
B. cancer.
C. asexual reproduction.
D. meiosis.

7. Separated pieces of the parent organism can develop into new individuals by

A. vegetative reproduction.
B. budding.
C. fragmentation.
D. regeneration.

8. This is the portion of the cell cycle between divisions:

A. prophase
B. anaphase
C. metaphase
D. interphase

9. Mitosis consists of prophase, metaphase, anaphase, and

A. telophase.
B. cytokinase.
C. chromatase.
D. replicase.

10. The two sister chromatids of each chromosome are attached to spindle fibers radiating from opposite ends of the cell during

A. metaphase.
B. cytokinesis.
C. telophase.
D. interphase.

11. The sister chromatids condense to become thicker and visible when viewed through the microscope during

A. telophase.
B. metaphase.
C. prophase.
D. anaphase.

12. DNA replication occurs during

A. prophase.
B. interphase.
C. telophase.
D. prophase.

13. The process of growing back lost body parts is called

A. vegetative reproduction.
B. budding.
C. fragmentation.
D. regeneration.

14. The spread of malignant cells to new locations is called

A. sexual reproduction.
B. cancer.
C. asexual reproduction.
D. meiosis.

15. During G1 phase of interphase, the cell

A. grows.
B. replicates.
C. reproduces.
D. condenses.

16. The nucleolus and nuclear envelope disappear during

A. metaphase.
B. telophase.
C. anaphase.
D. prophase.

17. This is when a parent organism produces offspring by growing a tiny replica of itself on some part of its body:

A. vegetative reproduction
B. budding
C. fragmentation
D. regeneration

18. The centromeres of each chromosome are pulled by the spindle fibers toward the ends of the cell during

A. metaphase.
B. telophase.
C. anaphase.
D. prophase.

19. When new plants grow from the stems, roots, or leaves of an existing plant it is called

A. vegetative reproduction.
B. budding.
C. fragmentation.
D. regeneration.

20. The chromosomes are moved to the center of the cell by the spindle fibers attached to the centromeres during

A. metaphase.
B. telophase.
C. anaphase.
D. prophase.

MARSHMALLOW MEIOSIS

LIFE CYCLE OF THE REEBOP AND SEXUAL REPRODUCTION

INTRODUCTION

Reebops are imaginary organisms whose life cycle is similar to humans and other animals because they sexually reproduce and are diploid organisms made of diploid cells. Chromosomes exist in homologous (similar) pairs in diploid cells. The gametes (egg and sperm) of the Reebop and human are haploid cells with one-half the total number of chromosomes. These chromosomes do not exist in pairs. Meiosis is the process that creates haploid cells and reduces the chromosome number by one-half. What would happen if the chromosome number was not reduced by one-half? Reebops are extremely fertile and after conception, growth (mitosis) occurs at an astonishing rate!

In this activitiy, you will simulate the processes of male meiosis, female meiosis, fertilization, and the rapid growth (mitosis) of the Reebop zygote (fertilized egg) to the fully developed Reebop!

Each group will create one Reebop baby. The Reebop parents are the same parents for each of these babies. The parents are here in the classroom. Ask your teacher if you may see them. Will your baby look like them?

Chromosomal analysis has revealed that Reebops have seven pairs or fourteen total chromosomes. Every body cell of the Reebop has this total number of chromosomes. The human species has twenty-three pairs or forty-six total chromosomes. Again, all body cells of humans have this total number.

DIRECTIONS

DIPLOID CELLS AND HOMOLOGOUS PAIRS OF CHROMOSOMES

1. Obtain your **MEIOSIS AND FERTILIZATION KIT** from the teacher.

2. From the white envelope in this kit, take out the sign **DAD** and DAD's blue chromosomes. There are fourteen of them. Pair these chromosomes according to size. You will also notice that they may be paired according to the letter of the alphabet on each. There are oaktag signs in the kit that identify what you are doing. Take out these signs: **male diploid cell** and **male homologous pairs**, and place them next to DAD's blue chromosomes. Imagine that these chromosomes exist in a diploid cell in the reproductive organ of the male Reebop. The cell is diploid because it's chromosomes exist in pairs. This diploid cell will undergo the process of meiosis very soon.

3. Repeat Step 2 above for MOM. Her chromosomes are pink and there are also corresponding oaktag signs.

4. Turn over DAD'S and MOM's chromosomes so that you cannot see the letters on them. Keep them in their homologous pairs.

MALE MEIOSIS

5. Randomly choose one member of each pair of DAD's blue chromosomes and place them in a space (or desk) of their own. Take the chromosomes that you did not choose and put them back in the white envelope now. Put the oaktag signs away also that were used with the paired homologous chromosomes. Replace these signs with these other signs - **male meiosis, male haploid cell,** and **male gamete - sperm.** They should be next to the seven blue chromosomes no longer have a pair.

FEMALE MEIOSIS

6. Repeat step 5 for MOM's pink chromosomes. Repeat the corresponding directions for the oaktag signs also.

FERTILIZATION CREATES THE ZYGOTE

7. Fertilize MOM's haploid cell (egg) by gathering DAD's haploid cell (sperm) with it's seven chromosomes, and then pairing them with MOM's seven chromosomes. A zygote has now been created that has the instructions (DNA - genes) that will determine the traits of that individual. Return the previous male and female oaktag signs, the MOM and DAD signs, and retrieve these other signs: **fertilization, zygote diploid cell,** and **zygote homologous pairs.** You will also find a **BABY** sign in the white envelope. Note that the life cycle has been completed because the original parent cells were diploid and now the next generation has returned as a diploid cell.

8. Turn over all of the BABY's chromosomes so that you can see the letters. These letters are symbols for traits (genes) of the BABY REEBOP. Record these letter pair combinations on your BABY REEBOP ORDER FORM which is in the kit. You will need your Reebop Decoder Key on the front of the envelope to help you do this.

9. Circle the traits of your Baby Reebop on your order form.

10. Return all materials to the bag and envelope exactly how you originally found them, except for the BABY REEBOP ORDER FORM. Turn this in to your teacher who will prepare your order for tomorrow's lesson. On this day you will create your BABY REEBOP and observe the offspring of the Reebop parents.

OBSERVATION - ANALYSIS - CONCLUSION

Directions: Answer the following questions below.

1. How many different varieties of Reebop babies were made by the lab groups?

2. How many Reebop babies are identical to the parents?

3. How many Reebop babies are not identical to the parents?

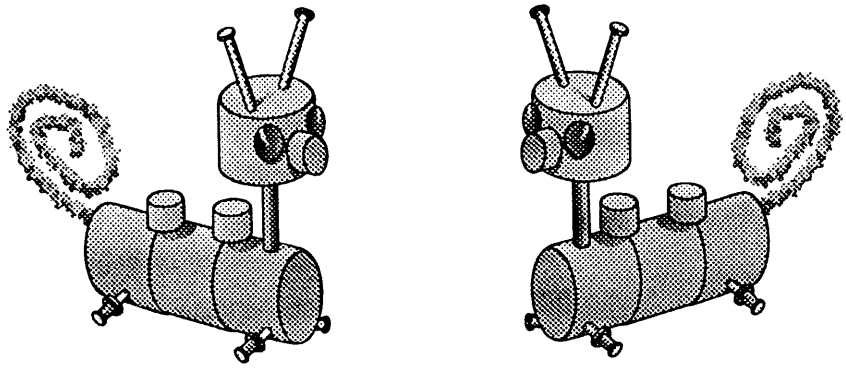
4. If the parents look like each other, how could babies be created that have different features?

5. Differences among members of a population are collectively called _____.

6. The process of change in living populations overtime is _____.

7. Why is variation amongst members of a species, important to the survival of that species?

MARSHMALLOW MEIOSIS



by Patti Soderberg

Explore genetics by raising reebops in the classroom

Are you in need of a simple activity that will help explain why meiosis is responsible for the tremendous variation that exists in every species? Try breeding reebops! Reebops are imaginary organisms that are prolific and require minimal care. These creatures are made out of marshmallows and other inexpensive materials that can be found around the home.

During the reebop activity, your students will have the opportunity to observe all of the offspring produced by one set of reebop parents. Your students will sort Mom and Dad reebop chromosomes, select the new baby reebop chromosomes, decode the secret code found on the baby reebop chromosomes, and construct the baby reebop according to the code. In other words, your students will be modeling the processes of meiosis, fertilization, development, and birth. After all of the babies are "born," the reebop family will be assembled so that all the offspring can be compared to one another.

GETTING STARTED

Prior to class, you will need to assemble the reebop parents (see Figure 1). Mom and Dad reebop each have a marshmallow head, two antennae (small nails), two eyes (thumb tacks), an orange nose (a colored miniature marshmallow), three body segments (large white marshmallows), two green humps (green miniature marshmallows), four blue legs (blue push pins), and a curly tail (a pipe cleaner). The creatures are easier to construct if you let the marshmallows sit out overnight to harden a bit. The reebops tend to be too floppy to stand properly if fresh marshmallows are used.

Chromosomal analysis has revealed that reebops have seven pairs, or 14 total chromosomes. Construct identical sets of Mom and Dad reebop chromosomes for the students to sort. Each pair of students will need a complete set of Mom chromosomes and a complete set of Dad chromosomes. Use the chromosome key

PHOTO COURTESY OF THE AUTHOR

(Figure 2) as your guide. I use different colored sheets of paper for each parent. For this article, we have selected red for Mom and green for Dad (you may wish to use your school colors).

Cut the paper into strips to create the chromosomes, sort them into one set per student group and place them in a large envelope. Each envelope should contain one set of 14 red chromosomes and one set of 14 green chromosomes. Each parental set should consist of seven pairs of chromosomes of different lengths. In order to ensure the greatest possible combination of phenotypes, the parents should be heterozygous at all loci, with each gene locus appearing on a different chromosome; seven traits, seven pairs of chromosomes—all able to sort independently (see Figure 2).

More traits, such as sex, can be easily added if you wish. Seven pairs of chromosomes seems to be a large enough number to insure that no two offspring produced by a class will appear identical. However, if you are working with a large group of students, you may want to increase the chromosome number to increase the certainty of variation among all offspring.

There are 128 chromosome combinations possible from an organism that has seven pairs of chromosomes (2 to the 7th power). Or, in other words, there are 128 possible genotype combinations from this arrangement. However, in this case the actual number of phenotypic combinations is less than 128 as some of the possible combinations of alleles code for the same phenotype (for example, both LL and Ll code for blue legs). If each gene locus were to exhibit codominance, then the number of genotype combinations would be the same as the number of phenotype combinations.

BREEDING REEBOPS

Introduce your students to Mom and Dad reebop and distribute the chromosome sets, one to each pair of students. Ask one member of each pair to take the red chromosomes, and the other the green. Have them turn the chromosomes face down on the table so that no letters are visible and ask each student to sort their set by length. At this point you may want to ask the students to hypothesize as to why the chromosomes can be sorted into pairs of similar length and why each pair differs in length from the other pairs.

Next, ask each pair of students to arbitrarily take one chromosome of each length from their set and place them together in a separate baby pile. This new set will be their reebop baby's chromosomes. The remaining chromosomes can be returned to the envelope. Each reebop baby should have 14 chromosomes, half red and half green.

The students can discover what their baby will look like by turning over their baby's chromosomes and decoding the secret code by referring to the key in

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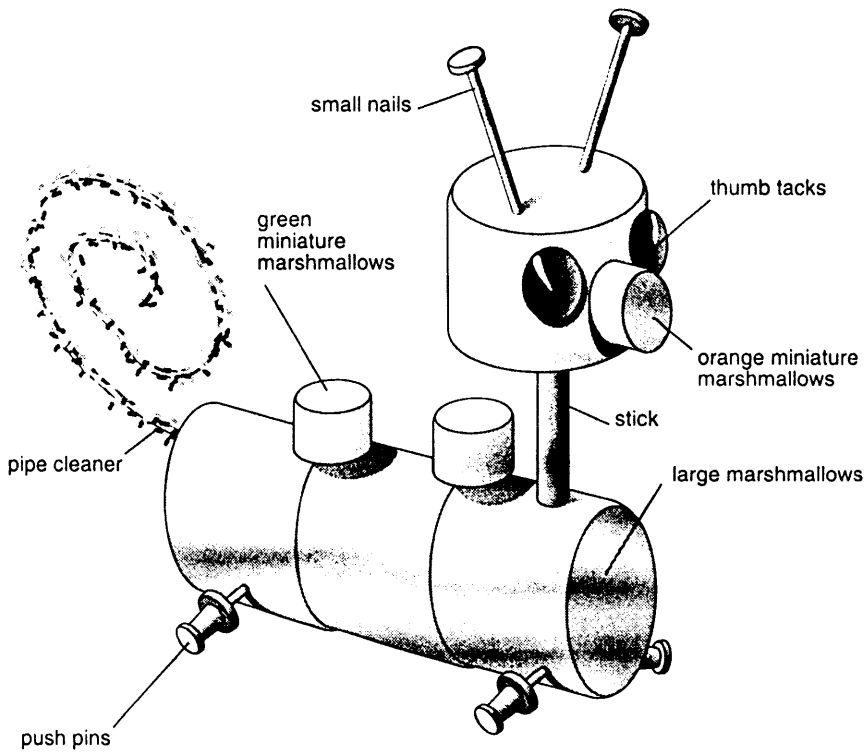
2 bags sticks toothpicks pipecleaners
Materials
6 g white marshmallows
small colored marshmallows
small nails - 100
thumb tacks - silver - 100
blue push pins } 200
red push pins }
12 envelopes
12 Fig 2 & Fig. 3

FIGURE 1. An adult reebop.



Toothpicks function as the unseen ligaments and tendons.

Figure 3. Each pair of students should construct a baby according to their secret code. Have the proud parents place the completed reebop babies in a designated nursery. Ask the students to observe the siblings. Are any two alike? Why are they all different? What makes identical twins identical? Are identical twins *exactly* identical? If not, why?

If, during the activity, you happen to have a pair of students who sort their chromosomes improperly and end up with either the wrong number of chromosomes, or end up with 14 chromosomes that do not include pairs of each of the seven lengths, resist correcting them at this point. If they are encouraged to build their baby according to their secret code, their reebop baby will most likely be missing some traits and have duplicates of others. That baby will be a wonderful example of the need for both the correct number and kind of chromosomes given to the baby by Mom or Dad.

If none of the groups of students mis-sorts their chromosomes, you may wish to have a pre-constructed baby that has extra parts and is missing others. This baby will be a perfect lead-in to a discussion of non-disjunction and the importance of complete sets of chromosomes in offspring.

RECOMMENDATIONS

I suggest that you and your students breed reebops to introduce the concept of meiosis *before* genetics is taught. You can refer back to the reebops when introducing a unit on Mendelian genetics. Also, try to minimize new vocabulary when directing the reebop activity. For example, you can begin by referring to the letters on the chromosome as "the secret code."

Multiple generations of reebops might be used to introduce a genetics unit.

At the end of the exercise, you can introduce the concept of a gene and stress that a gene actually consists of two forms, a paternal form and a maternal form. The reebops exercise should help your students understand the meaning of allele, independent assortment, meiosis, gamete, zygote, genotype, and phenotype before you introduce these terms at a later date. By using reebops, students should be able to comprehend the concept, then learn the scientific label.

THE REEBOP ADVANTAGE

Reebops are suitable for a wide range of ages. We have found that elementary teachers as well as college instructors are enthusiastic about the lessons they have taught with reebops. Of course, the goals of the reebop activity will vary depending on the grade level of the students. For example, with young children, the goal of the activity may be simply to understand the concept of generations.

With older students, the goals may be for students to discover why each parent contributes the same amount of genetic information to a child, why siblings in a given family look similar yet are all different, and why identical twins are identical. The reebops can be used with advanced students to teach concepts such as linkage and multiple alleles. They can even be used to teach population genetics, as reebop offspring can interbreed to produce numerous generations.

In addition, multiple generations of reebops might be used to introduce a genetics unit. The students could construct reebop pedigrees and look for patterns of inheritance (prior to learning about simple dominance), and subsequently infer models that account for these patterns. This would enable them to look at the world through Gregor Mendel's eyes (he also looked at seven independently sorting traits—in pea plants). They could engage in the type of

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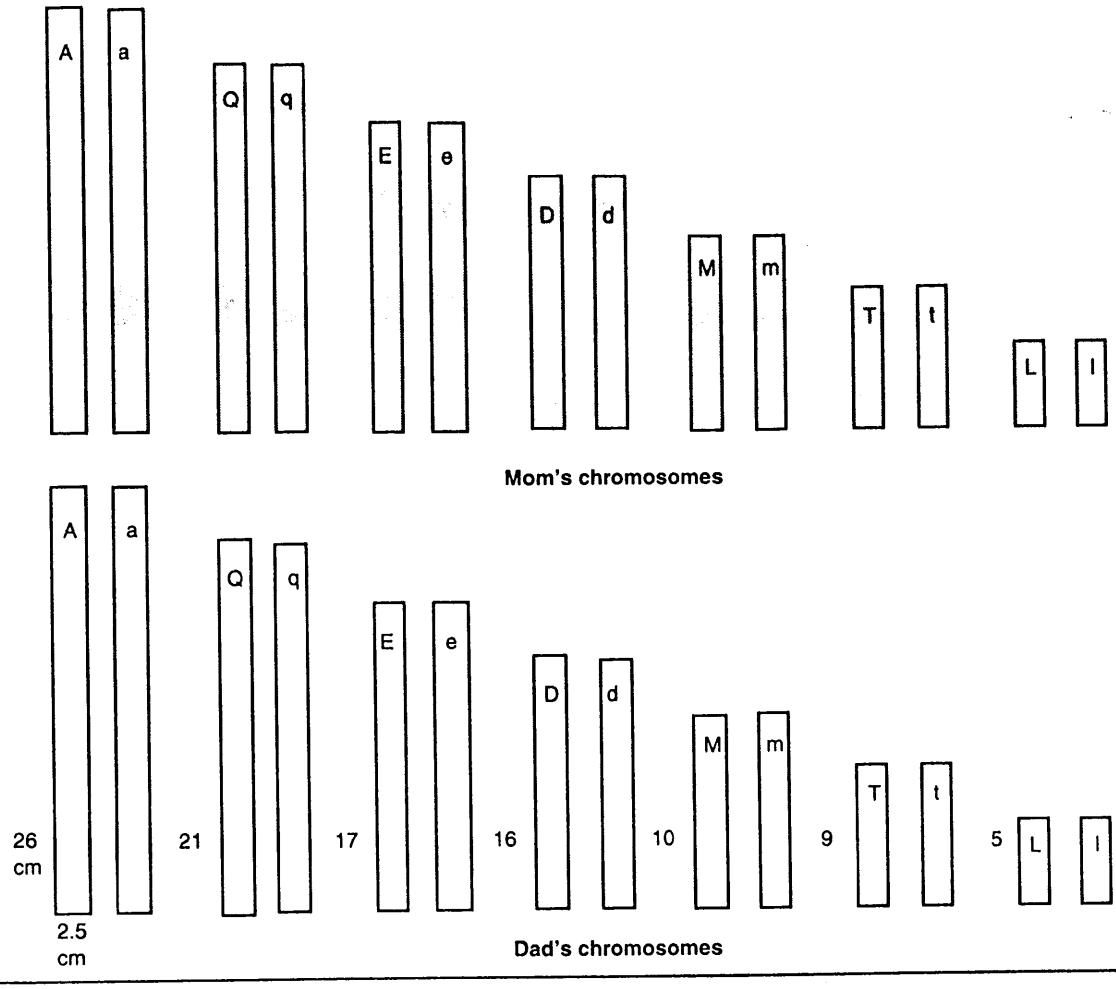
FIGURE 2. Reebop chromosome sets.



thinking similar to what Mendel did, by creatively building models.

I have found that the reebop activity generates numerous questions from students, especially when related to the effect of non-disjunctional events in humans. There are very few viable forms of aneuploidy (extra or missing chromosomes) in humans. One example is, of course, Down Syndrome. Most adolescents are familiar with Down Syndrome, particularly if they have seen the weekly television show "Life Goes On." Fetuses with either trisomy 13 or 18 who survive to birth will usually die shortly after.

There are living individuals who may exhibit a variety of sex chromosome aneuploidies. However in most cases, aneuploidy in humans will not result in viable offspring and a miscarriage will occur. A conservative estimate calculates that at least sixty percent of all miscarriages that occur before the twelfth week of gestation are due to an incorrect number of chromosomes in the developing fetus.

REEBOP WRAP-UP

The strength of the reebop breeding activity is that it helps students to understand that the function of meiosis is not only to reduce the chromosome number prior to sexual reproduction, but that it is a mechanism to ensure variation within a species.

As variation is the "raw material" for the process of natural selection, the driving force of evolution, it is important for our students to appreciate both the amount of variation and the causes of it.

After breeding reebops, students are more apt to recognize and understand both of these different functions of meiosis, because they are not getting bogged down in the jargon of phase names or genetics phenomena.

Patti Soderberg is the BioQUEST Project Coordinator at the University of Wisconsin-Madison, Room 226, Teacher Education Bldg., 255 North Mills St., Madison, WI 53706.

FIGURE 3. Reebop decoder key.

1 antenna = AA
2 antenna = Aa
No antenna = aa

1 green hump = MM
2 green humps = Mm
3 green humps = mm

Red nose = QQ
Orange nose = Qq
Yellow nose = qq

Curly tail = TT or Tt
Straight tail = tt

2 eyes = EE or Ee
3 eyes = ee

Blue legs = LL or Ll
Red legs = ll

2 body segments = dd
3 body segments = DD or Dd

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Questions for **MEIOSIS** (second edition) 1980 15 minutes
Encyclopaedia Britannica Educational Corporation

Directions: Read these questions before the film. During the film, answer these questions completely. After the film, the correct answers will be discussed. Be ready to share your answers with the class.

1. What is a body cell? What is a reproductive cell? How are they alike? Different? Why is cellular reproduction important?

2. What is an example of asexual reproduction?

3. What are chromosomes? Where are they located in the cell? What are they composed of?

4. How many chromosomes does a human cell have? A human gamete? Why does a gamete have half the number of chromosomes of other cells?

5. When a cell has paired similar chromosomes, what is it called? Give an example of this type of cell. What is a cell called that has unpaired chromosomes? Give an example of this type of cell.

6. What does the nucleus of a cell do? The nuclear membrane? The centriole? The chromosome? Which of these could a cell live without?

7. When does a cell divide? What happens to the chromosomes during cell division? What are chromatids? When are they formed? What are they composed of? Are chromatids paired or unpaired?

8. How many gametes are formed during single-cell division? Is there a difference in the number of male gametes formed and the number of female gametes? In a lifetime?

9. Why are more male gametes formed than female gametes?

10. What is pollen? Where is pollen formed? Where are the eggs formed? How does fertilization occur? What are some factors that will increase the likelihood of fertilization of plants?

11. Draw some steps of meiotic cell division. How is gamete formation different from regular cell division?

12. What are some of the factors that allow genetic diversity? When can this diversity occur?

13. What is crossing over? When can it occur? What is the outcome of crossing over?

14. What is shuffling? When can it occur? How is shuffling different from crossing over?

15. With all the opportunities for genetic diversity to occur, why do you think you resemble your parents? Sisters and/or brothers? Grandparents?

16. In higher organisms, all cells except gametes are diploid. What does diploid mean? Why do organisms need to have two sets of chromosomes? Why can't gametes have two sets of chromosomes?

OBSERVATION - ANALYSIS - CONCLUSION

Directions: Answer the following questions below.

1. How many different varieties of Reebop babies were made by the lab groups?

2. How many Reebop babies are identical to the parents?

3. How many Reebop babies are not identical to the parents?

4. If the parents look like each other, how could babies be created that have different features?

5. Differences among members of a population are collectively called _____.

6. The process of change in living populations overtime is _____.

7. Why is variation amongst members of a species, important to the survival of that species?

Questions for MEIOSIS: The Key to Genetic Diversity
Running Time: 26 Minutes HUMAN RELATIONS MEDIA

DIRECTIONS: Read these questions before the film. During the film, answer these questions completely. After the film, the correct answers will be discussed. Be ready to share your answers with the class.

1. What is the most important function of meiosis?

2. Describe the major events in meiosis I, listing the result of each interval.

3. How many cells are produced at the end of meiosis II from each starting cell?

4. Why is meiosis I called a reduction division?

5. Why are spindle fibers necessary?

6. Does the genetic complement inherited for one parent appear intact in meiotic daughter cells, or is there a mixing of chromosome sets?

7. What is crossing over and when does it take place?

8. How does crossing over contribute to genetic diversity?

9. Do haploid cells undergo meiosis?

10. What organs are responsible for meiosis in humans?

11. What are homologous chromosomes?

12. What is a bivalent or tetrad?

13. What is a mutation?

14. How are asexual and sexual reproduction different? What leads to greater genetic diversity?

15. Why is genetic diversity in a species important?

16. What are linked genes?

Name

A Chromosome Study

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An examination of the chromosomes of a cell under high magnification can give much information about an organism. If the cells are from an unborn human, its sex can be determined before it is born. It can also be determined if the unborn may have certain birth defects or problems caused by improper chromosome numbers in its cells.

The pages given to you by your teacher show chromosomes from a normal and abnormal unborn human. These are from body (somatic) cells and have been enlarged about 5000 times natural size.

In this investigation, you will

(a) learn what a karyotype is.
(b) prepare a karyotype of a normal human's chromosomes.
(c) prepare a karyotype of an abnormal human's chromosomes.

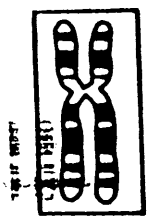
Materials

scissors
tape
1 page of normal chromosomes
1 page of abnormal chromosomes
2 charts for mounting of chromosomes

Procedure

Part A. Normal Human Karyotype

• Examine the page marked "Normal Human Chromosomes" supplied by your teacher. These chromosomes are actually an enlarged drawing of what is seen through a microscope. The chromosomes have also been stained to show their "banded" appearance. Note that two chromosomes are unshaded. They have been marked this way to aid you in preparing the karyotype. Cut out each chromosome with scissors. **CAUTION:** *Always be careful with scissors.* To make the task easier and faster, leave margins of paper along each chromosome. Cut them out as rectangles or squares as shown here:



• Prepare a karyotype of these chromosomes. A karyotype is a pattern of chromosomes from on cell grouped into pairs and then organized by size

• Match all chromosomes into pairs. To hel determine pairs, use the banding patterns seen o the chromosomes. Temporarily put the tw "unshaded" chromosomes aside. Mount eac chromosome pair onto the numbered chart pr vided by your teacher.

• Position the longest pair on the upper left-han corner. Consider them as pair number 1. Tap them into place. The next longest pair shoul follow until all pairs are taped on the sheet decreasing order of size.

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• The two unshaded chromosomes left over should be mounted in the lower right-hand corner above the words "sex chromosomes." Sex chromosomes determine the sex of an organism. In humans, a female results if both sex chromosomes match. These chromosomes are called XX sex chromosomes. In males, sex chromosomes do not match. They are called XY. The Y sex chromosome is much smaller than the X chromosome.

1. How many chromosomes are present in this karyotype? _____

2. How many chromosomes are present in each cell of this human? _____

Body cells are called somatic cells. Somatic cells are skin, liver, muscle, stomach, or kidney cells. The karyotype you just prepared is from a somatic human cell. The term "diploid chromosome number" or "2n number" refers to the total number of chromosomes in any somatic cell of an organism. The diploid number varies from species to species. However, it does not differ from somatic cell to somatic cell of an organism.

3. What is the diploid chromosome number for your karyotype? _____

4. What is the 2n chromosome number for your karyotype? _____

5. How many chromosomes would you expect to find in cells taken from the intestine of the person whose karyotype you just prepared? _____

6. Which sex chromosomes are present in the karyotype you prepared? _____

7. What is the sex of the person in the karyotype you prepared? _____

Part B. Abnormal Human Karyotype

Examine the page marked "Abnormal Human Chromosomes" supplied to you by your teacher. Again, the sex chromosomes are unshaded to make identification easier.

• Prepare a second karyotype as you did the first one. Use a new numbered chart to tape the chromosomes in place.

Finding the incorrect chromosome number in human somatic cells of an unborn alerts a doctor and parents to the fact that their unborn is abnormal and will be born with birth defects. If the unborn has an extra number 8 chromosome, it is born with trisomy 8 syndrome. If the unborn has an extra number 13 chromosome, it is born with Patau syndrome. An extra number 18 chromosome results in Edward syndrome. An extra number 21 syndrome results in Down syndrome. (A syndrome is a series of defects or problems.)

8. How many chromosomes are present in this karyotype? _____

9. What is the diploid chromosome number for this karyotype? _____

10. (a) Which chromosome pair is abnormal? _____

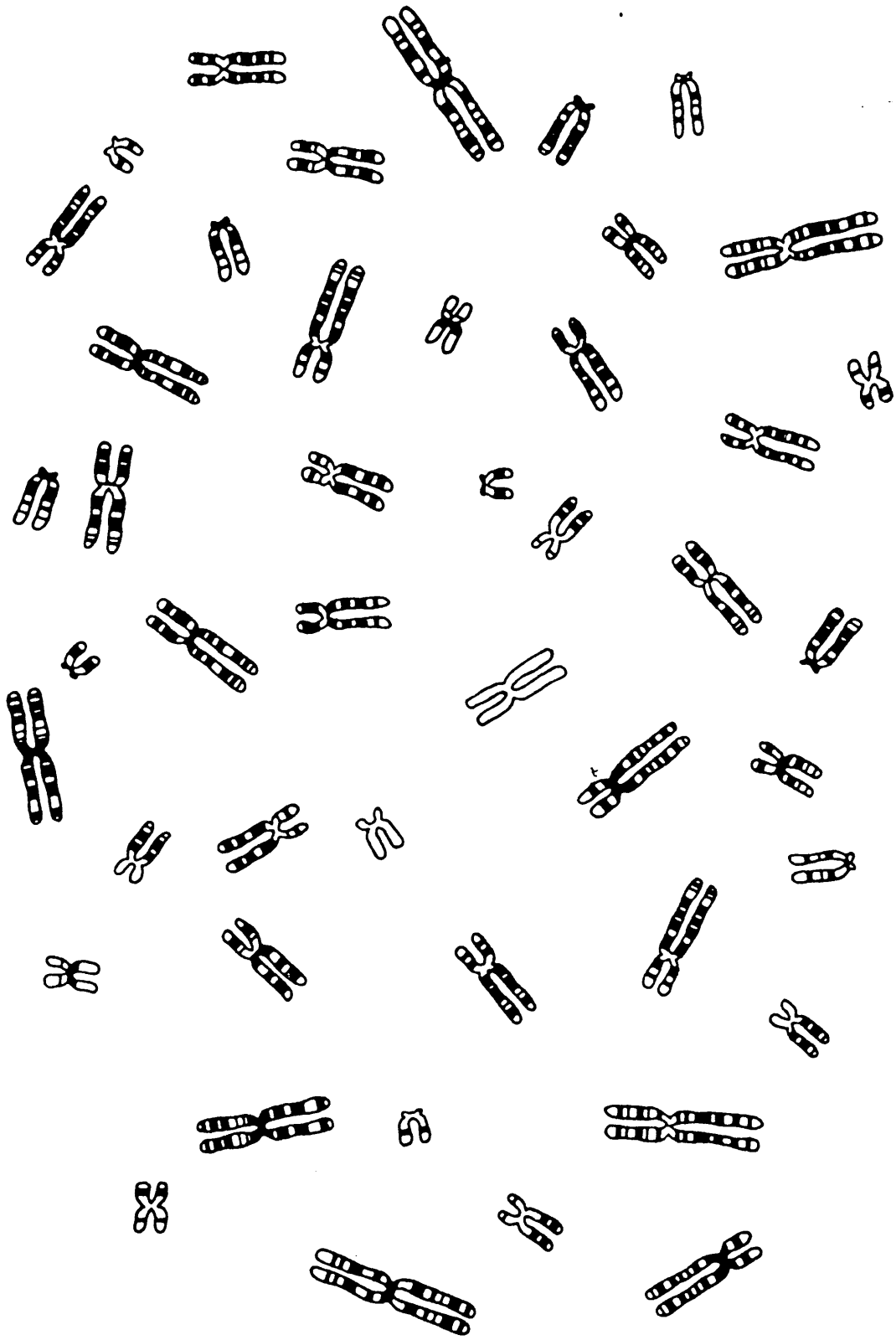
    (b) How is it abnormal? _____

11. What syndrome does this unborn have? _____

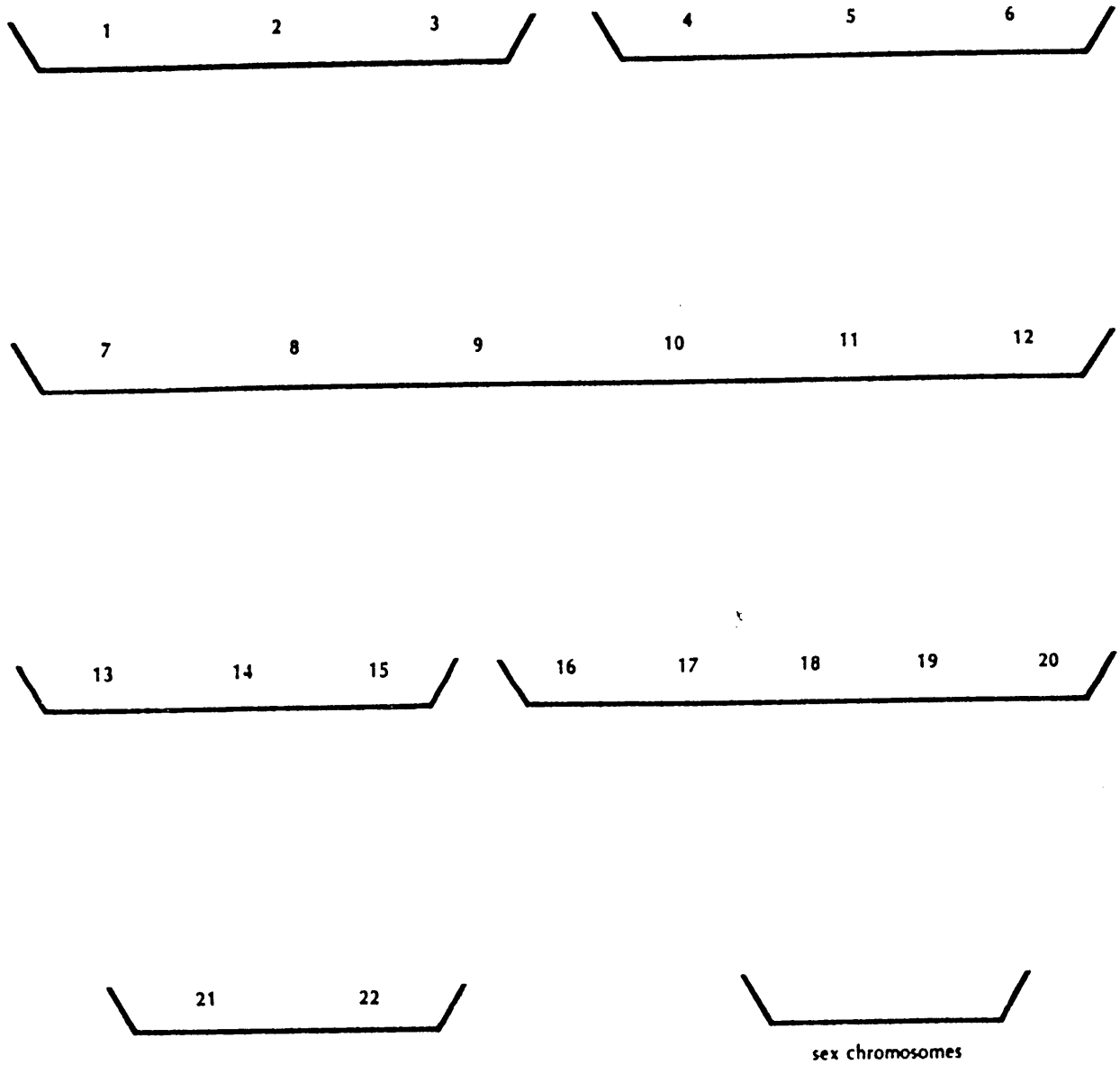
12. What sex will this unborn child be? _____

Analysis

1. Define
   (a) somatic cell _____
   (b) karyotype _____
   (c) diploid or 2n chromosome number _____
   (d) sex chromosomes _____
2. When karyotyping, what two major pieces of information can be gained about a child before it is born? _____



KARYOTYPE CHART FOR INVESTIGATION 21, "A CHROMOSOME STUDY"



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Karyotype

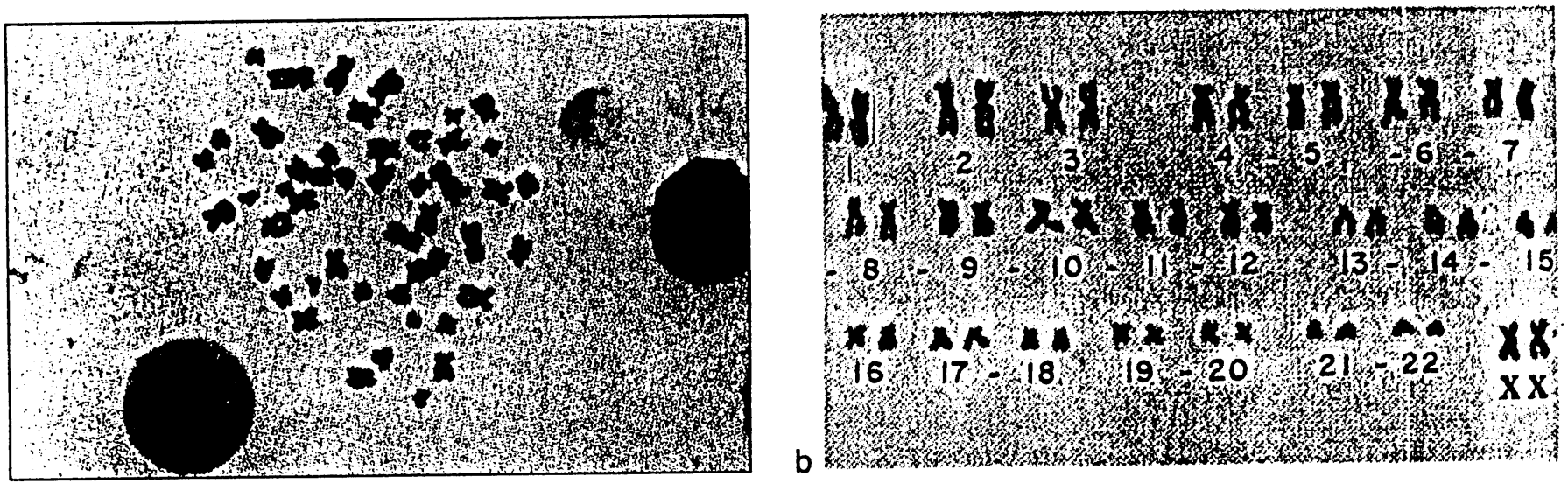

FIGURE 6–14. (a) Chromosomes can be photographed and then (b) paired in a karyotype. This karyotype shows the chromosomes of a normal human female. Humans have 23 pairs of chromosomes.

Name _____ Class _____ Date _____

Section Review

7.4

PART A *Complete the table by answering the questions in the first column.*

TABLE 1 COMPARING MITOSIS AND MEIOSIS

CHARACTERISTIC	MITOSIS	MEIOSIS
Does it occur in eukaryotes, prokaryotes, or both?	**1.**	**2.**
Does it occur in phases?	**3.**	**4.**
How does the number of chromosomes in the daughter cells compare to those of the parent?	**5.**	**6.**
Are the daughter cells genetically identical to each other and the parent cells?	**7.**	**8.**
How many daughter cells are produced?	**9.**	**10.**

PART B *Answer the following questions.*

1. What are the reproductive cells produced by meiosis called? _____

2. How does asexual reproduction differ from sexual reproduction? _____

_____

_____

3. Is meiosis involved in sexual reproduction, asexual reproduction, or both? _____

_____

4. How does the number of chromosomes in gametes differ from the number of chromosomes in an organism's body cells?

_____

5. How many chromosomes will an organism have in its body cells if its gametes contain the following numbers of chromosomes? **a.** 2_____ **b.** 10_____ **c.** 25_____

6. How does a diploid cell differ from a haploid cell? _____

_____

_____

7. What occurs during fertilization? _____

_____

8. What is a zygote? _____

9. What are the matching pairs of chromosomes in a diploid cell called? _____

_____

10. Are the cells involved in fertilization diploid or haploid? Why is this important? _____

_____

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Name _____ Class _____ Date _____

Section Review 7.6

Answer each of the following in complete sentences.

1. How does meiosis affect the characteristics within a population?

2. What is evolution?

3. Do individual organisms evolve? Explain.

4. What is variation?

5. Explain the two ways that meiosis leads to variation.

6. How do the traits of organisms resulting from asexual reproduction compare to the traits of their parents?

7. Why might asexual reproduction be a disadvantage to organisms if there is a sudden change in environmental conditions?

8. Why might sexual reproduction be an advantage to organisms if there is a sudden change in environmental conditions?

9. How do the conditions of an environment determine the traits that are beneficial to an organism?

10. How are traits that are beneficial to a population of organisms passed on to offspring?

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QUIZ 7.4 MEIOSIS AND SEXUAL REPRODUCTION AND 7.6 MEIOSIS AND EVOLUTION

DIRECTIONS: Number your answer sheet #1 - 10. Choose the term from the vocabulary bank for each definition below and then write this term on your answer sheet.

1. a cell that contains two complete sets of chromosomes (pairs of chromosomes)

2. reproductive cells that contain the haploid number of chromosomes

3. the process of joining an egg cell and a sperm cell of the same type of organism to produce a new individual

4. process of change in living populations over time

5. matching pairs of chromosomes in a diploid cell

6. the process which forms daughter cells with half the number of chromosomes of the parent cell

7. the process of combining chromosomes of two parents to produce offspring

8. the single cell that results from fertilization

9. a cell that contains only one complete set of chromosomes (the chromosomes are not in pairs)

10. differences among members of a population

VOCABULARY BANK

evolution variation diploid cell

haploid cell sexual reproduction zygote

homologous pairs gametes meiosis fertilization

MITOSIS ORNAMENTS EVALUATION

Name/s_____ Group/Table #_____

DESCRIBE the events and structures of each phase using your models. Record this in the space below.

INTERPHASE - PARENT CELL

PROPHASE

METAPHASE

EARLY ANAPHASE

LATE ANAPHASE

TELOPHASE

INTERPHASE - DAUGHTER CELLS

IDENTIFY the name of the following colored structures.

1. Blue_____

2. Green_____

3. Pink_____

4. Orange_____

5. Purple_____

6. Yellow_____

7. Uncolored dough_____

ANSWER the following questions using your models.

8. If the models represented the cells of an organism, what is the diploid number? What is the haploid number?

9. How many daughter cells were produced?

10. How many chromosomes are in each of the daughter cells?

11. How many chromosomes are in the parent cell?

12. Are the answers to questions 11 and 12 the same or different?

Name Date

Comparing Mitosis And Meiosis

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Your body carries out two different kinds of nuclear division. One is called mitosis and results in formation of new body cells for growth and repair. A second process is called meiosis and results in formation of reproductive cells only. There are several important differences between mitosis and meiosis.

In this investigation, you will
(a) compare the process of mitosis with meiosis.
(b) use model diagrams to show changes in cells during mitosis and meiosis.

Materials

pages of cell outlines
4 wool strands (18 mm long)
4 wool strands (30 mm long)

Procedure

Part A. Mitosis

Your teacher will supply you with outline diagrams for Part A of this experiment. Use only diagrams A, B, and C for Part A.

- Place the diagrams one below the other in proper order on your desk.

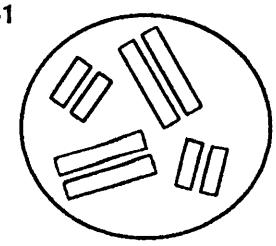
- Diagram A represents the outline of a cell before cell division or mitosis begins. Chromosomes are present inside the nucleus (but usually cannot be seen). Use wool strands to represent chromosomes. NOTE: A cell may contain many chromosomes. You will use only 4 chromosomes to help simplify this study.

- Place two long and two short pieces of wool (chromosomes) onto diagram A.

1. What is the total number of chromosomes present in this cell before mitosis? _____
2. How many long chromosomes are present before mitosis? _____
3. How many short chromosomes are present before mitosis? _____

- Before the cell begins mitosis, each chromosome makes an exact copy of itself. This process is called chromosome replication.

FIGURE 17-1



chromosome replication

- To show chromosome replication, match new strands of wool with each original. Long should match with long, short with short (Figure 17-1).

- Transfer your chromosomes to diagram B, and position them within the dashed outlines. During mitosis, doubled chromosomes line up along the cell's center.

4. What differences (if any) are there between the original and replicated (copy) part of each chromosome? _____

Doubled chromosomes now separate, and each part is pulled toward one end of the cell.

- Move those chromosomes lined up along the left side toward the cell's left. Move those chromosomes lined up along the right side toward the cell's right. Use the arrows as guides.

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• Once the doubled chromosomes separate, the original cell begins to pinch in half down the center. This process forms two new cells.

• Move the chromosomes on the left side of diagram B to the left cell of diagram C.

• Move the chromosomes on the right side of diagram B to the right cell of diagram C.

5. What is the total number of chromosomes present in each cell after mitosis (diagram C)?

_____

6. How many long chromosomes are present in each new cell? _____
7. How many short chromosomes are present in each new cell? _____
8. Compare your answers in questions 1-3 to those in questions 5-7. Are the two new cells just formed the same in chromosome makeup as the original cell? _____

In summary, some important things about mitosis include:

(a) every new cell formed has the same chromosome number,
(b) every new cell formed has the same chromosome number as the original cell,
(c) mitosis occurs in all body cells (somatic cells), and
(d) mitosis is responsible for growth and cell repair.

Part B. Meiosis

• Your teacher will supply you with outline diagrams for Part B of this experiment. Use only diagrams D, E, F, and G for Part B. Place the diagrams one below the other in proper order on your desk.

• Diagram D represents the outline of a cell before meiosis begins. Chromosomes are present inside the cell. Place two long and two short pieces of wool (chromosomes) onto cell diagram D.

9. What is the total number of chromosomes present in this cell before meiosis? _____
10. How many long chromosomes are present before meiosis? _____
11. How many short chromosomes are present before meiosis? _____
12. Check back to questions 1-3. Are there differences so far between mitosis and meiosis?

_____

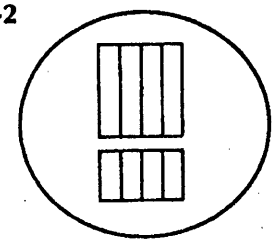
Before meiosis begins, the chromosomes replicate.

• Match new strands of wool with each original. Long should match with long, short with short. Before transferring your chromosomes to diagram E, one important step that is different in meiosis now occurs. One doubled long chromosome now pairs with the other doubled long chromosome.

• Place the four long chromosomes together.

• Do the same for the four short chromosomes which also pair at this stage. Each group of four is now called a tetrad (tetra = 4) (Figure 17-2).

FIGURE 17-2



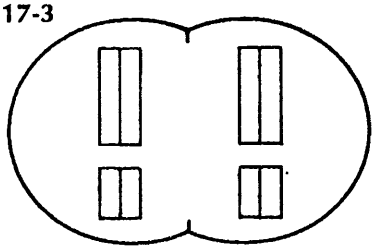
chromosome tetrads

13. Did this step occur in mitosis? _____

• Place your chromosome tetrads onto diagram E. Use the chromosome outlines to properly position them. During meiosis, the chromosome tetrads line up along the cell's center.

Chromosomes now separate and are pulled toward opposite ends of the cell. They separate, however, in a certain way. Each tetrad separates into the two original doubled chromosomes (Figure 17-3).

FIGURE 17-3



separating tetrads

Name _____ Date _____

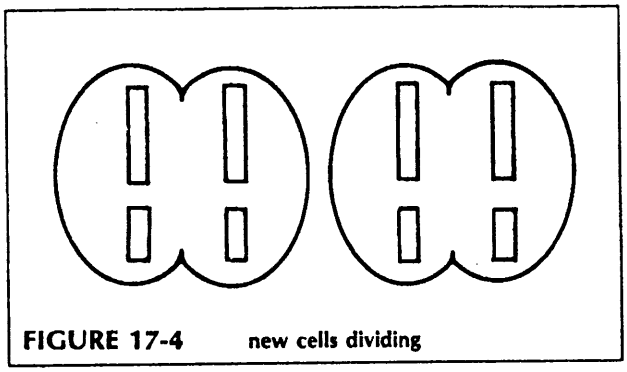


FIGURE 17-4 new cells dividing

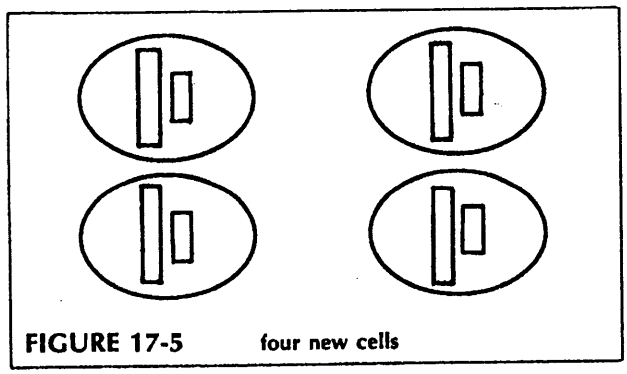


FIGURE 17-5 four new cells

• Move the doubled chromosomes toward opposite cell ends. Move those pairs lined up along the left center toward the left side of the newly forming cell. Follow the arrows as guides.

• Move the pairs lined up along the right center toward the right side of the newly forming cell. Follow the arrows as guides. Two new cells are formed as the original cell (Figure 17-3) pinches into two.

• Transfer those chromosomes on the right side of diagram E to the right circle of diagram F and position them within the dashed lines. Move those on the left side of diagram E to the left circle of diagram F and position them within the dashed lines.

14. (a) How many chromosomes are now present in each cell? _____

(b) How many chromosomes were present in the original cell? _____

(c) Is this step different from that which occurs after two cells form in mitosis?

_____

Each new cell just formed, quickly begins to divide again into two new cells (Figure 17-4). This step results in four new cells being formed from the original cell (Figure 17-5). The doubled chromosomes then separate leaving each new cell with a reduced number of chromosomes.

• Move your chromosomes from diagram F to diagram G. Position the chromosomes within the dashed lines.

15. (a) How many new cells are formed from one cell by meiosis (diagram G)? _____

(b) Does this step differ from mitosis? _____ Explain. _____

_____

_____

16. (a) What is the total number of chromosomes present in each new cell after meiosis?

_____

(b) Do any of the four new cells contain two long or two short chromosomes? _____

In summary, some important things about meiosis include:

(a) every new cell formed by meiosis has half the number of chromosomes as the original cell,
(b) no paired chromosomes are present,
(c) meiosis occurs only in reproductive organs, and
(d) meiosis is responsible for forming egg and sperm (gamete) cells.

Analysis

1. How many pairs of chromosomes are in each human body (somatic) cell? _____

2. How many pairs of chromosomes are in each egg or sperm? (Be careful.) _____

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3. In the exercise on meiosis just completed,

(a) are the chromosomes in pairs in the new cells? _____

(b) how does this differ from the process of mitosis? _____

_____

4. In humans, 46 chromosomes are in each body (somatic) cell, and 23 chromosomes are in each reproductive cell. In the chart below, fill in the chromosome number and process for each cell type.

CELL TYPE	NUMBER OF CHROMOSOMES IN CELL	PROCESS USED TO MAKE CELL (MITOSIS OR MEIOSIS)
stomach		
liver		
sperm		
heart		
egg		

5. Complete the following chart by checking the process of cell division in which each step occurs.

	MITOSIS	MEIOSIS
Two new cells are formed from each original		
Four new cells are formed from each original		
Replication of chromosomes occurs		
Doubled chromosomes pair to form tetrads		
Cells with a reduced chromosome number are formed		
Cells with the same chromosome numbers as original are formed		
Results in forming egg or sperm cells		
Results in forming somatic or body cells		
Each original cell divides only once		
Each original cell divides twice		
Tetrads are not formed		
Chromosomes move to the cell's center		

REVIEW OF CHAPTER 7 CELLULAR REPRODUCTION

I. MITOSIS, MEIOSIS, OR BOTH

DIRECTIONS: Write MI for mitosis, ME for meiosis, or B for both.

1. Daughter cells are not genetically identical to the parent cell
2. Daughter cells are formed with a reduced number of chromosomes
3. Chromosomes move to the cell's center
4. Produces more body cells
5. Asexual reproduction
6. Produces diploid cells
7. Four cells produced from the original
8. Variation
9. Daughter cells are genetically identical to the parent cell
10. Occurs in phases
11. Sexual reproduction
12. Produces egg or sperm cells
13. Produces gametes
14. Produces haploid cells
15. Original cell divides once
16. Homologous pairs line-up together at metaphase I, called tetrads
17. Chromosomes line-up in single file during metaphase
18. Tetrads are not formed
19. No variation

20. Two cells produced from original

22. Cells with the same chromosome number as original are formed

23. Crossing over

24. Occurs in eukaryotic cells

25. Replication of chromosomes occurs

II. MITOSIS

DIRECTIONS: Write I for interphase, P for prophase, M for metaphase, A for anaphase, T for telophase, and C for cytokinesis

26. Cell grows

27. Nucleolus and nuclear envelope disappear

28. Chromosomes replicate

29. Sister chromatids condense to become thick and visible when viewed through a microscope

30. Cytoplasm increases

31. Chromosomes cannot be seen

32. Completes the process of cell division

33. Cell membrane begins to pinch the cell in two as cytokinesis begins

34. New nuclei form around the chromosomes at each end of the cell

35. Cleavage furrow forms in animal cells

36. Sister chromatids are separated from each other

37. Microtubules that make-up spindle fibers begin to assemble

38. Centromeres of each chromosome are pulled by the spindle fibers toward the ends of the cell

39. Cell plate forms in plant cells

40. Cytoplasm and organelles are separated into two daughter cells

41. G1, S, G2

42. Sister chromatids are first present

43. Mitosis is complete

44. Two sister chromatids of each chromosome are attached to spindle fibers radiating from opposite ends of the cell

45. Chromosomes are thin and tangled

46. Longest phase of the cell cycle

47. Chromosomes are moved to the center of the cell

48. Number of organelles increases

III. MEIOSIS

DIRECTIONS: Write PI for prophase I, MI for metaphase I, AI for anaphase I, and TI for telophase I.

49. Cytokinesis

50. Homologous chromosomes are arranged in the middle of the cell

51. Separation of homologous chromosomes

52. Haploid cells

53. One chromosome from each pair present in each forming daughter cell

54. Spindle fibers pull chromosomes to opposite ends

55. Homologous pairs are tangled together

56. Chromosomes become thick and visible

57. Disappearing nuclear envelope

58. Crossing over

IV. SEXUAL OR ASEXUAL REPRODUCTION

DIRECTIONS: Write S for sexual and A for asexual.

59. Reshuffling of genes

60. Reebop babies or windpogs

61. Budding

62. Vegetative reproduction

63. Egg and sperm

64. Meiosis

65. Two parents

66. No variation

67. Mitosis

68. Body cells (somatic cells)

69. Zygote

70. Fertilization

71. Cancer

72. Haploid cells

73. Regeneration

74. One parent

75. Cloning

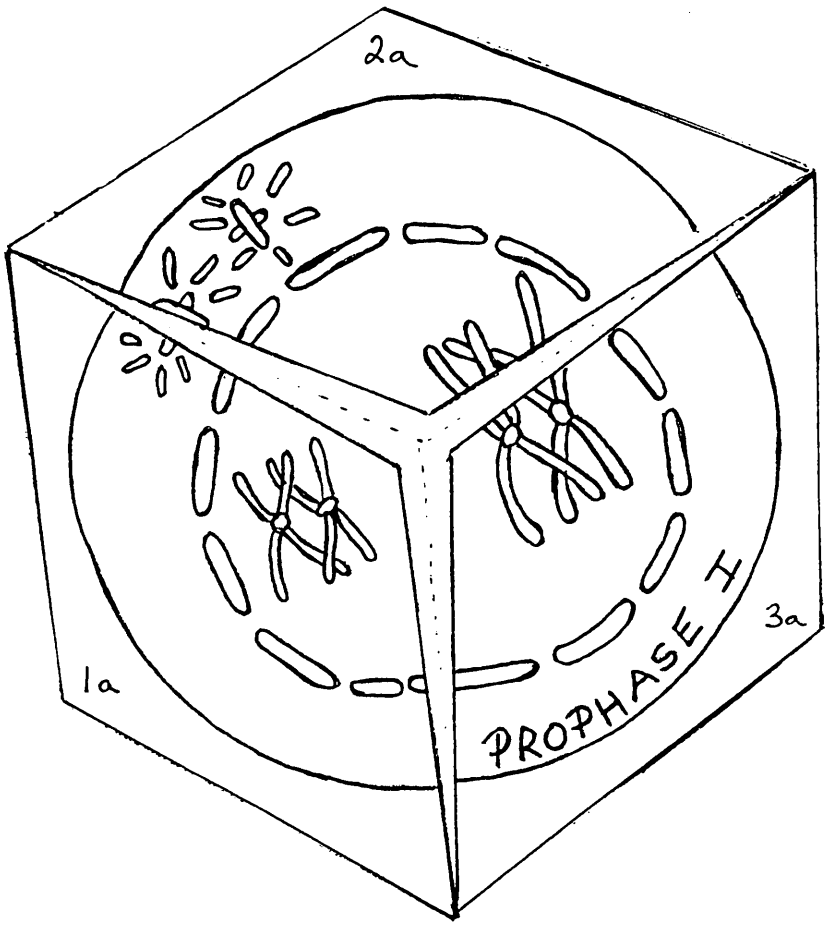
76. Variation

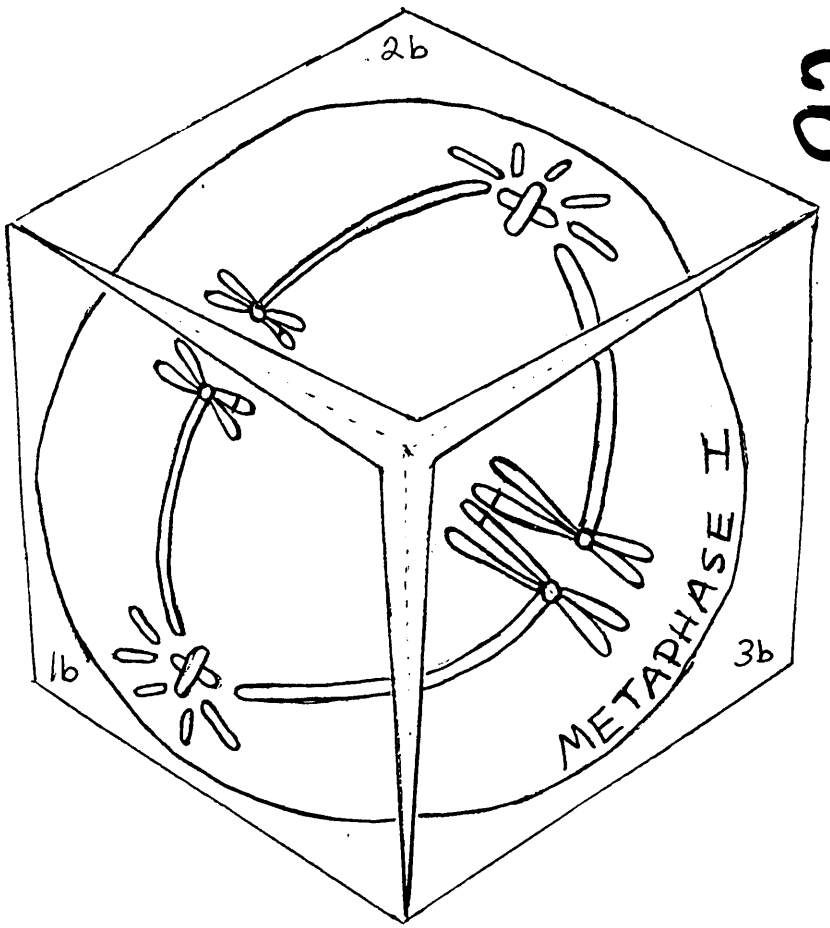
77. Evolution

78. Fragmentation

MEIOSIS HEXAFLEXAGON

Color the following organelles using different colors of your choice: nuclear membrane, centrioles, and spindle fibers. Choose a color for your small pair of chromosomes and a different color for your large pair of chromosomes. Locate Prophase I. Color one member of each pair solid and the other member color striped or dotted of the same color. Note that because the chromosomes are small, sharpened colored pencils work better than ones that have not been sharpened. During Prophase I the chromosomes cross over. Crossing over is the exchange of genes between pairs of homologous chromosomes. (They break and switch some parts!) Color the remaining chromosomes showing the cross over. See CLASSROOM EXAMPLE.





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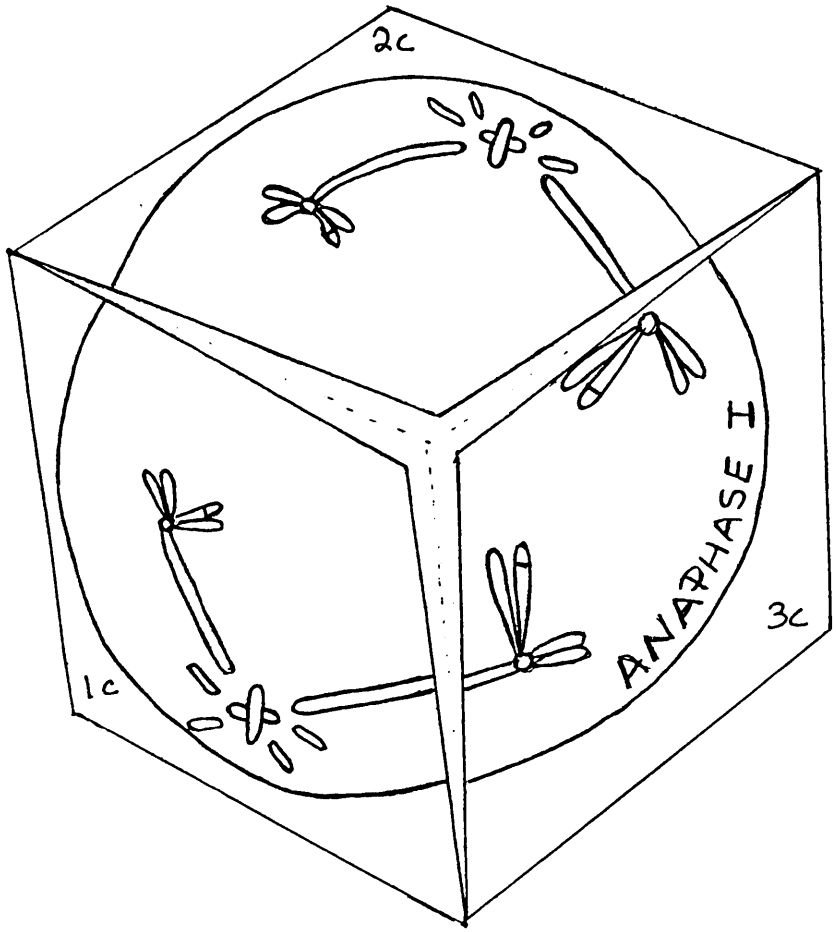
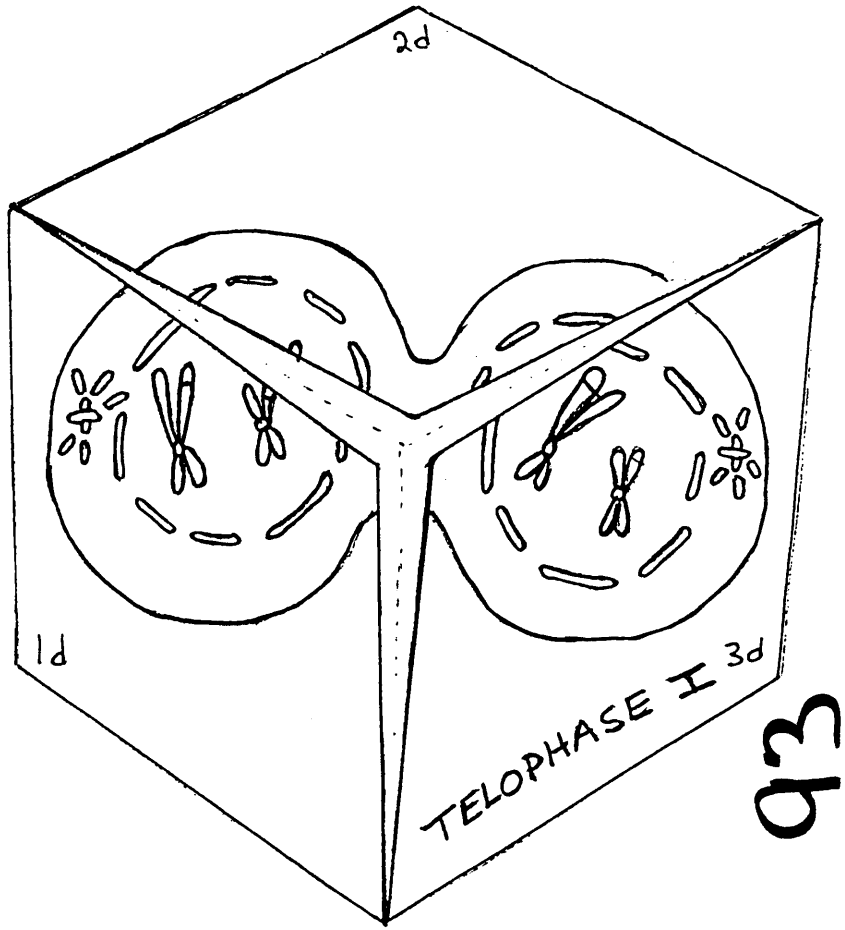




q3

Cut each diamond along the solid dark lines. Glue Figures 1a, 2a, and 3a to a surface of your hexaflexagon so that when the three diamonds come together it shows the complete picture. Do not glue over an opening. Glue Figures 1b, 2b, and 3b to a surface that is next to your first picture. When these three diamonds come together they should also show the complete picture. Repeat this for the other figures using the other two surfaces on your hexaflexagon. You will use this manipulative to learn about meiosis on another day in class. Write your name on your completed MEIOSIS HEXAFLEXAGON. Listen for instructions as to where to place your completed project.

Manipulative Hexaflexagon 45108

CONTENTS

ITEM	QUANTITY	DESCRIPTION
1	Pad/30	Patterns with assembly instructions

SUGGESTIONS FOR USE

The Manipulative Hexaflexagon is truly a hands-on product which helps illustrate any four-stage transformation, including mitosis, metamorphoses, and growth of organisms (for example: the development from tadpole to frog). The difference in this product, though, is that students, themselves, are the illustrators. By constructing and illustrating their own models, students develop their creative talents, as well as skill in listening to verbal instructions and following written instructions.

Construction of the Hexaflexagons is usually the final activity in the series of activities listed below. The initial activities are intended to familiarize students with the stages of mitosis and scientific transformation, and to help students develop skills in logical thinking, descriptive speaking, writing, and group interaction.

BACKGROUND NOTES

The idea for this project was born during a workshop to promote writing across the curriculum in North East ISD (San Antonio). At the workshop, biology teacher Roger Robison took part in an interesting activity presented by a fine arts consultant who sought to connect art, critical thinking, and writing Small collaborative groups attempted to write description of large, colorful art prints in such a manner that other groups could re-create the pictures sight unseen. The results of the activity generated lots of discussion (as well as lots of laughter) and suggested a potent application of the activity in the science classroom.

INTRODUCTORY ACTIVITIES

Before starting the study of cell division, try these adaptations of the art activity in your biology classes. Note that in the following activities:

- Writing is an effective tool for helping students to learn.
- The exercises are short, exploratory, informal, and ungraded.
- The idea for these exercises came from another discipline, yet are easily adapted to the science classroom.
- The activities create a link between art, biology, and writing.

You will need photos of the various stages of mitosis for these activities. Discarded catalogs from biological supply houses are excellent sources for colorful pictures. Also keep in mind the following suggestions:

- Laminating the pictures once they are mounted on poster board makes them more durable.
- Coding the series of pictures with a letter, number, or color makes sorting the sets simpler in preparing for the next class.
- Whole sheets of notebook paper or half-sheets of blank newsprint are convenient and just about the right size for making the drawings.
- Colored (map) pencils work well for this activity; pastels and other media may be messy to use or too expensive to purchase.

Activity 1: Describing and Drawing The Stages of Mitosis
Split students into pairs, or small teams. In place of art prints, give one student in each pair photographs of cells in various stages of mitosis. Have the second student in the team draw what they perceive each photo to look like based on the first student's verbal description. Once the students have traded their descriptions and drawn their interpretations, have them discuss the problems they encountered in completing the assignment. Common problems that often come up in these discussions include the need for a set of accurate instructions, the importance of a logical sequence to follow, the significance of details, and the benefits of a technical vocabulary.

Activity 2: Understanding The Progression of Stages of Mitosis
Give each group of students a set of photographs depicting all stages of cell division. Ask each group to arrange the cards in a what they feel is a logical sequence and then to write a justification for why they arranged the cards as they did. By the end of the period, students should be quite familiar with the appearance of the cells at each stage, knowledgeable about the progression of changes from one stage to the next, and prepared to learn the technical terms for a process that they have already deduced for themselves.

CONSTRUCTING THE HEXAFLEXAGONS

Instructions for assembling the Hexaflexagons are printed on the pattern sheets. Plan on using one class period for construction of the models. The remainder of the activity can be assigned as homework, or can be completed during a second session.

1. At the beginning of the period, pass out the patterns for the model.

2. Refer students to the written instructions on each pattern. Verbally explain the instructions for scoring the vertical and diagonal lines on the pattern. A sketch on the chalkboard or a transparency on the overhead projector can speed things up, if you choose.

3. Have students assemble their models. Students who need help to complete this step will benefit from one-on-one assistance at this point.

4. Once the models are assembled, have students complete the activity by drawing the stages of mitosis on the model to show the changes that occur in each stage for either an animal cell or a plant cell. (Since the model has only four usable surfaces, interphase is not included in the series.)

5. This activity can be graded in two parts: properly completing the model (70 points) and properly answering questions in a short oral quiz using the model (30 points). At the beginning of the period the next day, take about ten minutes to check the models for completeness and award appropriate points. At the end of the period on subsequent days, award students additional points for being able to answer questions about mitosis using their models. ("Show me anaphase." "What stage comes just before/after this one?" "Show me one structure that identifies the type of cell that you have." "Show me an aster." "Show me the shortest stage." "Does your cell have a cleavage furrow?" and so forth.)

Student reactions to this activity are usually quite favorable, and the grades for the activity are usually very high.

Roger L. Robison
Biology/Life Science Teacher
Douglas MacArthur High School
San Antonio, TX

MEIOSIS HEXAFLEXAGON

OBSERVATION AND ANALYSIS

DIRECTIONS: FLEX your hexaflexagon to reveal the events of meiosis.

SHOW:

1. crossing over
2. disappearing nuclear envelope
3. homologous chromosomes arranged in the middle of the cell
4. separation of homologous chromosomes
5. cytokinesis
6. haploid cells

ANSWER:

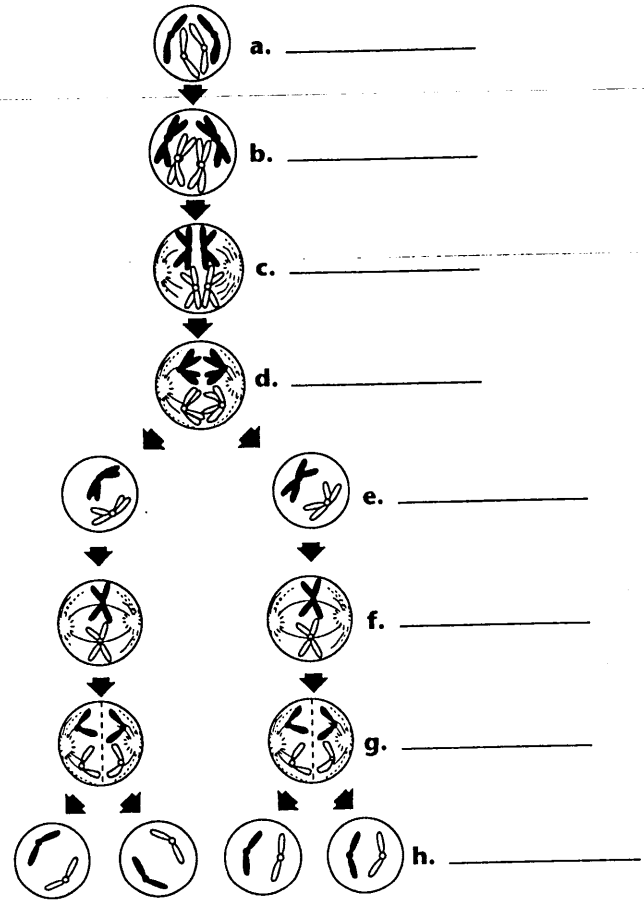
7. How many chromosomes are in the parent cell?
8. Is the parent cell a diploid or a haploid cell?
9. How many chromosomes are in each cell after telophase I?
10. Are these cells from question #9 diploid or haploid?
11. What is the relationship of the answer of #7 to the answer of #9?
12. After telophase I, the two cells enter Meiosis II, which is similar to Mitosis. How many cells are produced at the end of Meiosis II? Are these cells diploid or haploid? What is another name for these cells?

Name _____ Class _____ Date _____

Section Review

7.5

Study the diagrams. Then complete the following.



1. Identify the phases of meiosis I and meiosis II in the diagram by writing the name of the correct phase in each space.

2. Where are the sister chromatids at the start of meiosis? _____

3. During which phase of meiosis I do spindle fibers form? _____

4. During what phase of meiosis I do homologous pairs of chromosomes separate? _____

5. At the end of telophase I are daughter cells diploid or haploid? _____

6. Do chromosomes replicate at the beginning of meiosis I, meiosis II, or both? _____

7. What occurs during meiosis II? _____

8. What is crossing over and when does it occur? _____

9. What are genes and where are they located? _____ 97

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Critical Thinking Diagram Worksheet 7-1

Cell Division

Figure 1

Meiosis

Figure 2

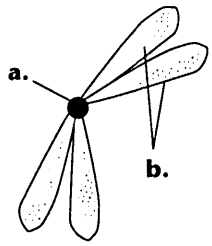

Figure 3

PART A *Complete the following.*

1. Beneath the cell labeled Cell Division, draw the correct number of cells that will be produced as a result of cell division. Include the correct number of chromosomes in each cell.

2. Beneath the cell labeled meiosis, draw the correct number of cells that will be produced as a result of this process. Include the correct number of chromosomes in each cell.

3. Identify the structure shown in Figure 3. _____

4. Label the parts identified as **a** and **b** in Figure 3. _____

PART B *Answer the questions following.*

1. What three processes are part of cell division? _____

2. What is mitosis? _____

_____

3. What is meiosis? _____

_____

4. How do the end results of mitosis and meiosis differ? _____

_____

_____

5. Why is it important for cells resulting from meiosis to be haploid? _____

_____

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Chapter 7 Test A

Choose the best answer for each question and write its letter in the blank.

_____ **1.** The phases in the life of a cell are called
a. interphase. **c.** the cell cycle.
b. replication. **d.** meiosis.

_____ **2.** The period of cell growth prior to division is
a. replication. **c.** reproduction.
b. anaphase. **d.** interphase.

_____ **3.** During the S phase of interphase, the chromosomes of the cell
a. replicate. **c.** condense.
b. are destroyed. **d.** triple.

_____ **4.** DNA replication in a cell results in
a. brother chromatids. **c.** sister chromatids.
b. triple chromatids. **d.** elimination of chromatids.

_____ **5.** Step 1 of cell division is called mitosis, and step 2 is called
a. cytokinesis. **c.** mitokinesis.
b. replication. **d.** centromere.

_____ **6.** Which is *not* a phase of mitosis?
a. prophase. **c.** metaphase.
b. biphase. **d.** telophase.

_____ **7.** In anaphase, the sister chromatids
a. separate from each other. **c.** condense and become thicker.
b. join together. **d.** become attached to spindle fibers.

_____ **8.** The cell is pinched in two and cytokinesis begins during
a. prophase. **c.** colored body continuation.
b. telophase. **d.** interphase.

_____ **9.** The assembling of microtubules that make up the spindle fibers occurs
a. during telophase. **c.** after mitosis.
b. during prophase. **d.** before mitosis.

_____ **10.** The term *cleavage furrow* refers to
a. mitosis in plant cells. **c.** cytokinesis in plant cells.
b. mitosis in animal cells. **d.** cytokinesis in animal cells.

_____ **11.** What is the term for the changes that take place in cells as they develop?
a. differentiation **c.** cytokinesis
b. growth factors **d.** cleavage

_____ **12.** Asexual reproduction is
a. reproduction by two parents asexually.
b. reproduction by one parent by cell division.
c. reproduction by one parent by fertilization.
d. reproduction by two parents by regeneration.

_____ **13.** During budding, a parent organism produces offspring by
a. growing a tiny replica of itself. **c.** spreading malignant cells.
b. being torn into many pieces. **d.** fragmenting.

_____ **14.** A lizard's ability to grow back its tail is an example of
a. asexual reproduction. **c.** tumor production.
b. regeneration. **d.** sexual reproduction.

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_____ **15.** Cancer is an example of
- **a.** cells acquiring abnormal size, shape, and abilities.
- **b.** disorganized cell growth.
- **c.** vegetative reproduction.
- **d.** continual fragmentation.

_____ **16.** What are sexual reproductive cells called?
- **a.** homologous pairs
- **b.** buds
- **c.** gametes
- **d.** chromosomes

_____ **17.** Matching pairs of chromosomes in a diploid cell are
- **a.** homologous pairs.
- **b.** gametes.
- **c.** diploids.
- **d.** zygotes.

_____ **18.** In which of the following ways is meiosis similar to mitosis?
- **a.** One parent cell makes four daughter cells.
- **b.** It occurs in eukaryotic cells.
- **c.** Daughter cells are not alike.
- **d.** One parent cell makes two daughter cells.

_____ **19.** The single cell that results from sexual reproduction is the
- **a.** zygote.
- **b.** gamete.
- **c.** bud.
- **d.** daughter cell.

_____ **20.** Which happens during meiosis II?
- **a.** Telophase I stops.
- **b.** Chromosomes become thick and visible.
- **c.** Daughter cells divide for the second time.
- **d.** Anaphase I continues.

_____ **21.** The exchange of genes between pairs of homologous chromosomes is
- **a.** crossing over.
- **b.** meiosis I.
- **c.** homologous pairing.
- **d.** crossing back.

_____ **22.** Each protien in an organism is coded for by an individual
- **a.** gene.
- **b.** chromosome.
- **c.** gamete.
- **d.** chromatid.

_____ **23.** During meiosis I, homologous pairs
- **a.** join together.
- **b.** separate.
- **c.** cross over.
- **d.** undergo mitosis.

_____ **24.** Differences among members of a population are collectively called
- **a.** variation.
- **b.** evolution.
- **c.** reproduction.
- **d.** asexual meiosis.

_____ **25.** The reshuffling of genes in sexual reproduction increases
- **a.** survival chances for some.
- **b.** uniformity.
- **c.** the division of chromosomes.
- **d.** deaths in a population.

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