A STUDY OF THE APPLICATION OF THE TESSI MODEL IN BIOLOGY 12

by

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ABSTRACT

Technology enhanced instruction (TEI) using computers is a relatively new pedagogical format. This study focuses on the application of TEI in secondary school biology. The study investigates: 1) achievement between two instructional methods in biology: computer enhanced vs. traditional, 2) changes in computer-related attitudes among students using technology enhanced instruction, and 3) the relationship between computer attitudes, computer experience and achievement among students in a computer technology enhanced environment.

The results of the study indicated that while there appeared to be no significant difference in achievement between the traditionally instructed and TEI groups, and no differences in achievement by gender in the TEI group, the students in the TEI group were observed to be engaged in the learning process in unique ways: exhibiting examples of self-direction, collaborative learning, and peer tutoring. The study also found that the students' computer attitudes were positively affected by TEI, and that the students were not disadvantaged by a lack of prior computer experience in a TEI environment.

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CHAPTER ONE

Introduction

A. Background to the Study

Innovative technology enhanced secondary science instruction is now a reality in British Columbia classrooms (Woodrow, Mayer-Smith, & Pedretti, 1996). As with any new instructional approach, there are expectations and assumptions regarding its effectiveness and its impact on students. What is needed however, is research on the impact of operational technology enhanced instruction (TEI) classrooms.

A number of educational theorists and science education specialists are calling for reforms to science education pedagogy (Gess-Newsome & Lederman, 1995; Linn, diSessa, Pea, & Songer, 1994; Hurd, 1994; Jonassen, 1994; Jonassen, Mayes, & McAleese, 1991; Sarason, 1990; Yager, 1991). One of the reasons for this summons to reform is the belief that commonly used transmissive science instruction methods do not promote student understanding (Linn, et al. 1994, Snir & Smith, 1995; Yager). Yager explains that transmissive science instruction focuses on rote learning and repeated practice designed to elicit an appropriate response from the students—with little emphasis being placed on the students' understanding of the material. It is also believed that this lack of emphasis on student understanding contributes to the persistence of scientific misconceptions (Jonassen; Perkins & Unger, 1994; Yager, 1991). To illustrate this point, Yager (1991) claims that "many of the most able students (such as university physics majors and engineering students) have as many misconceptions about science as the average high school student" (p. 53). Citing a number of studies, Snir and Smith (1995) identify some of these misconceptions as an inability to differentiate between the following concepts: weight and density; dead and inanimate; heat and temperature; and force, energy, pressure and momentum. Science education may increase its effectiveness by focusing upon student responsibility, opportunities for interaction, greater degrees of independence, and the opportunity to evaluate and experiment with "what if" questions concerning problems and their solutions.

Meanwhile, a growing number of educational theorists believe computer technology must play a role in science educational reforms (Linn, 1987; Saloman, Perkins, & Unger, 1991; Snir &

Smith, 1995; Woodrow et al., 1996). Saloman, Perkins, and Unger (1991) claim, computer technology, perhaps more than any previous educational innovation, is expected to improve student learning and understanding. Bell (1992) states, "teachers desperately need the advantages that today's technology offers to address the many diverse needs of students..." (Pg. 6). While computer technology has been available to educators for a number of years, only recently has technology been successfully integrated into educational practice (Woodrow et al., 1996). The following paragraphs discuss computer use in education.

There is strong government support for computer purchases by schools. In British Columbia schools, computer technologies are becoming available to teachers and students in ever increasing numbers. The British Columbia Teachers Federation Task Force on Microtechnology In The Schools (1986) states, that from 1980 to 1985 the number of computers in B.C. schools increased from 100 to 8,000, and in 1985, public schools in British Columbia had one computer for every sixty students. In 1995, the British Columbia Ministry of Education announced that it intended to spend one hundred million dollars on technology over the next five years. Part of this sum is to be spent on achieving a student to computer ratio in secondary schools of three to one. The direction of the Ministry is clearly pro-computer use.

Computer technology has undergone a tremendous increase in efficiency and affordability. Now, as never before, moderately priced computers are able to help classroom teachers manage their workload with what has become known as computer managed instruction (CMI) (Kinzer, Sherwood, Bransford, 1986). Some examples of CMI include marks programs, sophisticated word processing programs, computer-tracked attendance, computerized report card comments, and test generating programs with their accompanying test banks. Such applications enhance teacher effectiveness with their speed and accuracy.

Application of computer technology (hardware and software) to assist in the students' education is known as computer assisted instruction (CAI) (Kinzer et al., 1986). Kinzer et al. identified four available types of CAI software: (1) drill and practice; (2) tutorial; (3) simulations; and (4) computer games. Early studies have identified both positive and negative aspects of CAI. Chambers and Sprecher (1983) found that CAI actively involved students in the learning situation, provided individualized self paced instruction, offered immediate feedback, and helped solve classroom behaviour problems. Careful examination of these benefits, however, indicates that other than affecting classroom management, this use of the technology shares the same benefits of early forms of programmed instruction and the earliest "teaching machines"—such as self-paced instruction and learner feedback (Heinrich, Molenda, & Russell, 1985).

Four identified detriments to CAI are: (1) overemphasis of factual based learning (Becker, 1986); (2) the observation of the high mortality rates of mechanical devices in schools (Miller, 1983); (3) possible stress reactions of children who are interacting with electronic media over prolonged periods (Jorde, 1987); and (4) the widespread problem of poorly programmed "drill sergeant" type software in which students quickly lose interest (Diem, 1986). However, all of these studies on the use of CAI were conducted in the previous decade with the technology available at that time. Given the rapid advancement in technology, the results of these earlier studies are possibly no longer applicable. In fact, the term CAI, the technology, and the research associated with it, is dated.

However, there is some very useful information regarding the computer technology used for CAI in the past: a documented knowledge base of its effectiveness in the classroom. The research literature from the past ten years provides qualitative and quantitative accounts of the technology available at that time; but, since computer technology is constantly evolving, it is difficult for the research knowledge base to keep up with the effects of the latest technologies.

Over the past ten years, educational computer applications have changed rapidly. It is a challenge to the innovative educator to keep up with the latest educational offerings and applications of computer technology. Linn (1987) claims that science educators have not yet satisfactorily met the challenge to revise traditional approaches to both technology and classroom teaching and set new priorities based on the new technologies and information available to them. New technologies are now available to increase the educational applications of computers. These technologies include interactive laser disc players, interactive CD-ROM players, hardware and software applications that allow computers to capture and playback audio and video clips, computers that read word processing files aloud, computer simulations that are able to realistically model situations either too complex or too dangerous to be easily demonstrated in the classroom, computer software interfaces that expedite extremely accurate data collection and analysis, and modems—allowing world wide information access and communication. Certainly the application of the early 1980's technology was extremely limited compared with the technologies and applications available today.

An example of a more recently developed educational application of technology is multimedia, and multimedia applications are now being used in B.C. classrooms. Moonen and Collis (1991), define multimedia in the following way:

> We will call a learning, instructional, or demonstration environment 'multimedia' if it makes use of two or more of the following media: text, graphics, sound, computer animations, photos, or moving video; connected (either electronically or conceptually) through a computer program; it supports interactivity between the learner and the media; and it shows aspects of the interactivity on one or more computer screens. (p. 209)

The purpose of multimedia in education is to provide the learner with the full range of learning experiences possible with a computer. Interactive multimedia educational applications include instructional presentations, student tutorials, and laboratory simulations.

Technology Enhanced Instruction (TEI) involves the use of technological resources to aid in student learning and access to information (Woodrow, Mayer-Smith, & Pedretti, 1997). A TEI classroom would include multimedia applications as well as other technological teaching tools such as microcomputer-based lab (MBL) interfaces and the associated data gathering probeware, interactive testbank software, laserdisc players, digital video discs, presentation software and projection equipment to present information and examples (Woodrow et al., 1996).

A TEI classroom will differ from traditionally instructed classrooms by more than just the availability and use of technology. For example, Collins (1991) predicts that as computers become integrated into classroom practice, teachers will shift from whole-class teaching toward small group instruction, and from lecturing to coaching. He indicates these changes will occur because the technology will take over the traditional "information presenter" role of teachers, allowing teachers to interact in new and more effective ways with their students. He also indicates corresponding changes to the roles of the students. Students will become more engaged, learn at their own rates, and become collaborative as opposed to competitive (Collins, 1991; Jonassen, 1994). Moonen and Collis (1991) claim, technology enhanced instruction has the potential to do more of the things we want to do in education—motivate learners, appeal to learners with different learning styles, stimulate problem solving and creativity, and bring the larger world into the classroom. Anderson & Klassen (1981) predict that the technology enhanced classroom will also help promote the ideals of computer literacy: that students will use the computer as a tool in their school work and that students will develop the necessary skills, understandings, and attitudes to function in a collaborative setting using computers.

Technology enhanced instruction is currently being used in British Columbia secondary school physics classrooms. The model of TEI currently being used in these classrooms is known as Technology Enhanced Secondary Science Instruction (TESSI). TESSI was initiated in 1991/92 by Dr. Janice Woodrow and two secondary school physics teachers—Aubry Farenholtz and Gordon Spann. The goal of the TESSI project is the integrated and effective use of instructional technologies in science pedagogy to enhance student learning (Woodrow et al, 1996). To paraphrase Woodrow et al.'s description of TESSI physics classrooms: TESSI project classrooms are permanently equipped with computer technologies such as eight computers for students use, a computer for teacher use, a laser printer station, a local area network to connect the computers to the print station and a multimedia centre (consisting of a TV, VCR, laserdisc player, and projection presentation system). The multimedia centre serves as both a teacher presentation centre and a student learning station. However, TESSI classrooms differ from traditional classrooms by more than just the availability of technology. The students in TESSI classrooms exhibit markedly different behaviour than their traditionally instructed peers. TESSI students work with study guides that direct them to the appropriate learning resources. The use of the study guides promote self-directed and self-paced learning. The students access learning resources such as computer animations and simulations, multimedia applications, laserdisc images and movies, data acquisition labs, traditional labs, and text and CD-ROM information sources. Because the student to computer ratio is usually about 3:1, students often work in small groups to complete activities together. Some benefits of these student work groupings include recorded instances of collaborative learning, peer instruction, and high rates of on-task behaviour. Most of the student's assessment is carried out interactively on the computers. The teacher's role in a TESSI classroom also differs from the role played by teachers in a traditional classroom. TESSI teachers rarely lecture, instead they provide "just in time" (Woodrow, et al., 1996, p. 243) instruction to the small student groups when the students encounter difficulties, have questions, or require other types of assistance.

It appears that the role of the students and the teachers in a TESSI physics classroom does indeed change in ways predicted by Collins (1991), Moonen and Collis (1991), and Anderson and Klassen (1981). One of the purposes of this study is to see if similar changes occur when the TESSI model is introduced in grade 12 biology classrooms.

B. Problem

The focus of this study is an evaluation of the application of technology enhanced secondary science instruction (TESSI) in biology. There is strong school and government support for increasing the availability of and accessibility to computer technology for British Columbia secondary school students. The diversity and nature of the hardware and software currently available has greatly outdistanced the existing research base. At this time, there are few studies available involving technology enhanced applications in education. There is a need for more research studies involving TEI to increase our understanding of this new pedagogical approach.

C. Research Questions

To evaluate the application of the TESSI model in Biology 12, the study addresses five questions: (1) Will the use of TESSI significantly increase student achievement in biology? 2) Will a statistically significant interaction occur between gender and mode of instruction (traditional vs. TESSI)? (3) Will the students' attitudes towards computers affect their performance in a TESSI biology classroom? (4) Will the students' attitudes towards computers be significantly affected by the use of TESSI and will there be a statistically significant interaction between gender and time of testing? and (5) What effects might previous computer experience have on student achievement in a TESSI biology classroom?

D. Significance of the Proposed Study

This study will be significant in the following ways: (1) the study will contribute to the knowledge base of TEI, (2) the study will investigate the effects of computer attitudes and computer experience on student achievement in a TEI classroom—two affective factors involving student performance that have not been previously researched, (3) the completion of this study will necessitate the design of new materials to incorporate TEI based on the TESSI model into biology instruction, and (4) the results of this study and the materials used during this study will be available for the use of other educators.

CHAPTER TWO

Literature Review

A. Computer Assisted Instruction

There are a number of studies related to the effects of computer assisted instruction. The majority of these studies have investigated the effects of various computerized simulations and instructional programs on student achievement, attitudes, and gender achievement equity.

One of the most valuable ways to assess the effectiveness of a new instructional technique is to evaluate its effect on student achievement. Lockard, Abrams, and Many (1994) provide a summary of eleven studies involving the use of CAI compared to standard instructional settings. The learning outcomes cover a diverse range involving different learning tasks. All of the studies indicated no significant differences in achievement between the computer using groups and the traditionally instructed groups.

Other studies, investigating the achievement of CAI in science education, have provided mixed results. Lewis, Stern, and Linn (1993) studied the effects of a computer simulation on the understanding of thermodynamics among grade 8 science students. Their results indicated significantly increased performance on an achievement posttest by the experimental group compared to a non-computer using control group. Choi and Gennarro (1987) studied the effectiveness of using computer simulated experiments to improve the students' learning of the volume displacement concept. They chose 111 junior high school students as their subjects. Their results indicated that there was no significant difference in performance on the posttest for the computer using experimental group when compared to the non-computer using control group but, the experimental group required only one fourth the time to perform equally well on the posttest. The results suggest that TEI may embrace benefits not yet clearly understood.

B. Gender Differences in Science Achievement

Gender differences, favouring males, are well documented in science achievement (Choi & Gennaro, 1987). Young and Fraser (1994), analyzed the Second International Science Study results. They found that statistically significant gender differences in science achievement, favouring males, existed for 10 and 14-year-old students and also for students in year 12 of high school. Using the British Columbia Science Assessments as one reference, Jovanovic, Solano-Flores, and Shavelson (1994), claim that by the time students reach the seventh grade, males' and females' performance on standardized tests of science achievement begin to diverge, with females falling behind males. Previous studies have indicated that CAI environments have reduced or eliminated gender differences in science achievement (Lazarowitz & Huppert, 1993; Lewis, Stern, & Linn, 1993; Hounshell & Hill, 1989).

C. Computer Related Attitudes

Very little research has been done involving computer attitudes in a technology enhanced environment. However, Woodrow (1994) claims it is important to investigate the effects of technology on students with regards to their attitudes, and that "it has not been clearly established which student characteristics and instructional procedures promote the acquisition of positive attitudes towards computers" (p. 310). Reece and Gable (1982) suggest that courses using computers must also promote the development of positive attitudes towards computers; otherwise computer implementation efforts are a waste of time and money. Simonson, Maurer, Montag-Torardi, & Whittaker (1987) agree with the preceding statement, they assert that the promotion of positive attitudes towards computers is a crucial factor in preparing students for success in a computer dependent society. However, in a three year long study of computer attitudes that tracked British Columbia secondary school students as they progressed from grade 8 to grade 11, Woodrow found that a negative attitude-age correlation existed. As a result of this finding, Woodrow suggests that to maintain positive attitudes among computer users, computers must be employed in ways that students continue to find valuable as they mature. Little is currently known with regard to how, or if, student attitudes towards computers will vary in a technology enhanced classroom.

D. Gender Differences in Computer Attitudes

There is evidence that there are gender differences in computer attitudes of secondary school students. Colley, Hill, Hill, and Jones (1995) indicate that abundant evidence exists to indicate that females like computers less than males do. In support of the preceding statement, Shashaani (1994) found secondary school aged females were significantly less interested in computers and significantly less confident in their computer abilities than males of the same age. Shashaani also found less significant effects favouring males for the perceived utility of computers in our society. Woodrow (1994) found, among grade 11 students, that males had significantly better attitudes towards computers than females on the following subscales: acceptance, confidence, and liking. No research studies are available to indicate if gender related differences in computer attitudes will affect achievement in a technology enhanced classroom.

E. Gender Differences in Computer Use Patterns

Gender differences regarding computer use patterns are also well documented (Busch, 1995; Colley, et al., 1995; Shashaani, 1994; Taylor & Mounfield, 1994). Colley et al. (1995) suggest that very marked gender differences exist regarding computer use, and they refer to this discrepancy as the "gender gap" (p. 20). Shashaani (1994) found that three times as many male secondary school students ranked in the "high use" category of computers as compared to females, and she also found that this gender based differentiation in use increased with student age. Similarly, Woodrow (1994) discovered that junior secondary age males use a computer more often than females of the same age group. Shashaani observed further gender differences regarding computer use: males take more computer courses than females, and males had significantly more experience in all aspects of computing. Shashaani also found that a lack of experience and activity with computers—as appears to be the case with female secondary students—was related to decreased participation and interest in computer related activities. This finding, that a lack of experience was related to participation, may be a factor that influences student success in a technology enhanced classroom. However, both Shashaani and Woodrow studied students in computer science courses where the students were learning about computers rather than using computers to learn.

There is evidence that the use of computers in non-programming environments can improve female students' attitudes towards computers while concurrently increasing their computer experience and literacy (Levin & Gordin, 1989). The technology enhanced classroom may represent the appropriate type of environment to accomplish this improvement. In fact, Baylor (1985) has determined that females develop more favourable attitudes towards computers than males in CAI environments. In support of this, Chen (1986) found that gender differences in attitudes disappeared in computer integrated classrooms that did not involve programming. Shashaani (1994) suggests that increasing females' exposure to computers "may help to break the cycle of 'computer dislike' and lack of computer experience" (p. 360). These earlier studies suggest there is a need to investigate effects of technology enhanced science instruction on gender differences in computer attitudes and use patterns.

F. Prior Computer Use and Achievement

Although the relationship between prior computing experience and achievement in technology enhanced science classrooms is currently unknown, Chambers and Clarke (1987) found that secondary students with prior computer experience participated more in class activities involving computers than those students who did not have such experience. However, no studies have been carried out to determine the effects of prior computing experience on science achievement in technology enhanced environments. The investigation of this relationship is important to determine factors that may influence student success in TESSI classrooms.

G. TEI Studies Involving Biology

Hounshell and Hill (1989), compared achievement in biology between a "computer loaded" experimental group and a control group. Students in the experimental group were using computers an average of sixty percent of each class. The instructor had 100 software items available to incorporate in the classroom. The control group consisted of students in traditionally instructed, non-computer using, classes. The study consisted of 202 volunteers in grades 10 -12 who had to take a required biology course. Of the 202 volunteers, 76 were randomly assigned to the control groups- consisting of five classes with no more than 15 per class, and the other 126 students were assigned to the comparison groups- with an average class size of 24. The study was conducted over 27 weeks. The authors chose the Comprehensive Test of Basic Skills, available from McGraw-Hill, to measure student achievement. This test has published reliability and validity data. The results of the study indicate that the computer loaded experimental group scored significantly higher ($p < .05$) on the achievement instrument.

Lazarowitz and Huppert (1993) conducted a four week study of junior science students with a focus on one particular computer software application. The purpose of the study was to determine if students using the software program "The Growth Curve of Microorganisms", developed by the authors, would demonstrate increased achievement on a content assessment test and a science processes test compared with a control group. Gender equity on the two instruments was also compared. The experimental and control groups performed the same lab investigations of bacterial growth. The experimental group was able to use the software to simulate changes in independent variables and predict their effect on bacterial growth. The control group learned the same content without using the software package. The study involved 181 students from five grade 10 biology classes. These students were randomly assigned into experimental and control groups. The experimental group consisted of 82 students divided into two classes. The control group consisted of 99 students divided into three classes. The experimental and control groups were taught by the same three biology teachers.

The results obtained by Lazarowitz and Huppert (1993) were (1) a two-way ANOVA indicated the experimental students scored significantly higher on the content assessment test than the control group; (2) the females in the experimental group achieved significantly higher scores than those in the control groups ($p < .01$), although no significant difference in the mean scores by gender within each group were reported; (3) MANCOVA analysis of the process skills test scores revealed the experimental group scored higher on four skills and significantly higher on three skills, and the control group scored higher on only one skill; and (4) only one gender specific significant difference appeared in the experimental group: females scored higher than males on control of variables. Females in the experimental group scored higher in five skills (two of them were significantly higher) compared to females in the control group. Males in the experimental group scored higher in five skills, but not significantly higher.

A pilot study conducted by Strauss and Kinzie (1994) involved the assessment of attitudes, achievement, and gender differences between two classes of high school biology students. One class of 9 students was chosen as the experimental group, and used a multimedia laserdisc frog dissection program. Another class of 11 students, the control group, performed a frog dissection in the traditional manner. The experiment was conducted over a short timeline: one-and-one-half periods for the control group and three periods for the experimental group. Strauss and Kinzie (1994) developed their own instrument to measure achievement and attitude. Content-related achievement and attitude test validity was established by five experienced biology teachers. Both measures were administered as pre- and posttests. Internal consistency reliability (alpha) estimates were 0.68 for the achievement test and 0.77 for the attitude questionnaire.

The results of the experiment were determined using a one-way ANOVA on the achievement pre- and posttest results of the two treatments. No significant differences were found between the experimental and control groups. Both groups performed significantly higher on the posttest. No significant difference was found by gender on the posttest in either group. The attitude test was mainly concerned with the students' attitudes towards conventional dissection practices. No differences were reported by gender. Two significant differences were reported (1) those students who used the simulation became less positive about the value of animal dissection and (2) those who did the conventional dissection became more positive about animal dissection.

While there appear to be a number of design and methodology problems in the Strauss and Kinzie study, the authors state that this was only a preliminary study and that follow up research needed to be done. Despite design and methodology problems, this study has been included here since it involved the use of up-to-date technologies in biology education.

H. Summary

Research into the effective use of computers to supplement instructional practices in science education has identified two trends that validate its practice. The trends are equal or increased achievement, sometimes occurring in less time and therefore more efficiently, and elimination of the gender differences that usually exist on science achievement tests.

CHAPTER THREE

Methodology

The purpose of this study is to evaluate the application of technology enhanced secondary science instruction (TESSI) in Biology 12. The research was conducted over the course of the cell ultraprocesses unit of Biology 12 at a secondary school in Langley, B.C. The sample consisted of all of the Biology 12 students enrolled at the school for the 1993/94 and 1996/97 school years. The 1993/94 students represented the traditionally instructed group, and the 1996/97 students represented the TESSI group. The first two research questions, involving a comparison of achievement and gender equity in achievement between the two modes of instruction (traditionally instructed vs. TESSI), were examined utilizing a posttest only analysis with non-equivalent groups. The last three research questions, involving the effects of student computer attitudes on achievement in a TESSI classroom, the effect of TESSI on student computer attitudes, and the effects of prior computer experience on achievement in a TESSI environment, utilized a one group pretest-posttest design, that consisted of only the TESSI group.

A. Application of the TESSI Model in Biology 12

The context of this study involves the application of the TESSI model to one unit of Biology 12 instruction. The TESSI biology classroom in this study was equipped with technologies such as eight student computers, a local area network, a teacher computer (that also acts as a network server), a laser printer, and a multimedia centre. The classroom was also supplied with the resources to provide the student instruction, such as laserdiscs, CD-ROMs, multimedia presentations, computer animations and simulations, and data acquisition probeware. The TESSI biology students were supplied with a study guide, prepared by the researcher (see APPENDIX F), that directed them to the appropriate instructional resources. The study guide used in this study was modeled after the study guides developed for use in the previously described TESSI physics classrooms, and included a similar format—including a similar structure and the use of many of the same icons used in the physics guides. The researcher also adopted and adapted classroom routines similar to those utilized by the TESSI physics teachers. These routines included the: (1) promotion of student-centered learning that focused on the use of the technological resources rather than teacher-directed lecturing, (2) encouragement of small group work, (3) practice of having the students write interactive quizzes on a computer when they felt adequately prepared to do so, (4) practice of allowing the students to rewrite an equivalent, but different, interactive quiz if they did not reach their personal goal on their first try, and (5) establishment of a global date for the unit test. Although not specifically addressed in the following research questions, the researcher wondered whether students learning biology using the TESSI model would exhibit patterns of behaviour—such as collaborative learning and self-directed learning—similar to those reported for physics students in Woodrow et al.'s (1996) study.

B. Research Hypotheses

Five null hypotheses were evaluated to provide information related to the problem:

1. There will be no statistically significant difference in biology achievement between traditionally instructed students and students taught using the TESSI model.
2. There will be no statistically significant interaction between gender and mode of instruction (traditional verses TESSI) on biology achievement.
3. Student attitudes towards computers will have no statistically significant affect on achievement in a TESSI biology classroom.
4. There will be no statistically significant differences in attitudes towards computers for TESSI group students by time of testing, and there will be no statistically significant interaction between gender and time of testing on computer attitudes.
5. Previous computing experience will have no statistically significant effect on achievement in a TESSI biology classroom.

C. Unit of Study

This study investigated the application of the TESSI model as applied to Biology 12. In British Columbia, Biology 12 students study cell biology and human anatomy and physiology.

This study was conducted over the course of a cell biology unit entitled cell ultraprocesses. The cell ultraprocesses unit was chosen for the study because it is generally regarded as the longest and most comprehensive unit in the Biology 12 curriculum. During the cell ultraprocesses unit, students typically study the movement of substances into and out of cells, the role of enzymes in metabolic reactions, and the metabolic reactions of the cells themselves—including the reactions of the cellular respiration pathway. The completion of this unit takes approximately 6 weeks in schools where the students take approximately three 1 hour classes of biology each week.

D. Site Selection

The research for this thesis took place in a secondary school in Langley, B.C. Two reasons existed for the site selection. The first reason is that the researcher is the biology teacher at the participating secondary school. The second reason is that the Ministry of Education School Information Profile 1993/94 (1994), lists the Langley school district as typical on 25 out of 27 criteria it specifies. The typicality of the Langley school district should positively effect the generalizability of the study.

E. Sample Selection

The sample in this study consisted of 96 students enrolled in Biology 12. The traditionally instructed group consisted of all 37 students (8 males and 29 females) enrolled in Biology 12 (2 classes) during the 1993/94 school year. The TESSI group consisted of 59 students (32 females and 27 males) enrolled in all three of the Biology 12 classes offered at this school during the 1996/97 school year. The reason for choosing the 1993/94 classes (as opposed to a more recent year) is that the researcher has been employing alternate teaching strategies over the past two years, and therefore the 1993/94 classes were the most recently available traditionally instructed classes. The higher enrollment in the 1996/97 Biology 12 classes is due to both an increase in school enrollment, and an increase in the Biology 12 participation rate from 35% in 1993/94 to 52% in 1996/97. Permission of the District Administrator was received prior to the commencement of the study. In addition, informed consent was obtained from the subjects' parents and the subjects.

F. Instrumentation

Instruments were chosen to provide data on achievement, gender, and computer use and attitudes. All instruments were administered as pre- and posttests to the TESSI group. However, the traditionally instructed group was only given a posttest of the achievement instrument because their participation was *ex post facto*.

The achievement test was composed of a unit test identical to the one given to the researcher's 1993/94 Biology 12 students on the cell ultraprocesses unit. The questions were obtained from a computer test bank prepared by the researcher and two other Biology 12 teachers from the researcher's school district. The researcher attempted to establish both content-related and criterion-related evidence of the instrument's validity. The content-related evidence of the validity of this instrument was determined by the researcher and two other Biology 12 teachers by establishing 100% consensus on the relevance of the items to the B.C. curriculum. The criterion-related evidence of validity of this instrument was determined by correlating the 1993/94 biology students' grades on the achievement instrument with their grades on the June 1994 biology provincial exam. The Pearson correlation coefficient between the student scores on these two measures is .76. Since criterion-related evidence of instrument validity is usually considered adequate with correlations greater than .75 (Shumacher & McMillan, 1993), the achievement instrument in this study seems to provide valid inferences of biological knowledge. The reliability of the achievement instrument was also determined. Reliability figures were determined by a pilot administration of the test at a site separate from the research site. The reliability, measured by the Cronbach Alpha method, was determined to be .84. Since the calculated reliability of .84 exceeds the generally accepted adequacy value for achievement instruments of .80 (Shumacher & McMillan, 1993), the achievement instrument used in this study has adequate reliability.

The instrument used to assess student computer attitudes was the Computer Attitude Scale (CAS). The CAS was designed by Gressard and Loyd (1987), and the CAS instrument measures computer anxiety, computer confidence, and computer liking by using a 5 point Likert scale ranging from strongly disagree to strongly agree. Higher scores represent better attitudes on each of the subscales. The CAS was evaluated by Woodrow (1991) for reliability. The Cronbach Alpha reliability of this instrument has been determined by Woodrow (1991) to be 0.94, who also states that there is adequate evidence of criterion-related validity with regards to this instrument. However, while Woodrow (1991) indicates the total instrument score appears to represent an excellent, reliable measure, she cautions against the use of the subscale scores for the measurement of various dimensions of attitudes towards computers. This caution is warranted because Woodrow found evidence that the instrument measures only two attitude dimensions (computer anxiety and computer confidence) and not three as the Computer Attitude Scale developers claimed. As a result, the statistical analysis in the present study was conducted on the total instrument scores as opposed to the separate subscale scores. The researcher has incorporated an additional section on the attitude instrument to obtain demographic information regarding student gender and computer experience (see APPENDIX C).

G. Research Design

In order to address the purpose of this study, two research designs were used (see Figures 1 and 2). The first design, used to address the first two hypotheses, consisted of an alternate treatment posttest-only with nonequivalent groups analysis. The second design, used to address hypotheses three through five, consisted of a one group pretest-posttest design. The alpha level of significance was set at .05 prior to the beginning of the study.

The alternate treatment posttest-only with nonequivalent groups design (see Figure 1) was used in order to identify whether a difference in achievement and/or a difference in achievement by gender existed between the traditionally instructed group and the TESSI group. Both the traditionally instructed group and the TESSI group received the same achievement posttest based on the cell ultraprocesses unit. An analysis of covariance (ANCOVA) statistical procedure, rather than an analysis of variance (ANOVA) procedure, was chosen to evaluate the posttest achievement data because ANCOVA helps to compensate for differences between the nonequivalent groups based on the covariates chosen for the analysis. The covariate used in the statistical analyses consisted of the sum of the students' grade from their Science 10 course added to their grade from their Biology 11 course. The rationale for this choice of covariate was that the Science 10 grade was a good indicator of each individual's general science knowledge, while the Biology 11 covariate served as a better measure of their biology knowledge. One-way ANCOVA and factorial ANCOVA was used on the data obtained by the posttest achievement instrument to determine if any significant main effects in the samples exist. The data provided by the factorial analysis procedure was also examined to determine if statistically significant two-way interactions exist.

A one group pretest-posttest design (see Figure 2) was used in order to address the effects of computer attitudes, computer experience, and gender differences in computer attitudes and experience on achievement and attitude changes. The computer attitude instrument was administered to the students in the researcher's 1996/97 biology classes as a pretest prior to the commencement of the students' computer use. This instrument, excluding the background computer information section, was readministered at the conclusion of the cell ultraprocesses unit (approximately 11 weeks after the pretest). The achievement instrument was administered as a pretest prior to the cell ultraprocesses unit and then readministered six weeks later as a posttest at the conclusion of the unit. The reason for the differing lengths of time between the pretest and posttest administration of the attitude and achievement instruments is that the researcher thought the computer attitude pretest should be administered before the students actually began using the computers, and since the TESSI students started using the computer technology before the cell ultraprocesses unit researched in this study began, the administration of the computer attitude pretest occurred five weeks before the administration of the cell ultraprocesses achievement pretest. Students who wrote the pretests were tracked throughout the study. Students with incomplete data sets were deleted from the final statistical analysis. Univariate repeated measures ANOVA was used on the data obtained by the pretest and posttest administration of both the computer attitude and achievement instruments to determine if any statistically significant differences in the samples exist with regards to the main effects tested and any two or three-way interactions that occurred. Univariate repeated measures analysis was chosen to analyze the data because: (1) the procedure can determine statistically significant increases between the pre and posttest administration of a dependent variable by the different levels of the independent variables tested, (2) the procedure provides increased statistical power to find a significant difference if it exists over standard analysis of variance or t-test procedures, and (3) the procedure has the capability to analyze both the main effects and interactions presented by the independent variables (Lomax, 1992). Homogeneity of variance tests were conducted simultaneously with the statistical analyses to ensure that the data were suitable for the statistical tests being performed.

Figure 1. Diagram of achievement comparison analysis.

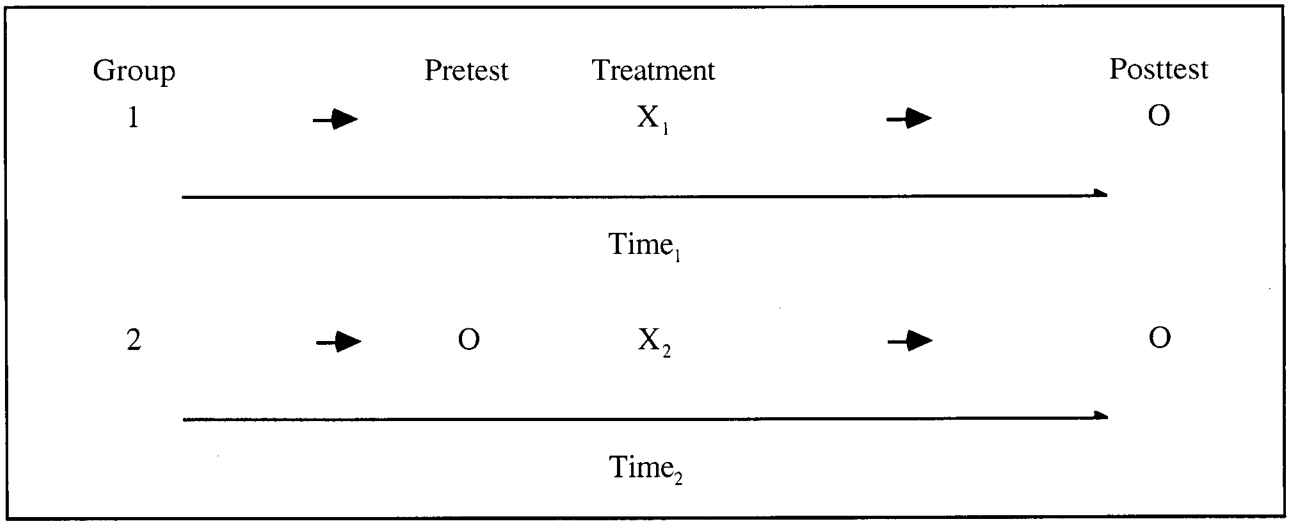
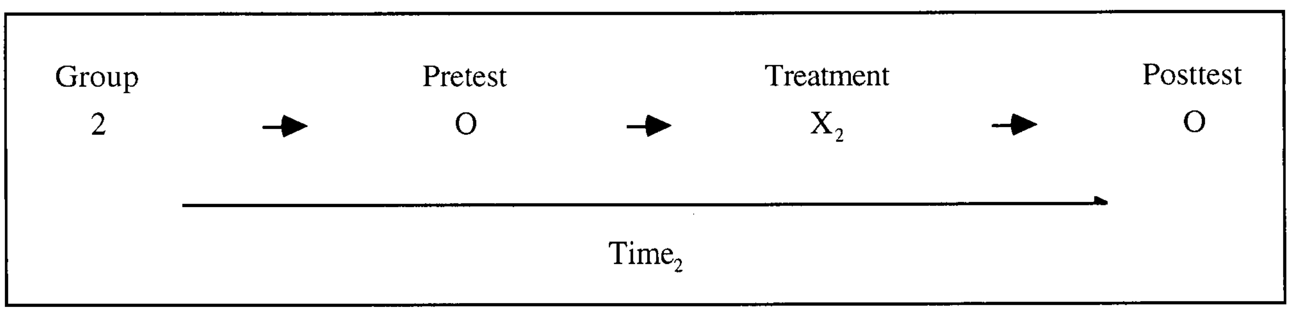


Figure 2. Diagram of computer attitude and computer experience design.



Legend for Figure 1 and Figure 2.

O = the administration of the instrument(s)

1 = traditionally instructed group

2 = TESSI group

X_1 = traditional instruction (administered at $Time_1$)

X_2 = technology enhanced (TESSI) instruction (administered at $Time_2$)

In addition to the quantitative techniques used in this study, the researcher also conducted qualitative observations of the TESSI group. The researcher's role was that of participant-observer

(Shumacher & McMillan, 1993). A participant-observer is an interactive research role assumed when a researcher has a role in the site he or she intends to study (Shumacher & McMillan, 1993). In this study, the researcher had a role as the students' teacher. To obtain the necessary qualitative data, the researcher recorded written, systematic observations of the participants as they interacted with the technology, the researcher, and each other over the course of the cell ultraprocesses unit. These observations were recorded in a journal and also on a diagram that showed the physical layout of the classroom. The researcher recorded such observations for 33 of 36 classes. The researcher missed three classes due to absence. The collected data were then used to add further evidence and insight to the findings of the study in the following ways: (1) after determining the statistical results for each hypothesis, the researcher then coded the qualitative observations to determine what, if any, hypotheses they applied to; and (2) the researcher then included the qualitative observations he judged to be relevant to the quantitative findings into the presentation of data in Chapter Four.

H. Variables

The independent treatment variable in this study was the method of biology instruction: traditional (lecture) instruction vs. TESSI. The categorical subject variables used in this study were gender, background computer experience (categorized into high, medium, and low blocks), and computer attitudes (also categorized into high, medium, and low blocks). The dependent variables in this study were the Biology 12 cell ultraprocesses unit test and the Computer Attitude Scale.

I. Data Collection

Informed consent of all participants in the researcher's 1996/97 biology classes was obtained during the first week of classes in September 1996. Consent was granted by all but one of the students' parents. Those students whose parents had consented to their participation also gave their own consent.

The Computer Attitude Scale, including the section on background student computer use was administered to the TESSI classes, in the form of a pretest, during the third week of

September 1996. The achievement test was administered as a pretest to the TESSI group in the first week of November 1996—just prior to the beginning of the cell ultraprocesses unit. Both the Computer Attitude Scale (without the background computer use section) and the achievement test were administered as posttests to the TESSI group during the third week of December 1996. The achievement test was administered to the traditionally instructed group during the third week of December 1993. A high response rate was obtained for the TESSI group instruments. Complete data sets were obtained on 59 of the 65 students enrolled in Biology 12 as of September 1996.

J. Summary

The purpose of this study was to evaluate the application of TESSI in a Biology 12 setting. The study included two research designs: an alternate treatment posttest-only with nonequivalent groups analysis, and a one group pretest-posttest design. Both research designs were carried out over the course of the Biology 12 cell ultraprocesses unit. The sample consisted of all the Biology 12 students enrolled in a secondary school in Langley, B.C. during the 1993/94 and 1996/97 school years. The 1993/94 students represented the traditionally instructed group and the 1996/97 students represented the TESSI group. The instruments chosen were an achievement test designed to assess the students' knowledge of the cell ultraprocesses unit and a computer attitude instrument. All students in the study wrote the achievement posttest, and the TESSI students wrote both pretests and posttests of the achievement instrument and the computer attitude instrument. One-way ANCOVA and factorial ANCOVA were used to find if a significant difference on the achievement posttest existed between the traditionally instructed group and the TESSI group or by gender. Univariate repeated measures ANOVA and qualitative observations were used to determine: (1) if prior computer experience or computer attitudes affected achievement among the TESSI students, and (2) if the computer attitudes of those students in the TESSI group changed over the course of the study. The results of these analyses are presented in Chapter Four.

CHAPTER FOUR

Presentation of Data

The purpose of this study was to investigate the effects of technology enhanced biology instruction, following the TESSI model, to determine if certain student variables such as previous computer use and attitudes towards computers affect student achievement in a TESSI environment. The data obtained from the achievement instruments and the computer attitude questionnaires were analyzed using SPSS for the Power Macintosh Version 6.1.1. Descriptive statistics are presented to clarify the characteristics of the sample. Inferential statistics related to the various hypotheses were used to analyze the data. Results of statistical significance and theoretical interest are included in the discussion.

A. Description of the Sample

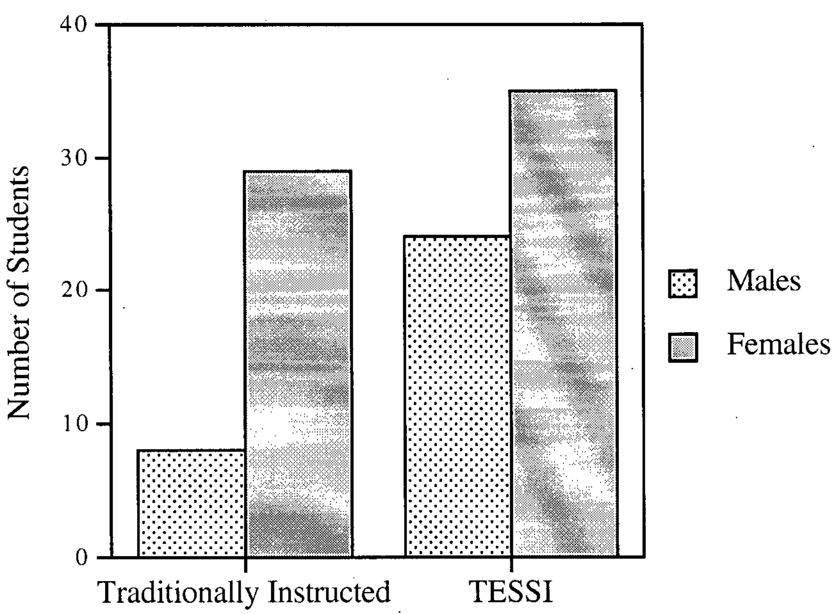
This section describes student background for the purposes of defining the sample and providing information concerning the generalizability of the results. Both the traditionally instructed and TESSI groups' background are described in terms of size, composition, and gender (see Figure 3).

The traditionally instructed group (N=37) was composed of the entire 37 students enrolled in the researcher's two 1993/94 Biology 12 classes. Of these 37 traditionally instructed students (8 males and 29 females), 21% (n=8) were grade 11 students (7 females and 1 male) on an accelerated program. These accelerated students did not take a Science 10 course, instead they proceeded directly from Science 9 into Biology 11 followed by Biology 12. The remaining 29 students were in Grade 12 and had each taken science courses from grade 8 to grade 12. All of the traditionally instructed students were fluent in English.

Sixty five students were enrolled in the researcher's three 1996/97 Biology 12 classes at the beginning of the year. Of these 65 students, complete data sets were obtained for 59 students. The six students with incomplete data sets were deleted from the study. Two of the students with incomplete data sets transferred schools, one student developed an attendance problem, one student's parent refused her participation in the study, and two other students missed the administration of the posttests due to illness. The remaining 59 complete data sets were useable and the results are reported in this document.

The TESSI group (N=59) was composed of 27 males and 32 females. Of the 59 TESSI group students, 23% (n=14) were grade 11 students (6 males and 8 females) on an accelerated program. Unlike the accelerated grade 11 students in the traditionally instructed group, the grade 11 students in the TESSI group had completed a combined Science 9/Science 10 course. The remaining 46 students were in grade 12 and had each taken a full complement of junior science courses. In addition, the TESSI group included two English-as-a-second-language students (1 male and 1 female).

Figure 3. Gender composition of traditionally instructed and TESSI groups.



The next five sections will provide a detailed description of the data used in the analyses of hypotheses one through five, the methods of statistical analyses employed, the results of the analyses, and the assessment of the hypotheses based on the results of the analyses. Cochrans and Bartlett-Box Homogeneity of variance tests conducted on the data undergoing analyses were all determined to be nonsignificant. These nonsignificant findings indicate the data used in this study were suitable for the parametric analyses conducted. Since hypotheses three through five involved only the TESSI group, these hypotheses were investigated both quantitatively and qualitatively (there were no qualitative observations available for the traditionally instructed group because their participation was *ex post facto*). In the case of hypotheses three through five, the quantitative statistical analysis have been used to verify or reject the hypotheses, and the qualitative findings have been used to add insight to the quantitative findings.

B. Hypothesis One

Hypothesis one proposed that there would be no statistically significant difference in achievement between the traditionally instructed group and the TESSI group on an achievement posttest for the cell ultraprocesses unit. To assess this hypothesis, mean scores on the achievement posttest were determined for each of the two groups (see Table 1).

The achievement posttest scores for each group were tested using a one-way analysis of covariance (ANCOVA) procedure. The covariate used in this procedure consisted of the sum of the student's Science 10 and Biology 11 grades. The result of the ANCOVA procedure indicates that there was no significant difference in achievement between the two groups on the posttest achievement instrument. As a result, null hypothesis one was not rejected.

Table 1

Achievement Posttest Mean Scores and Standard Deviations for the Traditionally Instructed and TESSI Groups

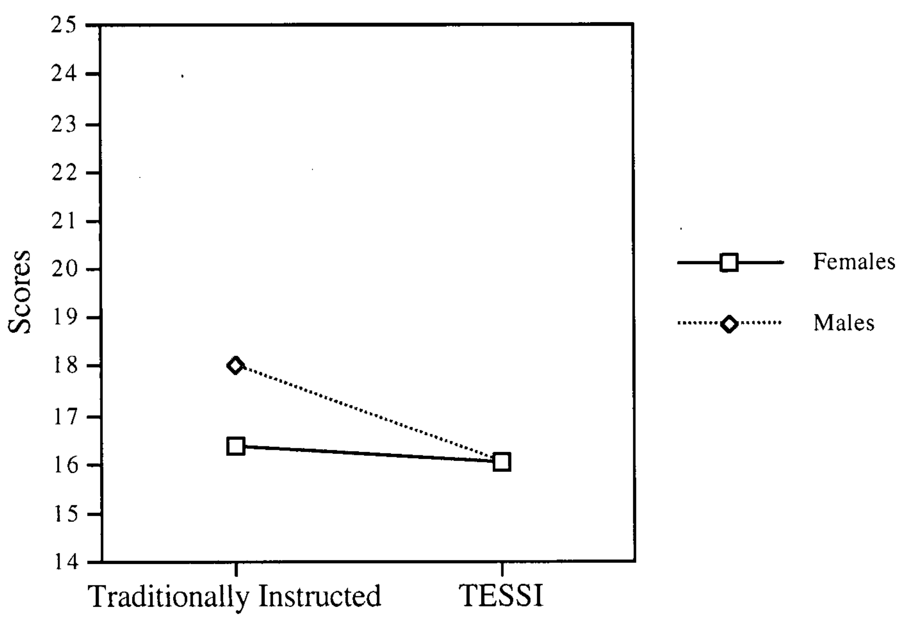
	Traditionally Instructed Group			TESSI Group		
	N	$\overline{X}$	SD	N	$\overline{X}$	SD
Entire Sample	37	16.73	4.92	59	16.06	5.15
Males	8	18.00	4.52	27	16.04	5.04
Females	29	16.38	5.04	32	16.07	5.05

C. Hypothesis Two

Hypothesis two stated that there will be no statistically significant interaction between gender and mode of instruction (traditional verses TESSI) on biology achievement. To test this hypothesis, means scores on the achievement posttest were examined by group (traditionally instructed vs. TESSI) and by gender (see Table 1).

The means for achievement posttest scores by gender within each group were tested using factorial ANCOVA. As in hypothesis one, the covariate consisted of the sum of the student's Science 10 and Biology 11 grades. No statistically significant interaction was found between gender and mode of instruction (traditional vs. TESSI) on achievement. Therefore, the difference in biology achievement by gender in traditionally instructed and TESSI classes was not significant. Additionally no significant differences were found by gender for the traditionally instructed group's achievement posttest scores or the TESSI group's achievement pretest or posttest scores. As a result of this analysis, null hypothesis two was not rejected. Figure 4 shows a graphical representation of the mean achievement scores on the ultraprocesses unit posttest by group and by gender.

Figure 4. Interaction graph of achievement posttest scores vs. group by gender.



D. Hypothesis Three

Hypothesis three states that student attitudes towards computers will have no statistically significant affect on achievement in a TESSI biology classroom. To test this hypothesis, the students were blocked according to their pretest computer attitude scores into high, medium, or low categories (see Table 2). The maximum attainable score on the attitude test was 150. Students were blocked into their respective categories as follows: a score on the attitude test between 0 - 98 was counted as low, a score between 101 - 116 was considered medium, and a score between 117 - 150 resulted in a high designation. The divisions between the attitude categories were chosen to ensure the formation of at least three categories yet still maintain large enough sample sizes within each category to allow the statistical tests to be performed on the data. The raw data used to determine the students' computer attitude category is presented in APPENDIX A. The data by category was then analyzed by a univariate repeated measures procedure that was performed on the students' pretest and posttest achievement scores. The data was analyzed for the main effects of computer attitude category, time of testing (pretest vs. posttest administration of the achievement instrument), and gender on achievement. The data was also examined for significant two and three-way interactions.

No significant main effect was found for computer attitude category on achievement. This finding indicates that there was no statistically significant relationship between student computer attitude category and achievement. In addition, no significant main effect was found for gender; however, a significant main effect was found for time of testing, $F(1,57) = 121.61$, $p<.001$. This finding indicates that the TESSI students significantly increased their scores from pretest to posttest administration of the achievement instrument (see Table 3). No significant two-way interactions were found between attitude by gender, attitude by time of testing, or gender by time of testing on achievement, and no significant three-way interaction was found between computer attitude by gender by time of testing on achievement.

Because there was no statistically significant main effect for computer attitude category on achievement, null hypothesis three was not rejected.

Table 2

Achievement Pretest & Posttest Mean Scores for all TESSI Group Students by Student Computer Attitude

	All			Males (N = 27)			Females (N = 32)		
Attitude	N	Pre-test	Post-test	N	Pre-test	Post-test	N	Pre-test	Post-test
Low	21	8.7	16.6	9	8.9	15.4	12	8.7	17.5
Medium	18	8.1	15.7	6	8.5	16.5	12	8.0	15.2
High	20	10.0	15.7	12	10.7	16.0	8	9.1	15.2

Table 3

Univariate Repeated Measures Analysis Summary Table for Achievement by Computer Attitude Subscale, Gender, and Time of Testing

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO
Between Subjects				
Attitude	8.96	2	4.48	.19
Gender	3.64	1	3.64	.15
Attitude by Gender	25.09	2	12.54	.53
Error	1260.63	53	23.79	
Within-Subjects				
Time	1344.90	53	11.06	121.61*
Attitude by Time	22.26	5	11.13	1.01
Gender by Time	4.22	1	4.22	.38
Attitude by Gender by Time	10.55	2	5.28	.48
Error	586.13	53	11.06	

*p<.001

Qualitative observations analyzed for hypothesis three add further insight to the quantitative finding that the students computer attitudes did not affect their achievement. The researcher's observations revealed that the student's computer attitudes also did not appear to correlate with their observed interactions with the technology. For example, Anna, a female student who had the fourth lowest attitude score among all of the TESSI students, was a member of a very productive and collaborative grouping. When Anna's group was proceeding through a computer activity, Anna appeared self-assured and, in fact, was usually the person controlling the mouse—and therefore the pace of the instruction. Anna's group consisted of four members (one male and two other females) who performed virtually all of the multimedia activities together—gathering the required number of headphone splitter jacks and headphones and assembling around one computer station. However, when an individual effort was required—such as writing an on-line interactive test—Anna was observed to competently perform this task as well. Anna also did very well on the achievement posttest (22/25), thus for her and the other members of her group (with more average computer attitudes), self-motivation appeared to play as important a role in their success as their computer attitudes.

However, such effective use of the technology was not demonstrated by all students. Another student, John, who scored a very low 49/150 (the second lowest score among the TESSI group) on his computer attitude test, was observed to interact with the technology in a manner very different from Anna. John often worked in a group with three other students (one male and three females). One of John's partners, Matt, also had low attitude scores, but the two females in the group were classified into the medium attitude and high attitude category. John's group was often far less productive than Anna's. Interestingly, John's group was also less likely to try new technologies as they were introduced to the class. For example, because of early accessibility problems with the laserdisc player, the multimedia animations from the laserdiscs were digitized and placed on the computer workstations for the students to view. This digitized use of technology provided improved access to the information resources and decreased distractions for the students (access to the information was improved because there were eight computer stations as opposed to only one laserdisc player in the classroom, and because students could use headphones at the computer stations, it also lowered the classroom noise level and resulted in fewer distractions for the students). However, John's group continued to be the only group in this class to continue to use the laserdisc technology—somewhat to the dismay of other students in the room who were distracted by the audio output from the laserdisc (headphones could not be used with the laserdisc player). None of the members of John's group scored highly on the achievement posttest—they scored from a low of 12 to a high of 15 out of 25. Again, motivation and/or interest appeared to be more of a factor in this group's achievement than computer attitudes.

Two more interesting cases are those of Gus and Misty. Each of these students had the top attitude scores for their respective gender, each was highly self-motivated, and exhibited similar, introverted behaviours. Both Gus and Misty scored very well on the achievement posttest, and both also preferred to work alone. These two students were confident in their abilities both academically and technologically. Also interestingly, they were not seen participating in the commonly observed behaviors of peer-tutoring or collaboration. Gus and Misty appear to be self-directed, successful, and happy to keep their knowledge to themselves.

In general, no definite pattern of computer use, group dynamics, or achievement pattern related to computer attitudes were identified qualitatively. Although 3 of 57 students in the study had decreased scores from the achievement pretest to the achievement posttest and 9 students improved by 5 marks or fewer, only one of these students was categorized as having low computer attitudes, and as the quantitative results verify, there appears to be no striking evidence of computer attitude affecting achievement.

E. Hypothesis Four

Hypothesis four proposed that there will be no statistically significant differences in attitudes towards computers for the TESSI students by time of testing, and there will be no statistically significant interaction between gender and time of testing on computer attitudes. This hypothesis was tested by utilizing the computer attitude pretest and posttest scores for the Computer Attitude Scale (see Table 4).

Table 4

Computer Attitude Pretest and Posttest Mean Scores and Standard Deviations for the TESSI Group

		Pretest		Posttest	
Variables	N	$\overline{X}$	SD	$\overline{X}$	SD
Entire Sample	59	105.88	19.96	108.78	17.65
Males	27	109.67	21.09	115.00	16.06
Females	32	102.69	18.69	103.54	17.46

A univariate repeated measures ANOVA statistical procedure was carried out on the computer attitude pretest and posttest scores by gender and time of testing to determine the effect of TESSI biology instruction on computer attitudes. The data was analyzed for the main effects of time, gender, and the two-way interaction of gender by time of testing on attitudes. Figure 5 shows the interaction graph of the mean scores used in this analysis. No statistically significant main effect was found for time of testing (see Table 5). This result indicates that the TESSI group students did not significantly increase their computer attitudes from pretest to posttest. Although not related to the hypothesis being tested, a statistically significant main effect was found for gender, $F(1,57) = 4.17$, $p<.05$ (see Table 5). This result indicates that the male students scored significantly higher on their mean combined attitude pretest and posttest than did the female students. No statistically significant interaction between gender and time of testing was determined (see Table 5 and Figure 5). This result indicates that the joint effect of gender and time of testing on computer attitudes was not significant. As a result of this analysis, null hypothesis four was not rejected.

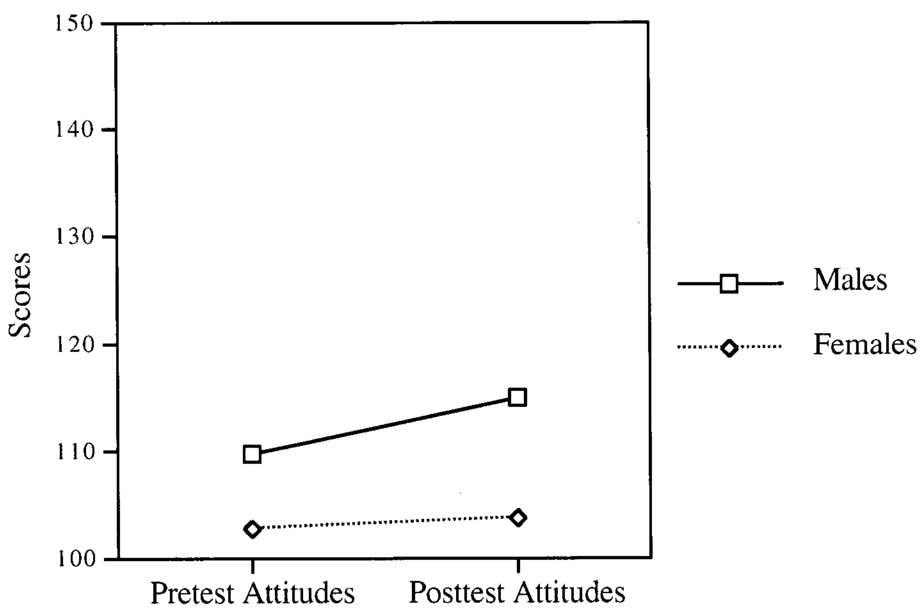
Table 5

Univariate Repeated Measures Analysis Summary Table for Computer Attitude Pretest and Posttest Scores by Gender and Time of Testing

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO
Between Subjects				
Gender	2491.88	1	2491.88	4.17*
Error	34076.73	57	597.84	
Within-Subjects				
Time	279.38	1	279.38	3.55
Gender by Time	147.59	1	147.59	.176
Error	4480.11	57	78.60	

*p<.05

Figure 5. Mean computer attitude pretest and posttest scores by gender.



The researcher's findings as participant-observer contributed some interesting information on computer attitude changes of the TESSI students. Barry, a male student, who scored in the medium range for computer attitudes, responded to the question of how he was enjoying this class as follows, "At the beginning of the year [when the class first started to use computers] I thought oh - oh...but now I really like it." When Barry was asked if he thought the technology was helping him learn. He responded, "Yes. It provides more choices...more resources to reinforce what you're learning—going beyond the textbook...It's good. I've changed the way I study now—from more than one thing" (classroom conversation with teacher, November 1996). Clearly, despite his early apprehensions, Barry enjoyed the class and his results indicate he was successful in accessing information from a number of different sources. Interestingly, the above comments were recorded after Barry had written his attitude pretest, but his attitude posttest score was exactly the same as his pretest. This suggests the attitude instrument was not sensitive to the particular changes in Barry's attitudes towards the technology that he expressed in his conversation.

Two other students, Mary and Li-Chang, provided a more international perspective. Both are ESL students. Mary has recently immigrated from Europe and Li-Chang is a landed immigrant from Asia. Mary, despite having very low attitude pretest scores, actually invited her mother into the classroom one day at lunch and demonstrated examples of the technology we were using. Her mother, who studied biology overseas, was impressed and indicated that she wished they had this when she was in school. Li-Chang, a student with medium computer attitudes, was twice observed coming in after school to view the multimedia animations. When asked what he liked about the technology, he said, "I like it because, when the teacher is talking I miss sometimes what he is saying because my English is not so good. But this way I can replay the movie as many times as I need to understand" (classroom conversation with teacher, November 1996). Mary's pretest attitude score was the third lowest in the class at 64. Despite her apparent enthusiasm for the technology, her attitude posttest score only increased to 69. Li-Chang's computer attitude increased from pretest to posttest, particularly on the anxiety subscale—indicating his anxiety towards computer use had decreased. In Mary's case, perhaps the instrument again was insensitive to observed changes in her attitudes, or perhaps her enthusiasm for the technology could be attributed to a novelty effect that had worn off before her attitude posttest.

The qualitative results suggest that at least some of the student's attitudes may have changed in ways that may not have been measured by the attitude instrument. The quantitative results indicate that statistically significant changes in attitudes for the TESSI students did not occur over the course of this study and there was no statistically significant interaction between gender and time of testing on computer attitudes.

F. Hypothesis Five

Hypothesis five stated that previous computing experience will have no statistically significant effect on achievement in a TESSI biology classroom. To test this assumption, the TESSI group was blocked according to their prior computer experience (see Table 6). Assignment to an experience block was conducted by assigning numerical values to the items from the demographic portion of the attitude instrument that indicated the students previous experience with computers. The items chosen by the researcher to indicate computer experience were the number of computer courses taken and hours of computer use per week for each student. The sum of the preceding numerical values, a maximum sum of 9, was then used to block the students into the appropriate category. Students with a total between 1 - 3 were assigned to the low category, a score of 4 - 5 resulted in a medium designation, and a score of 6 - 9 elevated the subject to the high classification. Categories were created to obtain at least three levels of computer use and still maintain adequate sample sizes within each category to facilitate the statistical analysis. The raw data used to determine the students' computer experience category is presented in APPENDIX B. The mean scores and sample sizes of each category are indicated in Table 6. The meaning of the "low" categorization requires further clarification as follows. Although the students in the low computer use category did have far less experience than the students in the "high" use category, only five of the students in the low experience group (a sample too small for statistical analysis) actually had quite limited computer experience. These five students (two females and three males) indicated that they had not taken any computer courses and they also indicated two hours or less of computer use per week. The remaining 15 students in the low category indicated a more moderate level of computer experience. Overall the students in the TESSI group indicated that they were quite experienced at using computers: ninety two percent of the TESSI group indicated having taken at least one computer course, and sixty one percent claimed to have had two or more computer courses. Furthermore, all but four of the TESSI students indicated owning home computers. Because of the generally high level of computer experience for the students, the classification of students into the low computer experience category is best regarded as relative to the computer experience of the other TESSI students, as opposed to meaning that the students in the low category had limited computer experience.

A univariate repeated measures analysis was carried out on the resulting experience blocks for the main effects of time of testing (pretest vs. posttest administration of the achievement instrument) and gender on achievement. The data was also examined for significant two and three-way interactions. In addition, to support the researcher's interest in gender related issues, the data was also examined by one-way ANOVA to determine if there was a statistically significant difference in computer experience by gender.

The analysis of the subject blocking by computer experience revealed no statistically significant main effects for computer experience for all subjects or by gender on the dependent variable of achievement (see Table 7). The TESSI group significantly increased their achievement scores by time of testing $F(1,53) = 110.63$, $p<.001$ (see Table 7). No significant two or three-way interactions were found. In addition, no statistically significant effect was found for computer experience by gender. As a result of these analyses, null hypothesis five is not rejected.

Table 6

Mean Achievement Pretest & Posttest Scores by Background Student Computer Experience

	All			Males (N = 27)			Females (N = 32)		
Computer Experience	N	Pre-test	Post-test	N	Pre-test	Post-test	N	Pre-test	Post-test
High	15	9.6	14.6	10	9.9	14.2	5	10.0	15.4
Medium	24	8.9	16.8	9	10.4	18.0	15	8.1	16.0
Low	20	8.4	16.1	8	8.2	15.6	12	8.5	16.5

Table 7

Univariate Repeated Measures Analysis Summary Table for Achievement by Computer Experience, Gender, and Time of Testing

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO
Between Subjects				
Experience	18.64	2	9.32	.40
Gender	2.97	1	2.97	.13
Experience by				
Gender	52.94	2	26.47	1.13
Error	1236.60	53	23.33	
Within-Subjects				
Time	1195.16	1	1195.16	110.63*
Experience by Time	41.04	2	20.52	1.90
Gender by Time	3.02	1	3.02	.28
Experience by				
Gender by Time	.65	2	.33	.03
Error	572.57	53	10.80	

*p<.001

The analysis of the qualitative results seem to support the quantitative finding that the level of computer experience for the TESSI students did not influence their achievement. For example, Dalene, a female student who had taken two computer courses but usually spent less than one hour per week using a computer, was categorized as being low in computer experience. However, Dalene's posttest achievement score was 84%, and classroom observation indicated that Dalene was not the least bit intimidated by the technology. Even when in a group situation, viewing an animation or gathering data using MBL probeware, Dalene was always confidently in charge of the mouse, and therefore the computer. Dalene seemed to enjoy the technology enhanced classroom environment: as evidenced by the following comments, "I like it, seeing a picture on an overhead doesn't help to just see it, it's way better in an animation...where you can see that something is fluid and moving" (classroom conversation with teacher, November 1996). Commenting on the self-pacing the technology allows, Dalene observed, "I really like this class because I know what I am supposed to do, I don't have to wait for the teacher to give out an assignment" (classroom conversation with teacher, September 1996). Dalene's limited computer experience does not seem to have hindered her achievement or her ability to interact with the technologies.

Another student, Jason, characterized into the medium experience category, experienced a great deal of success in this learning environment. He attained a score of 88% on the achievement instrument, and he and other members of his group, were observed to demonstrate very little "off task" behaviour. Jason commented that, "I like [learning with the technology], it is easy. It seems to take less effort to learn the stuff, but I seem to learn it just as well or better" (classroom conversation with teacher, November 1996). Obviously, Jason is unhindered by his fairly moderate computer experience. These findings suggest that achievement in a TESSI environment is due more to learning style or motivational factors than to computer experience.

Conversely, Helen, a female student whose computer courses and use resulted in a medium experience categorization, was not initially favorable to the environment. Although Helen was observed to be a competent user of the technologies, she expressed concerns soon after the course began: "I don't think you're teaching us, I like it when the teacher talks to us and we discuss things afterwards" (classroom conversation with teacher, September 1996). Helen is describing her preference for a typical traditional teaching style—one in which she has experienced a great deal of success. Interestingly, about two months later, Helen's attitude towards the class changed—probably due to the success she was experiencing in the class—she claimed she now liked the class and it had "just taken some time to get used to it" (classroom conversation with teacher, November 1996).

The researcher did notice that students with more experience, though not necessarily achieving any better than those students with less experience, seemed less uncertain when it came to trying the new technologies. For example, Bjorn, a male student with a high level of computer experience, was excited and enthusiastic about the students' first encounter with MBL probeware.

At Bjorn's direction, his group carried on more trials than were required; even before they had completed the lab, Bjorn was already speculating on the possible causes of the results. The visual and rapid nature of the graphical readout from the MBL probeware seems to have expedited Bjorn's understanding of the concepts involved. Another student, Jackie—a female categorized as having low computer experience—was observed during this lab to assume a much more passive role. Jackie was content to help in the performance of the lab techniques and with the clean-up, but she did not encourage others in her group to carry on with further investigation, or question the results they had obtained.

It seems as if computer experience had no detectable quantitative impact on the students' achievement or observable qualitative effect on the students' ability to interact with the technology.

G. Summary

The investigation of hypotheses one and two, comparing mode of instruction, utilized a posttest only nonequivalent groups analysis. The posttest consisted of a unit test for the Biology 12 cell ultraprocesses section administered to both groups. The study involved a sample size of 96, and consisted of students taking Biology 12 at a secondary school in Langley school district during the 1993/94 and 1996/97 school years.

The determination of hypotheses three through five—investigating attitude changes as a result of TESSI biology instruction, and achievement with respect to computer experience—used a one group pretest-posttest design. The sample consisted of 57 students in the researcher's 1996/97 Biology 12 classes. At the time of this study (1996/97), this was the only school in British Columbia offering TESSI biology. The pretests consisted of a survey designed to determine the subject's computer attitudes and background computer experience and an achievement pretest on the Biology 12 cell ultraprocesses unit. Both the computer attitude instrument and the achievement instrument were readministered as posttests at the conclusion of the unit.

The statistical analyses of the data, supported by the qualitative findings (for hypotheses three through five), has revealed that: (1) there is no significant difference in achievement on a biology unit test between the traditionally instructed group and the TESSI group; (2) there was no significant interaction between gender and mode of instruction (traditional vs. TESSI) on achievement; (3) TESSI student achievement on a biology unit posttest is independent of computer attitudes; (4) there was no significant increase in computer attitude scores for the TESSI group over the course of this study, and there was no significant interaction between gender and time of testing on computer attitudes; (5) TESSI student achievement on a biology unit posttest was independent of previous computer experience.

CHAPTER FIVE

Findings, Limitations, and Implications

This study attempted to find out if students perform as well in a TESSI biology classroom as students taught the same content in a traditional lecture-oriented manner and if subject variables such as computer attitudes or computer experience affect student achievement. The research which compared the mode of instruction (traditional versus TESSI), was conducted by comparing student achievement in a traditionally instructed group from the researcher's 1993/94 Biology 12 classes with Biology 12 students enrolled in the implementation year (1996/97) for TESSI biology. The achievement portion of the study was conducted over a six week period, and is examined by hypotheses one and two. The research involving student attitudes and computer experience was conducted over an 11 week period using only the researcher's 1996/97 Biology 12 classes. The investigation of computer experience and its relation to biology achievement is discussed in hypotheses three. The research involving computer attitudes over the course of the study involves hypothesis four, and the investigation of the relationship between computer experience and biology achievement is examined in hypothesis five.

A. Discussion

The analyses of this study has involved quantitative statistical analysis of data obtained from instruments designed to gather information on student achievement in biology and student computer attitudes. The researcher also collected qualitative data in this study as a participant-observer. Both the quantitative and the qualitative findings of this study will be included in the following discussion sections.

B. Discussion of Hypothesis One

Since Biology 12 is a provincial examinable course in British Columbia, the researcher was interested in examining the achievement of students learning in a TESSI environment. The findings of this study indicate that there were no significant differences in achievement between computer-instructed and traditionally instructed students in a secondary school setting, as measured by a biology unit posttest. This finding is consistent with many other research studies (Choi & Gennarro, 1987; Morrell, 1992; Strauss & Kinzie, 1994), but does not support the findings of other studies, where the computer-using groups achieved significantly higher achievement test scores (Hounshell & Hill, 1989; Lewis, Stern, & Linn, 1993; Lazarowitz & Huppert, 1993).

While the results indicate that the students in the TESSI group performed as well on the achievement instrument as those in the traditionally instructed group, there may be plausible explanations why the TESSI group did not significantly outperform the traditionally instructed group. The achievement instrument, although it demonstrated evidence of adequate reliability and validity, may not have measured all of the cognitive affects of TESSI instruction. The achievement instrument tested mainly knowledge recall and not the understanding that many educational technology proponents, such as Linn et al. (1994) and Jonassen et al. (1991), claim is the result of technology enhanced instruction. Perhaps an instrument constructed of higher cognitive level questions may have favoured the TESSI group more. The *ex post facto* nature of the traditionally instructed group, however, did not allow the researcher to change the cognitive level of the questions; because, for comparison purposes the instrument had to be identical to one administered to the 1993/94 biology students. However, achievement at an equal level with a traditionally instructed group may actually be a significant finding in itself, especially when the dramatically altered roles of the student and the teacher in the TESSI classroom compared with the student-teacher interaction in a traditionally instructed classroom are considered. As was predicted by Collins (1991) and observed in TESSI physics classrooms by Woodrow et al. (1996), the TESSI students in this study did exhibit collaborative behaviours, increased engagement, and self-pacing, while the teacher's role definitely shifted from a majority of whole-class instruction to a majority of individual or small group instruction. Because of the shift from primarily large group to small group instruction, and the increased number of student-teacher interactions that accompanied this shift, the researcher felt that he was much more aware of the students' subject matter knowledge in the TESSI classroom compared with the traditionally instructed classrooms.

C. Discussion of Hypothesis Two

Gender differences in science achievement, such as those observed in the traditionally instructed group (see Figure 4) were also investigated. The results of this study indicate that gender differences favouring males did not appear in the TESSI biology treatment group. This result is consistent with other findings that indicate computerized instruction reduces or eliminates science gender differences in science achievement (Lazarowitz & Huppert, 1993; Lewis, et al., 1993; Hounshell & Hill, 1989). However, the result also indicates that while both males and females performed at about the same level on the achievement test in the TESSI biology classes, neither group did as well as their counterparts in the traditionally instructed group, but these differences were not statistically significant. Female students in the traditionally instructed group scored just slightly higher, on average, than female students in the TESSI group, but males in the traditionally instructed group averaged a score of 18 compared to an average score of 16 for TESSI group males. Sample size and selection may have affected the results and contributed to these differences as much as, or perhaps more than, the differences in the instructional treatments. There were only 8 males in the traditionally instructed group as compared with 27 in the TESSI group. Based on their mean achievement posttest score of 18/25, the low number of eight males in the traditionally instructed group appears to represent a ceiling effect with regards to the achievement test results. The treatment group sample probably represents a more typical group of male students due mostly to its larger size.

D. Discussion of Hypothesis Three

Hypothesis three investigated the affects of the students' attitudes towards computers to see if these attitudes were related to achievement in a TESSI biology classroom. The statistical analysis revealed that there were no significant differences in achievement between the TESSI students blocked into low, medium, and high computer attitude categories (see Tables 4 to 6). Each category of students showed a significant increase in scores from the achievement pretest to the achievement posttest. Statistically, then, it appears that computer attitudes do not affect achievement in a technology enhanced biology classroom. No other research studies are available to verify findings of the present study.

Since the students in the TESSI classrooms received most of their formal instruction from the technologies—the laserdisc player and laserdiscs, the computer animations, the computer tutorials, and the MBL probeware—it was essential for these students to competently access and control the available resources. This necessity raises the possibility that those students who had negative attitudes may have accessed the technology less or in different ways than those students who had higher attitudes and, as a result, students with negative attitudes may have realized decreased achievement. The patterns of student technology use observed by the researcher seemed to be quite individualized and did not correspond with the researcher's expectations that differences in computer attitudes would result in differences in computer use patterns.

E. Discussion of Hypothesis Four

Hypothesis four investigated the effects on student computer attitudes of TESSI biology instruction. The students' attitudes were determined by the administration of a pretest followed 11 weeks later by a posttest. The statistical analysis indicated that the students did not significantly increase their attitudes towards computers over the course of this study, that males scored significantly higher on their mean combined attitude pretests and posttests than did the females (see Table 5), and that there was no significant interaction between gender and time of testing on attitudes.

A number of researchers have indicated that the development of positive computer attitudes in technology enhanced instruction is an important affective outcome (Reece & Gable, 1982; Simonson et al., 1987; Woodrow, 1994). Simonson et al. claim such outcomes are crucial for preparing students for our increasingly technological world. The results of this study indicate that while the TESSI students' attitudes towards computers did improve over the course of the study, the improvement was not significant. Examination of Figure 5 indicates that most of the attitude increases that occurred were among the male students only.

The results of this study verify the findings of other related studies. The data from this study indicated that males had higher computer attitudes than females both prior to and following 11 weeks of TESSI instruction. Colley et al. (1995), Shashaani (1994), and Woodrow (1994) also found in their research that males had better computer attitudes than females. Both Shashaani and Woodrow found statistically significant differences favouring males for computer attitudes, but, similar to the present study, Colley found the resulting differences in attitudes were not statistically significant.

The results of the present study also partially support the findings of Levin and Gordin (1989) that females' attitudes towards computers may improve in a computer using environment that does not involve programming. It was determined that the females' attitudes did improve in the non-programming TESSI environment. Females increased their computer attitudes slightly from a pretest mean of 102.69 to a posttest mean of 103.54. However, these improvements in attitudes were minimal, and could be attributable to other factors such as either error in the attitude instrument, regression to the mean, or both.

Another interesting finding was each of the top five students in terms of pretest computer attitudes, showed a decrease in their total attitude scores from pretest to posttest. No other pattern could be determined to explain this result, such as previous computer courses or level of experience. Perhaps, then, the indicated decrease in attitude scores could be attributed to the fact that they are now using computers for educational purposes rather than using them for more recreational pursuits such as games or internet browsing, or perhaps the decrease could be due to regression to the mean.

Although the statistical analysis did not reveal significant changes in the students' attitudes towards computers, the qualitative findings (presented in Chapter Four) suggested the possibility that the students' attitudes may have changed over the course of the study in ways that were not measured by the attitude instrument.

F. Discussion of Hypothesis Five

The analysis of hypothesis five focused on the impact of prior computer experience on achievement in a technology enhanced environment. Few other studies have investigated this effect, although Chambers and Clarke's 1987 study revealed that secondary students with prior computing experience participated more in computer-based class activities than those students with less computer experience. There is no other research available that has investigated the effect of computer experience on achievement in a technology integrated setting such as TESSI.

Because the classroom routine required that all students in the TESSI biology classes be able to access information and take quizzes on a computer, this requirement raises the possibility that based on Shashaani's (1994) finding—that female students' lack of experience with computers was related to decreased participation in computer related activities—there may appear to be hesitation or negativity on the part of female students towards the technology enhanced environment, and that such factors may result in decreased achievement for the female students. However, the results of this study indicate that there is no evidence to support such a possibility:

(1) There was no statistically significant difference found for prior computing experience by gender—a result not supported by the findings of other studies (Busch, 1995; Colley et al., 1995; Shashaani, 1994; Taylor & Mounfeild, 1994). It appears that a significant "gender gap" (p. 20) in computer experience such as that described by Shashaani (1994) does not exist between the genders of this study, or perhaps that the demographic portion of the attitude instrument was not sensitive enough to expose such a difference in experience. The survey did reveal: (i) that 37% of the male students were in the high computer experience category compared to only 16% of the females; (ii) females were more commonly categorized in the medium experience category than males; 47% of the female students compared to 33% of the male students; and (iii) that females (38%) were more common in the low computer use category than males (30%).

(2) Hypothesis two revealed that no significant difference in achievement by gender occurred among the TESSI students, and hypothesis five indicated that among the TESSI group no statistically significant interaction was found between gender, level of computing experience, and time of testing on achievement.

(3) Qualitative observations seemed to support the quantitative findings that the students' ability to access the technology was independent of both their level of computer experience and their gender.

It seems as if achievement in a TESSI biology classroom is independent of computer experience. This is an important finding in regards to the TESSI project, since it appears that even students with limited computer experience can operate the technologies and learn in a technology enhanced environment.

G. Limitations of the Study

Since the research for this study has been carried out using two different designs, the limitations of each design will be discussed separately. The results of the posttest only with non equivalent groups achievement comparison study between the 1993/94 Biology 12 classes and the 1996/97 Biology 12 classes must be interpreted with caution because of a number of constraints to the internal validity of the design. One constraint to the design is the lack of random sampling and assignment techniques in the study, and therefore non significant differences found in this study may be due to differences in the composition of the groups as opposed to differences in the treatments. To help overcome the problem of selection, the analysis of covariance statistical procedure was used because it helps to correct for differences in the groups based on the covariates chosen.

Time is a constraint to the design of this study. That fact that three years had passed between the traditionally instructed group's instruction and the TESSI group's instruction may have impacted the study in a number of ways: (1) the researcher/instructor may have improved on his teaching methods during this time period, (2) overall changes to the attitudes of students towards biology as a subject may have affected the results of this study in unknown ways, (3) the school has grown in enrollment by 133 students since 1993/94. This growth in school population has affected class sizes and the number of courses offered. The effects of history on this study are difficult to estimate, but must be considered as a constraint to the study.

Experimenter affects, although not purposely engaged by the researcher, may have been apparent to the subjects in the TESSI group. The *ex post facto* nature of the traditionally instructed group would eliminate experimenter effects for the 1993/94 classes. It is unknown in what, if any, way that the treatment group subjects may have been affected by the researcher.

Subject effects may also have occurred within the TESSI group. Once again, such effects would not have occurred in the traditionally instructed group because the data from this group was used in an *ex post facto* manner. The TESSI students may have acted differently simply because they were participating in an experiment and experiencing the novelty effect—known as the Hawthorne effect. However by the time the study began, the students had been using the computers for two months and had most likely grown accustomed to the novelty of using the technology. In addition, the researcher had been making observations of the students previous to the beginning of the study for the purposes of the TESSI project journal and, as a result, over the course of the study, the students were observed to be more comfortable with the process of data gathering by the researcher.

The final constraint to the internal reliability of this study is statistical conclusion validity: a problem that exists when statistical tests are misused. While the researcher does not consider the statistical test of ANCOVA to be misused in this instance, the assumptions of ANCOVA include the use of a random population sample—an option not available to the researcher. Given the robust nature of the ANCOVA procedure and the homogeneity of the regression slopes involved in the analysis, the statistical results obtained in this analysis are deemed to be valid despite the lack of random selection.

Problems of external validity of the achievement design must also be considered. The lack of random selection limits the generalizability of the study. Because the Langley school district is typical in 25 out of 27 criteria specified by the Ministry of Education, the results are generalizable beyond the participants of this study—at least to other classrooms composed of students with similar characteristics within the province of British Columbia.

Pretest-posttest sensitization may have occurred for the TESSI students since, unlike the 1993/94 traditionally instructed students, the TESSI students received an achievement pretest on the cell ultraprocesses unit. The administration of the pretest to the TESSI group was not related to the achievement research analysis, but was related to the attitude and computer experience components of this study. However, if treatment group students were sensitized to the pretest, they did not demonstrate a familiarity with the instrument by improving their posttest scores to a level significantly better than the traditionally instructed group, and most of the subjects were surprised to discover that they had written the achievement posttest as a pretest some seven weeks earlier—indicating that they did not recognize or remember the questions from the pretest.

The one group pretest-posttest design used to investigate the affects of computer attitudes and experience on achievement has the following constraints to its internal validity:

(1) Because only one group is used in this design, history is the most serious threat. The researcher can not exactly state how this threat may have impacted the results of this study, but since no major events occurred during the course of the study that may have likely affected the majority of the subjects in regards to their computer attitudes or attitudes towards the usefulness of biology, the threat of history is likely minimal.

(2) Statistical regression may have been a factor in the results of this study because the subjects were blocked according to their pretest computer attitudes. Since a change in computer attitudes was related to a hypothesis of the study, the student with low attitudes may have indicated improved attitudes on the posttest due to regression to the mean rather than to a real improvement in attitudes due to the TESSI biology instruction.

(3) The threat of pretesting may also have impacted this study. Students in the study may have changed their attitudes towards computers as a result of becoming sensitized to certain attitudes regarding computers by the pretest. The fact that 11 weeks passed between the administration of the pretest and the administration of the posttest, as well as the different appearance of the posttest (it was missing the demographic section), probably minimized the influence of this threat to the study results. Pretest-posttest sensitization related to the achievement instrument was not likely to have been a factor in this study for the reasons indicated previously.

The effect of instrumentation was minimized because the computer attitude pretests and posttests were administered to the three classes on the same days of the week and times as the pretests. Therefore, the general prevailing attitudes were not likely to be due to different days of the week or times of the day; however, the fact that the posttests were administered during the last class before Christmas break may have affected the students' attitudes and achievement.

The external validity of the results used to study the effects of computer attitudes and experience on achievement is limited because only one group was used in the study. The possibility that the teaching method interacted with the subjects cannot be completely ruled out. However the effects of such an interaction are not known. The generalizability of this study was limited to a similar group of subjects in a similar setting. Once again, due to the shared characteristics of the site, the generalizability of the results could be extended to a similar group of students at most secondary schools in British Columbia.

This was an exploratory study, and the research conducted here was carried out with the researcher's realization of the limitations of the chosen designs. However, the ability to carry out research in an educational setting is always a challenge and often compromises must be made and the resulting limitations recognized.

H. Recommendations for Further Research

This study investigated: (1) general achievement and gender impacts of technology enhanced secondary science instruction in biology instruction compared with traditional instruction methods and by gender, (2) the affects of TESSI biology instruction on student computer attitudes, (3) whether previous computer experience influenced achievement in a technology enhanced biology classroom.

The researcher feels that his level of experience in choosing and developing technology enhanced learning tools may have affected the results of the study. The experience the researcher gained by the qualitative interaction undertaken in this study would lead him to revise the student materials used in this unit. The revisions would likely include the replacement of the fill-in-the-blank type of questions with questions that would summarize the student's understanding of the concepts involved. The researcher hopes that these revisions would make the materials easier to understand, more "user friendly", and allow the students to use the materials more efficiently. The researcher would like to repeat the achievement study using an experimental design and the revised instructional materials. An experimental design may reduce the plausible rival hypotheses extant in the current study and perhaps allow increased causality to be determined from the results.

Other interesting and informative studies could be conducted to determine if differences within the TESSI model as applied to biology instruction impact student achievement or preference of learning environment. For example, as more technological resources become available to support TESSI classrooms, students could be given more options to choose from to learn a particular concept. It would be useful to examine quantitatively and qualitatively the choices made and the resulting achievement patterns displayed by these students.

Additionally, as indicated previously, the achievement instrument used in this study examined mainly low level cognitive outcomes. Since technology enhanced instruction is known to often enhance higher cognitive level understanding (Lajoie, 1993; Lewis et al., 1993; Ryba & Anderson, 1990; Snir & Smith, 1995), it would be interesting to repeat the study utilizing an achievement instrument designed to cover a broader range of learning outcomes thus allowing a comparison by cognitive level of student achievement between traditional and TESSI instruction.

The study has lead the researcher to develop a number of insights regarding student success in TESSI classrooms, and the researcher feels there are other factors, not identified by this study, that are important determiners of student success in a TESSI environment. Other factors that could be investigated involve student motivation, locus of control, and learning styles. Based on the qualitative observations, the researcher believes that learning style plays a strong role, if not in determining success, then at least in explaining the students preference of learning environments. It would be prudent to investigate this aspect of student learning with regards to their achievement and attitudes towards TESSI instruction.

I. Conclusions

Technology enhanced secondary science instruction is becoming more widely recognized as an option for student instruction. Currently, the Ministry of Education is soliciting school districts with a view to expand the number of sites offering TESSI. TESSI is serving as a catalyst to change science education, not just for the purposes of modernization, but also for the purposes of optimization (Woodrow et al., 1996). The challenge of educators is to implement educational technology in ways that are effective in terms of both student learning and cost.

Overall, the results of this study are intriguing. TESSI offers a dramatic increase in student involvement in their learning by offering an example of technology enhanced learning in action. Yet, despite a unique learning environment, students in the researcher's TESSI classroom are expected to achieve as well as their traditionally instructed counterparts, based on the results of TESSI instruction at four other school sites, over the past four years. Current student performance tends to support this expectation. Additionally, gender differences, often apparent on science achievement tests, were not apparent in the TESSI biology classes. Perhaps TESSI instruction offers a means of reducing or even eliminating the gender issue in science achievement.

It has also been shown that even in a technology dependent environment, students, independent of gender, with limited computer experience are not disadvantaged compared with other more sophisticated computer users in terms of achievement.

In conclusion, this study has attempted to add to the existing research base regarding technology enhanced science instruction. The study has supported the findings of other studies, with the exception of the nonsignificant differences in computer attitudes between males and females on the attitude pretest. This study has shown that biology students learning in a TESSI setting achieved as well as traditionally instructed students, TESSI instruction does not create gender differences in achievement, neither computer attitudes nor level of computer experience affect achievement in a TESSI classroom, and that TESSI instruction significantly increased the computer liking of the students. Since neither previous computer experience nor computer attitudes affect student achievement in a TESSI classroom, it remains to be seen what, if any, subject variables can be found that affect student achievement in technology enhanced biology instruction.

While the results of this study may not have shown significantly increased achievement by the TESSI students, there are other factors that suggest TESSI is an important pedagogical endeavour. Students in the TESSI classrooms in this study were actively involved not just in learning biology but also in learning how to learn. The TESSI students learned to work collaboratively, manage their time in a self-directed environment, access information from a number of different resources, and set and accomplish their own goals. While more research is needed to confirm such a possibility, it seems likely that TESSI students are learning transferable skills that may benefit them in post secondary education and/or a workplace environment.

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APPENDIX A

Raw Computer Attitude Data

Case	Attitude Pretest Score	Category
1	46	
2	49	
3	64	
4	70	
5	75	
6	81	
7	84	
8	87	
9	87	
10	90	
11	91	Low
12	91	
13	92	
14	92	
15	93	
16	95	
17	95	
18	96	
19	97	
20	98	
21	98	
22	99	
23	99	
24	101	
25	102	
26	102	
27	103	
28	103	
29	104	
30	104	Medium
31	105	
32	105	
33	106	
34	107	
35	110	
36	111	
37	111	
38	113	
39	116	
40	117	
41	117	
42	117	
43	117	
44	117	
45	117	
46	118	
47	118	High
48	118	

Case	Attitude Pretest Score	Category
49	118	High
50	119	
51	122	
52	123	
53	128	
54	131	
55	132	
56	136	
57	142	
58	146	
59	150	

APPENDIX B

Raw Computer Experience Data

Case	Hours/Week	Computer Courses	Total	Category
1	1	0	1	
2	1	0	1	
3	2	0	2	
4	1	1	2	
5	1	1	2	
6	1	1	2	
7	1	1	2	
8	1	1	2	
9	1	1	2	
10	2	0	2	Low
11	1	1	2	
12	1	1	2	
13	1	1	2	
14	2	0	2	
15	1	2	3	
16	2	1	3	
17	1	2	3	
18	1	2	3	
19	1	2	3	
20	1	2	3	
21	2	2	4	
22	3	1	4	
23	3	1	4	
24	2	2	4	
25	2	2	4	
26	3	1	4	
27	1	3	4	
28	3	1	4	
29	2	2	4	
30	2	2	4	
31	3	1	4	
32	3	1	4	Medium
33	2	2	4	
34	2	2	4	
35	2	2	4	
36	3	2	5	
37	3	2	5	
38	4	1	5	
39	3	2	5	
40	3	2	5	
41	1	4	5	
42	2	3	5	
43	2	3	5	
44	2	3	5	
45	4	2	6	
46	2	4	6	
47	5	1	6	
48	4	2	6	High

Case	Hours/Week	Computer Courses	Total	Category
49	4	2	6	High
50	4	2	6	
51	4	3	7	
52	4	3	7	
53	5	2	7	
54	3	4	7	
55	5	3	8	
56	5	4	9	
57	5	4	9	
58	5	4	9	
59	5	4	9	

APPENDIX C

Computer Attitude Pretest

September 1996

THE UNIVERSITY OF BRITISH COLUMBIA

Faculty of Education
Department of Curriculum Studies
2125 Main Mall
Vancouver, B.C. Canada V6T 1Z4
Tel: (604) 822-5422 Fax: (604) 822-4714

Computer Attitude Questionnaire

Section 1: Background Computer Use

Please fill in the appropriate space on the computer card corresponding to your answer to the following questions.

1. Approximately how many hours a week do you use a computer?

A. less than 1 hour
B. 1 to 2 hours
C. 2 to 4 hours
D. 4 to 6 hours
E. more than 6 hours

2. What type of home computer do you own?

A. Macintosh
B. IBM or IBM compatible
C. Other
D. None

3. What is the most common activity you do on a computer?

A. word processing
B. internet/worldwide web browsing
C. games
D. programming
E. other

4. How many computer courses have you taken in school (include those you may be taking currently).

A. None
B. One
C. Two
D. Three
E. More than three

Section 2: Computer Attitude Survey

Key:
Strongly Disagree (SD) A
Disagree (D) B
Undecided (U) C
Agree (A) D
Strongly Agree (SA) E

Please fill in the appropriate space on the computer card corresponding to your reaction to the following questions.

	SD	D	U	A	SA
5. I'm no good with computers.	A	B	C	D	E
6. Generally, I would feel OK about trying a new problem on the computer.	A	B	C	D	E
7. I don't think I would do advanced computer work.	A	B	C	D	E
8. I am sure I could do work with computers.	A	B	C	D	E
9. I'm not the type to do well with computers.	A	B	C	D	E
10. I am sure I could learn a computer language.	A	B	C	D	E
11. I think using a computer would be very hard for me.	A	B	C	D	E
12. I could get good grades in computer courses.	A	B	C	D	E
13. I do not think I could handle a computer course.	A	B	C	D	E
14. I have a lot of self-confidence when it comes to working with computers.	A	B	C	D	E
15. I would like working with computers.	A	B	C	D	E
16. The challenge of solving problems with computers does not appeal to me.	A	B	C	D	E
17. I think working with computers would be enjoyable and stimulating.	A	B	C	D	E
18. Figuring out computer problems does not appeal to me.	A	B	C	D	E
19. When there is a problem with a computer run that I can't immediately solve, I would stick with it until I have the answer.	A	B	C	D	E
20. I don't understand how some people can spend so much time working with computers and seem to enjoy it.	A	B	C	D	E
21. Once I start to work with the computer, I would find it hard to stop.	A	B	C	D	E
22. I will do as little work with computers as possible.	A	B	C	D	E
23. If a problem is left unsolved in a computer course, I would continue to think about it afterward.	A	B	C	D	E
24. I do not enjoy talking with others about computers.	A	B	C	D	E
25. I will use computers many ways in my life.	A	B	C	D	E
26. Learning about computers is a waste of time	A	B	C	D	E

	SD	D	N	A	SA
27. Learning about computers is worthwhile.	A	B	C	D	E
28. I'll need a firm mastery of computers for my future work.	A	B	C	D	E
29. I expect to have little use for computers in my daily life.	A	B	C	D	E
30. I can't think of any way that I will use computers in my career.	A	B	C	D	E
31. Knowing how to work with computers will increase my job possibilities.	A	B	C	D	E
32. Anything that a computer can be used for, I can do just as well some other way.	A	B	C	D	E
33. It is important to me to do well in computer class.	A	B	C	D	E
34. Working with computers will not be important to me in my life's work.	A	B	C	D	E

Thank you for your cooperation, please hand in your questionnaire and computer cards.

APPENDIX D

Computer Attitude Posttest

December 1996

THE UNIVERSITY OF BRITISH COLUMBIA

Faculty of Education
Department of Curriculum Studies
2125 Main Mall
Vancouver, B.C. Canada V6T 1Z4
Tel: (604) 822-5422 Fax: (604) 822-4714

Computer Attitude Questionnaire

Computer Attitude Survey

Key:

Strongly Disagree (SD)	A
Disagree (D)	B
Undecided (U)	C
Agree (A)	D
Strongly Agree (SA)	E

Please fill in the appropriate space on the computer card corresponding to your reaction to the following questions.

	SD	D	U	A	SA
1. I'm no good with computers.	A	B	C	D	E
2. Generally, I would feel OK about trying a new problem on the computer.	A	B	C	D	E
3. I don't think I would do advanced computer work.	A	B	C	D	E
	SD	D	N	A	SA
4. I am sure I could do work with computers.	A	B	C	D	E
5. I'm not the type to do well with computers.	A	B	C	D	E
6. I am sure I could learn a computer language.	A	B	C	D	E
7. I think using a computer would be very hard for me.	A	B	C	D	E
8. I could get good grades in computer courses.	A	B	C	D	E
9. I do not think I could handle a computer course.	A	B	C	D	E
10. I have a lot of self-confidence when it comes to working with computers.	A	B	C	D	E
11. I would like working with computers.	A	B	C	D	E
12. The challenge of solving problems with computers does not appeal to me.	A	B	C	D	E
13. I think working with computers would be enjoyable and stimulating.	A	B	C	D	E
14. Figuring out computer problems does not appeal to me.	A	B	C	D	E

	SD	D	N	A	SA
15. When there is a problem with a computer run that I can't immediately solve, I would stick with it until I have the answer.	A	B	C	D	E
16. I don't understand how some people can spend so much time working with computers and seem to enjoy it.	A	B	C	D	E
17. Once I start to work with the computer, I would find it hard to stop.	A	B	C	D	E
18. I will do as little work with computers as possible.	A	B	C	D	E
19. If a problem is left unsolved in a computer course, I would continue to think about it afterward.	A	B	C	D	E
20. I do not enjoy talking with others about computers.	A	B	C	D	E
21. I will use computers many ways in my life.	A	B	C	D	E
22. Learning about computers is a waste of time	A	B	C	D	E
23. Learning about computers is worthwhile.	A	B	C	D	E
24. I'll need a firm mastery of computers for my future work.	A	B	C	D	E
25. I expect to have little use for computers in my daily life.	A	B	C	D	E
26. I can't think of any way that I will use computers in my career.	A	B	C	D	E
27. Knowing how to work with computers will increase my job possibilities.	A	B	C	D	E
28. Anything that a computer can be used for, I can do just as well some other way.	A	B	C	D	E
29. It is important to me to do well in computer class.	A	B	C	D	E
30. Working with computers will not be important to me in my life's work.	A	B	C	D	E

Thank you for your cooperation, please hand in your questionnaire and computer cards.

APPENDIX E

Achievement Pre and Posttest

1993 and 1996

Cell Ultraprocesses Test

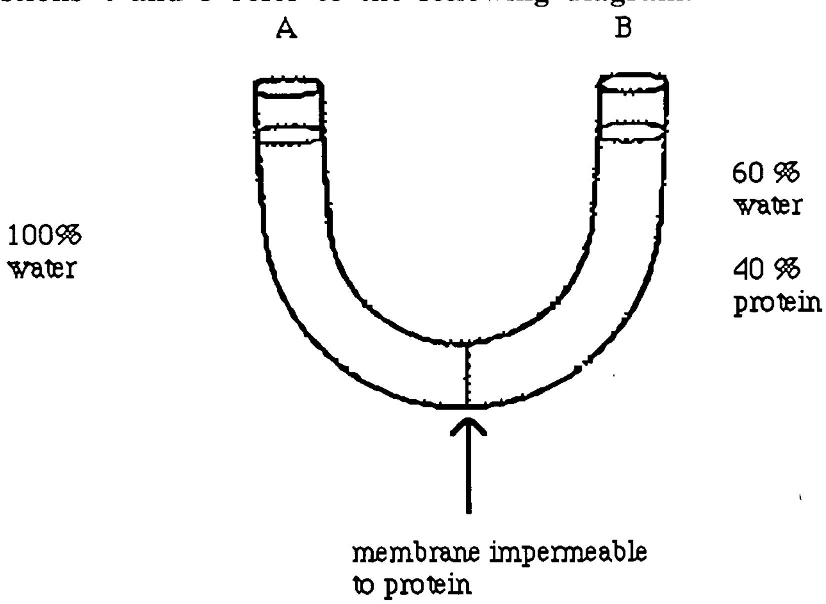
Name:
Date:
Blk:

1. Which one of the following processes uses ATP when it functions?
   a) diffusion
   b) osmosis
   c) passive transport
   d) bulk flow
   e) active transport

2. Which of the following would be an example of active transport?
   a) movement of sugar from a 4% to a 10% solution
   b) wilting of a plant
   c) exchange of gases in the alveoli
   d) swelling of red blood cells in distilled water
   e) movement of sugar from a hypertonic to a hypotonic region

3. Carrier molecules are required for
   a) facilitated diffusion
   b) diffusion
   c) osmosis
   d) pinocytosis

Questions 4 and 5 refer to the following diagram.



4. During this experiment , what will happen to the water level?
   a) Due to gravity the water cannot move.
   b) It will rise in side B since water will tend to pass from the area of higher concentration to the area of lower concentration.
   c) It will remain the same because atmospheric pressure is equal on both sides of the system.
   d) It will rise in side A, since water (not the substances in it) will tend to pass from the area of greater concentration to the area of lesser concentration.

5. What will happen to the protein solution of side B?
   a) It will become less concentrated since water passes from B to A.
   b) It will become less concentrated since starch moves from A to B.
   c) It will become less concentrated since water passes from A to B.
   d) It will become more concentrated since water passes from B to A.

6. A slice of potato placed in cold water becomes very stiff and hard after several hours because
   a) water has passed into the potato cells to produce turgor pressure.
   b) cellulose synthesis has been stimulated.
   c) salt has entered the potato.
   d) water has passed out of the potato cells causing plasmolysis.

7. Red blood cells are isotonic to 0.9% NaCl. A red cell will swell to bursting in which of the following solutions?
   a) 0.9% NaCl.
   b) 0.5% NaCl.
   c) 11.00% NaCl.
   d) 1.00% NaCl.

8. Isotonic means that
   a) only osmosis will occur.
   b) the solute concentration outside the cell is greater than inside the cell.
   c) the solute concentration outside the cell is less than inside the cell.
   d) the solute concentration outside the cell is the same as inside the cell.

Questions 9 and 10 refer to the following equation.

$$\underset{\mathbf{1}}{\text{urea}} + \underset{\mathbf{2}}{\text{water}} \xrightarrow[\mathbf{3}]{\textbf{urease}} \underset{\mathbf{4}}{\text{carbon dioxide}} + \underset{\mathbf{5}}{\text{ammonia}}$$

9. Which of these is/are the enzyme ?
   a) 1 and 2.
   b) 3 and 4.
   c) 3.
   d) 1.

10. Which of these is/are the substrate?
    a) 3 and 4.
    b) 1 and 2.
    c) 1.
    d) 5.

11. What part of your diet supplies you with coenzymes?
    a) fats
    b) vitamins
    c) carbohydrates
    d) proteins
    e) amino acids

12. NAD is
    a) an enzyme.
    b) a coenzyme.
    c) a form of energy.
    d) a poison.

13. Enzymes
    a) act as a buffer in metabolic reactions.
    b) give energy to metabolic reactions.
    c) speed up metabolic reactions.
    d) change the direction of metabolic reactions.

14. glucose + oxygen ----> carbon dioxide + water.
    Side (a) Side (b)

    On which side of the above equation should you put the word "energy"?
    a) a.
    b) b.
    c) Both of the above are true.
    d) None of the above are true.

15. When ADP is converted to ATP:
    a) hydrogen ions are required.
    b) phosphate is released.
    c) energy is required.
    d) energy is released.

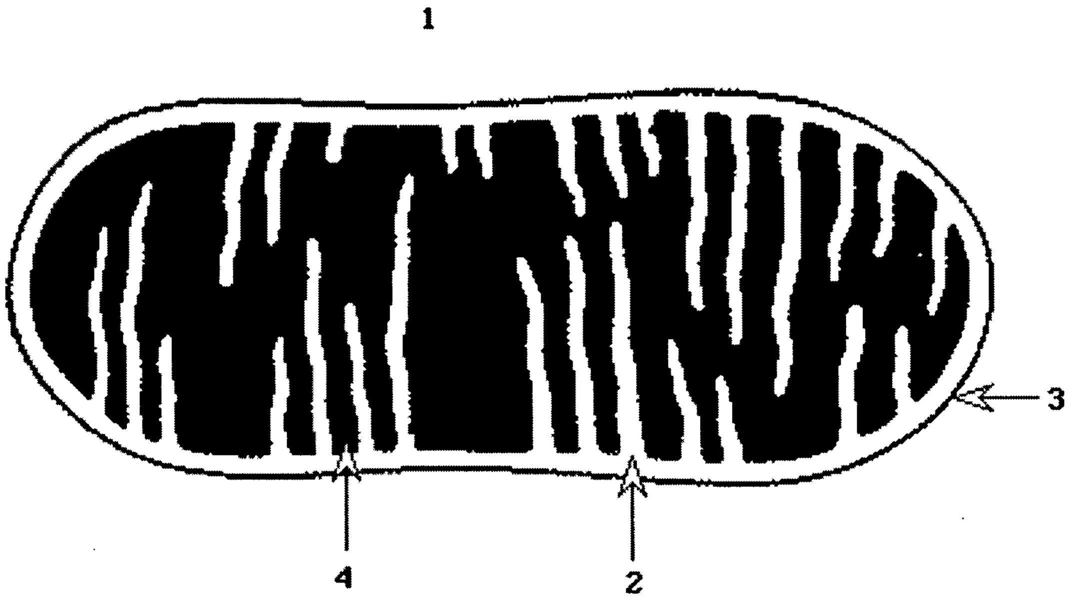
16. Which of these molecules could react with ADP to form ATP?
    a) phosphate.
    b) 3 carbons.
    c) 2 pyruvic acids.
    d) Iron oxide.

17. The largest single source of energy resulting from the oxidation of one molecule of glucose comes from:
    a) $NADH_2$ produced in the Kreb's cycle.
    b) $NADH_2$ produced in glycolysis.
    c) ATP directly produced in Kreb's cycle.
    d) ATP directly produced in glycolysis.

18. The **final** acceptor for H_2 in aerobic respiration is
    a) oxygen.
    b) PGAL.
    c) glucose.
    d) pyruvic acid.

19. How many ATP are made by the passage of 10 H_2 down the cytochrome system during cellular respiration if they are brought there by $NADH_2$?
    a) 40
    b) 0
    c) 30
    d) 20

The following diagram is refered to in questions 20 to 22.



20. In the diagram, which is the location of the cytochrome system?
    a) 3
    b) 2
    c) 1
    d) 4

21. In the diagram, which is the location of glycolysis?
    a) 2
    b) 4
    c) 3
    d) 1

22. Which number best represents the location of the Kreb's cycle?
    a) 2
    b) 1
    c) 3
    d) 4

23. How many molecules of ATP are produced from one molecule of glucose during aerobic respiration?
    a) 3
    b) 34
    c) 38
    d) 6
    e) 2

24. Anaerobic respiration or fermentation is:
    a) energy-production by bacteria and yeasts.
    b) the breakdown of sugar in the absence of oxygen.
    c) the production of alcohol.
    d) aerobic respiration.

25. Which one of the following is an end product of anaerobic respiration in muscle cells?
    a) Ethyl alcohol
    b) Propyl alcohol
    c) Lactic acid
    d) Pyruvic acid

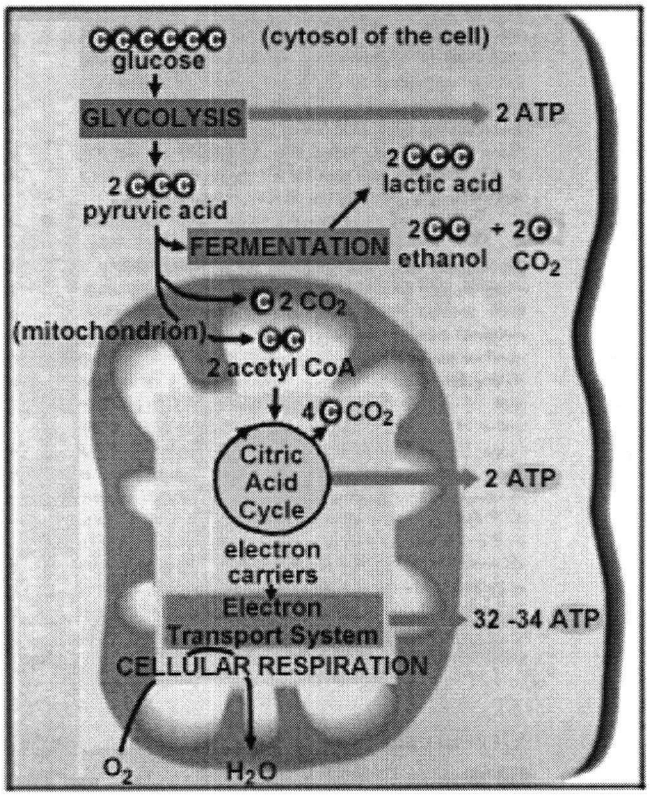
APPENDIX F

Cell Ultraprocesses Unit Study Guide

1996

Biology 12 Study Guide

CELL ULTRAPROCESSES



Name: ____________________

Date: ____________________

Blk: ______

Ultraprocesses Assignment Checklist

Description	Guide Reference	Done?	Mark
• Homework Check	Pg. #		
• Homework Check	Pg. #		
• Formal Lab: Solute Concentration of Potatoes	Pg. #7		
• Interactive Test: "Cell Membrane Function"	Pg. #9		
• Optional Corrective Assignment: Mader (7th.) Study Questions Page 71 # 2,3,5,6,7, & 10. Objective Question Page 71 # 8.	Pg. #9		
• Optional Interactive ReTest: "Cell Membrane Retest"	Pg. #9		
• Homework Check	Pg. #		
• Homework Check	Pg. #		
• Formal Lab: The Effects of Temperature on an Enzyme Catalyzed Reaction	Pg. #15		
• Interactive Test: "Cellular Metabolism"	Pg. #15		
• Optional Corrective Assignment: Audesirk & Audesirk: Review Questions Page 72 #3,4,5. **or** Mader (7th.) Study Questions Page 71 # 2,3,5,6,7, & 10. Objective Question Page 71 # 8.	Pg. #15		
• OPTIONAL Interactive ReTest: "Cell Metabolism Retest"	Pg. #15		
• Homework Check	Pg. #		
• Homework Check	Pg. #		
• Homework Check	Pg. #		
• Interactive Test: "Cell Respiration"	Pg. #29		
• Optional Corrective Assignment: Audesirk & Audesirk: Review Questions Page 155 # 1,2,3,4, & 7.	Pg. #30		
• OPTIONAL Interactive ReTest: "Cell Respiration Retest"	Pg. #30		
• **Cell Ultraprocesses Unit Exam**	Pg. #30		
• **Optional Cell Ultraprocesses Unit Exam Retest**			

Text References:
Audesirk & Audesirk
Pg. 106 - 118, 122 - 125
Mader
7th. Pg. 60 - 72

Cell Membrane and Cell Wall Function

The cell membrane plays a critical role in regulating what enters and leaves a cell. The following demonstrations and animations explain how molecules are able to pass through cells.

Key Words:

Define the following terms:

Semi-permeable: ____

____

Differentially permeable: ____

Cell membranes are said to be differentially permeable, this means they can ____________

____

A concentration gradient occurs when there is a difference between ____________

____

____

Diffusion occurs when there is ____

____

Osmosis is a special case of diffusion. Osmosis involves the movement of ____________.

Teacher Demo: Diffusion & Osmosis
Your teacher will model Diffusion & Osmosis.

Principle of Diffusion	Plasma Membrane Diffusion	Osmosis
Anatomy & Phys. laserdisc Side B	Anatomy & Phys. laserdisc Side B	Anatomy & Phys. laserdisc Side B
Search Frame 380	Search Frame 381 Step to Next	Search Frame 383 Step to Next 2

Questions:

1) What is a concentration gradient?

2) Describe the movement of particles due to diffusion?

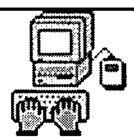
3) What sort of "particles" are subject to diffusion?

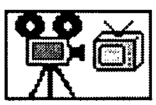
4) Describe Osmosis:

(continued on next page)

Factors affecting diffusion:

Factor	Affect on diffusion	Reason
increasing temperature		
increasing particle size		
increasing concentration gradient		





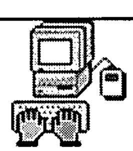
Computer Animation/Multimedia Center: S & B (Structure and Behaviour) of the Plasma Membrane.
(from Visualizing Cell Processes Laserdisc Side 1)

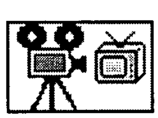
Search Chapter 4

This animation shows the movement of the molecules that make up the cell membrane.

Instructions:
1) Proceed to a computer station.
2) Sign in to AtEase.
3) Click on the Ultraprocess Movies folder.
4) Double click on S & B of the Plasma Membrane.
5) Click on "OK" when it tells you the file is locked.
4) Single click on the play triangle in the lower left of the window. (You now have a number of options for controlling the presentation:
   a) let the movie play until completion
   b) Press the pause button at any time to pause - just press play again to resume playing.
   c) Click on the forward or reverse keys (while paused or playing)
   d) Click and hold on the slider at the bottom of the window and drag it to the right or left to advance or retreat to a desired
5) When finished viewing the clip, single click on the button in the top left of the movie window
6) If are not going to view more movies, choose File/Close; to close MoviePlayer

Question:
1) Text book illustrations can not show movement. How does this animation of phospholipid molecules in a cell membrane differ from that in a text book.





Computer Animation/Multimedia Center: Passive (Diff) Transport
(from Anatomy & Physiology laserdisc Side 1)

Search Frame 17615

This computer animation shows the protein carriers involved in passive transport.

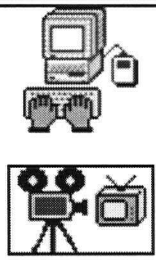
(continued on next page)

Questions:

1. Name the two molecules used in this example:

2. Describe the movement (relative to the concentration gradient) of each molecule:

3. Describe the direction (into or out of the cell) for each molecule and suggest reasons to explain this difference.



Computer Animation/Multimedia Center: Osmosis
(from Visualizing Cell Processes laserdisc Side 1)

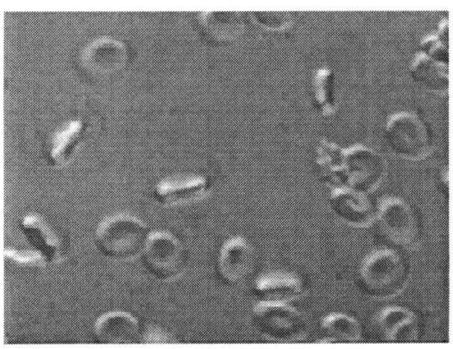
Search Chapter 5

This computer animation demonstrates the process of osmosis and shows how it can affect human cells.

Questions:

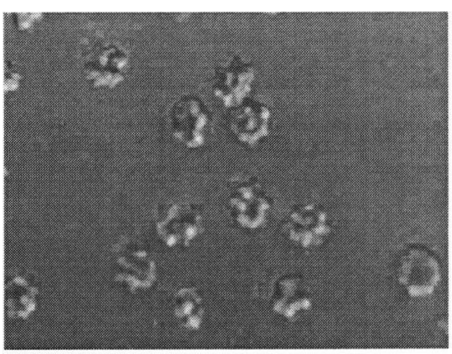
Look at the following images from the laserdisc and answer the associated questions. Hint: you may need to use your text(s) to help you find the answers.

1. How do water molecules pass through the plasma (cell) membrane?



1) Identify the tonicity of the solution containing these red blood cells:

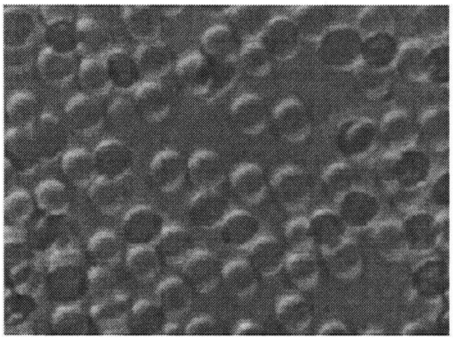
2) Describe how osmosis has contributed to this condition:



3) Identify the tonicity of the solution containing these red blood cells:

4) Describe how osmosis has contributed to this condition:

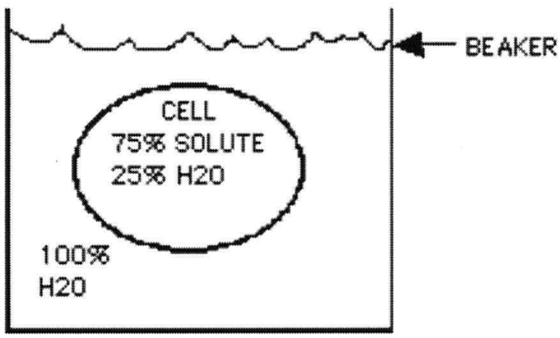
(continued on next page)



5) Identify the tonicity of the solution containing these red blood cells:

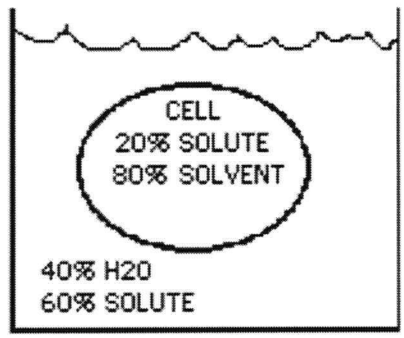
6) Describe how osmosis has contributed to this condition:

Predict the outcome of the following osmosis situations:



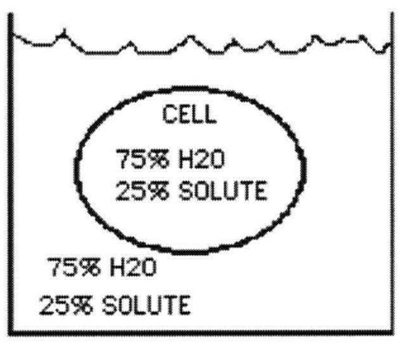
In the above example the cell will

____
due to the process of ____________ .
If the cell ____________ so much that it
____________. This is known as
____
The initial conditions above represent a(n)
________tonic solution.



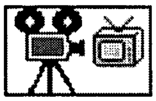
In the above example the cell will

____
due to the process of ____________ .
A large ____________ in size is known as
____________ .
The initial conditions above represent a(n)
__________tonic solution.



In the above example the cell will ____________ .
This condition is known as ____________
The initial conditions above represent a(n)

_________tonic solution.



Computer Animation/Multimedia Center: Transport Proteins
(from Visualizing Cell Processes laserdisc Side 1)

Search Chapter 6

This animation shows the shape and proposed action of transport proteins within cell membranes.

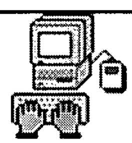
Questions:

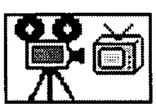
1) What molecules can simply pass through the plasma (cell) membrane?

2) How do some other larger molecules enter the cell?

3) Describe an analogy to represent the transport proteins.

4) Some of the proteins require ATP energy to transport molecules while others do not. What causes this difference?





Computer Animation/Multimedia Center: Facilitated Diffusion (Transport)
(from Anatomy & Physiology laserdisc Side A)

Search Frame 16830

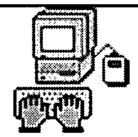
This animation demonstrates facilitated diffusion across a cell membrane.

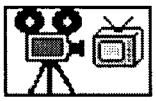
Questions:

1) Why can't glucose pass through the membrane without using a transport protein?

2) Explain why facilitated transport does not require energy (include the term concentration gradient in your explanation).

Facilitated Diffusion involves the movement of molecules such as glucose and amino acids. These molecules move across the membrane by being carried by ___________ molecules. This movement occurs only with (in the direction of) the concentration gradient.





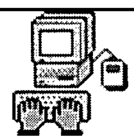
Computer Animation/Multimedia Center: Active Transport Across a cell Membrane
(from Physiological Concepts of Life Science Video counter 7 min 21 sec - 9 min 2 sec or # 0296-0357)

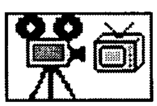
This animation shows the cell membrane proteins and their involvement in active transport.

Questions:
1. Why does active transport require energy (remember facilitated transport does not); Hint: it involves the concentration gradient.

2. What molecule provides the energy for active transport?

3. Describe the change in the protein caused by active transport.





Computer Animation/Multimedia Center: Active Transport
(from Anatomy & Physiology laserdisc Side A)

Search Frame 17615

This animation shows the protein function in the sodium/potassium pump.

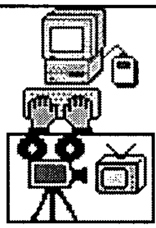
Note: the sodium/potassium pump will studied in more detail later- for now it provides a good example of active transport.

Active Transport

Involves moving molecules into or out of cells ___________ the concentration gradient. In other words, the molecules move from an area of __________ concentration to an area of __________ concentration.

Because it is __________ the concentration gradient, Active Transport requires energy. The energy is supplied by the ATP molecule. The reaction is ATP----> ADP + P + energy

Active transport also requires the use of __________ carrier molecules.



Computer Animation/Multimedia Center: Phagocytosis
(from Visualizing Cell Processes Laserdisc Side 1)

Search Chapter 7

This animation displays the process of phagocytosis and shows the process occurring in single-celled organisms.

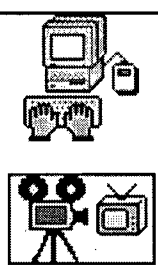
Questions:

1. What does the term phagocytosis mean?

2. What is the role of phagocytosis in primitive animals?

3. Describe an example of phagocytosis in humans.

Diagram the process of phagocytosis:



Computer Animation/Multimedia Center: Pinocytosis
(from Visualizing Cell Processes Laserdisc Side 1)

Search Chapter 8

A computer animation showing the process of pinocytosis in animated form and with living examples.

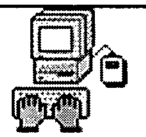
Questions:

1. What does the term pinocytosis mean?

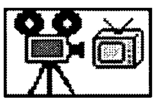
2. What is the role of pinocytosis in cells?

3. Describe an example of pinocytosis in animal cells.

Diagram the process of pinocytosis:



Computer Animation/Multimedia Center: Cellular Secretion
(from Physiological Concepts of Life Science Video. Counter: 9 Min 4 Sec to 11 Min 15 Sec)



This animation shows the interaction between the ribosomes, the golgi apparatus, and the cell membrane.

Questions:

1. What does the RER manufacture and send to the Golgi apparatus?

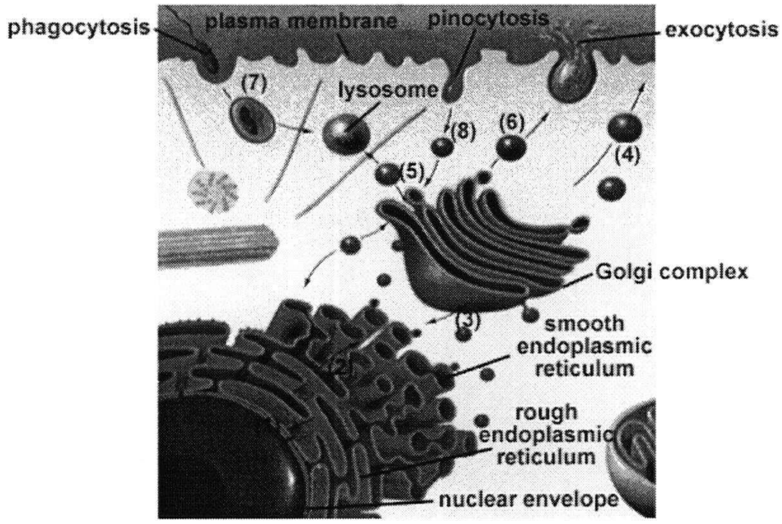
2. How does the RER transport its products to the golgi apparatus?

3. What may occur to proteins as they are passed between different parts of the golgi apparatus?

4. In this movie, what do they call the process of exocytosis?

5. List one example of a protein that is not excreted from the cell and indicate what this type of protein is often packaged in.

Indicate what is occurring at the locations shown below: (See Audesirk Pg. 91, Fig. 5-15).



1) ____

2) ____

3) ____

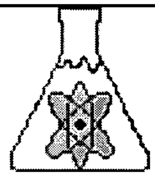
4) ____

5) ____

6) ____

7) ____

8) ____



Experiment

Laboratory Experiment: Solute Concentration of Potatoes
Begin Lab 13 from your lab manual. **NOTE**: you will need to prepare the solutions and the potato slices during one class period and complete the experiment after 24 hours - either during class time or after school.

Hand in the Experiment Separately to your teacher.

Fill in the following table on "How things get in and out of cells

Name	ATP Energy Req'd (Yes Or No)	With [ ] Gradient (√)	Against [ ] Grad. (√)	Brief Description
diffusion				
osmosis				
facilitated transport				
active transport				
exocytosis				
endocytosis: 1)phagocytosis				
endocytosis: 2) pinocytosis				

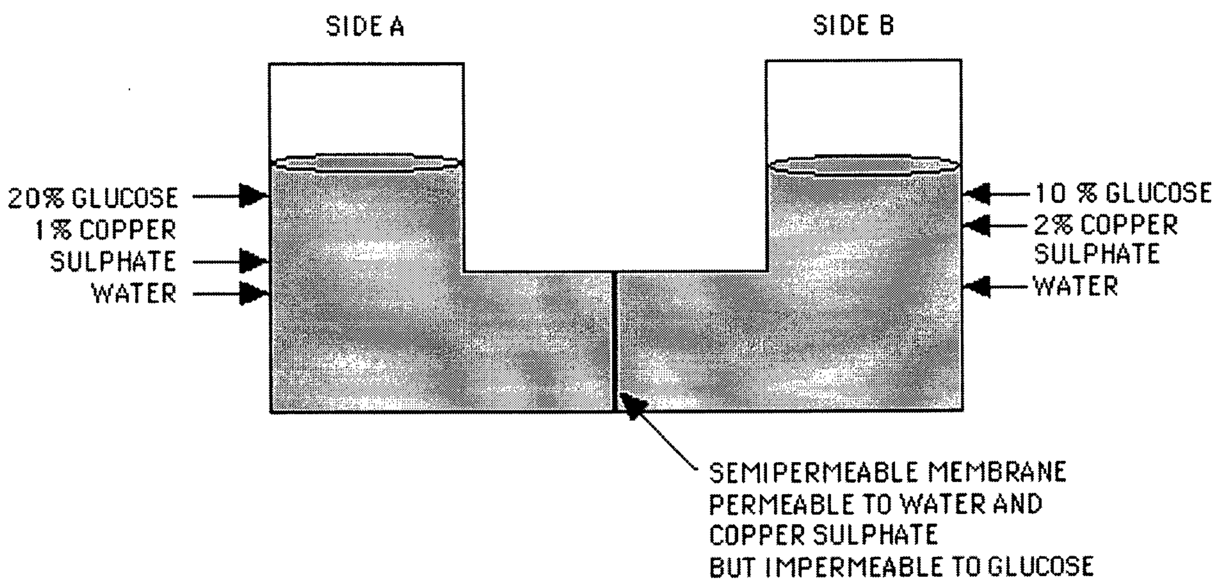
Complete the following osmosis problems:

1. If 0.9% NaCl solution is isotonic to a cell, then 1.0% NaCl solution is ____________________ to that cell.

2. When placed in a hypotonic solution, describe what will happen to:
   a) an animal cell-____
   b) a plant cell-____

3. Sea Urchin eggs are isotonic to sea water (4% salts, 96% water).
   3. Sea urchin eggs are normally released by the sea urchin into salt water (about 4% solute and 96% water). Describe what would happen to these eggs when placed in the following solutions:
   a) 4% salts; 96% H_2O ____________________________
   b) 1% salts; 99% H_2O ____________________________
   c) 20% salts; 80% H_2O ___________________________

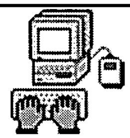
4. Examine the diagram below & answer questions a to c.



a) Describe what happens to the concentration of the glucose solution on side A and explain your answer. ____

b) Describe what happens to the concentration of the copper sulfate solution on side A. Explain.___

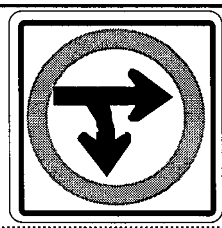
c) Describe **two** to ways increase the rate of diffusion across the membrane.______________

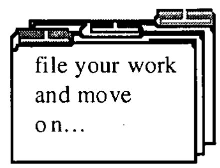
Interactive Test...
Test your progress on the computer. Take the test "**Cell Membrane Function**".

Your test will be marked automatically; print the results and hand them into the teacher.

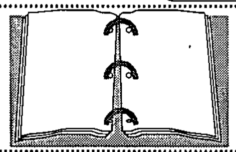
Compare Your Quiz Scores to Your Goal...



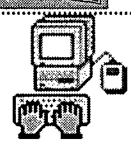
Goal Achieved!



Continue with the next topic...Cellular Metabolism.

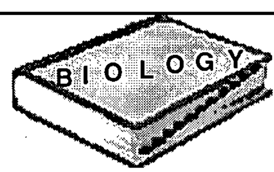


Corrective Assignments: Cell Membrane and Cell Wall Function:
Assignment: Mader (7th): Study Questions Page 71 # 2, 3, 5, 6, 7, & 10.
Objective Question Page 71 # 8

Interactive Test: Cell Membrane Re-Test

Test your progress on the computer. Take the retest "**Cell Membrane ReTest**". Your test will be marked automatically; print out the results and hand them in to your teacher.



Text References:
Audesirk & Audesirk
56 - 68
Mader
7th. Pg. 71 - 82

Cellular Metabolism

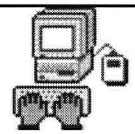
Enzymes allow the chemical reactions in our bodies to occur fast enough to keep us alive. Without these enzymes, the reactions could still occur - but not nearly fast enough to maintain life.

Define the Following:

1. metabolism: ______________________________

2. substrate: ______________________________

3. enzyme: ______________________________



Computer Tutorial: Enzymes
View scenes #1 - 7
(from Cyber Ed CD series)
Shows the basic function of enzymes in cell reactions

Instructions:

1) Proceed to a computer station.
2) Sign in to AtEase.
3) Obtain the Cyber Ed Cell Structure and Function CD from the storage area.
4) Place the CD in the CD-ROM drive and allow some time for the program to load.
5) Click on the Pink Cell Structure Folder.
6) Click on the "CED Cell Structure" Icon.
7) Click on continue/start/presentation/manual/OK
8) View Tutorial scenes # 1 - 7. You may not have time to complete this in one sitting - if not, Click on main menu and remember the last scene you have viewed.
9) When finished viewing the scenes, click on stop/main menu/Quit.
10) To continue viewing the presentation from a scene other than #1, follow steps 1 - 5, and for step 6): Click on continue/start/presentation/automatic/select location/OK
11) Enter the scene number you wish to jump to by clicking on the correct digits/click on "go to"

Questions:

1. Where are enzymes produced?

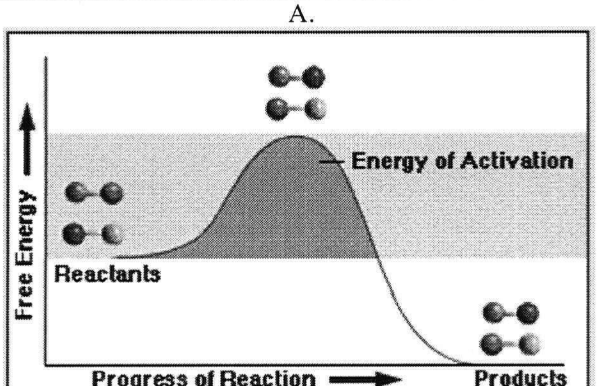
2. Where may enzymes be active?

3. What is the function of an enzyme?

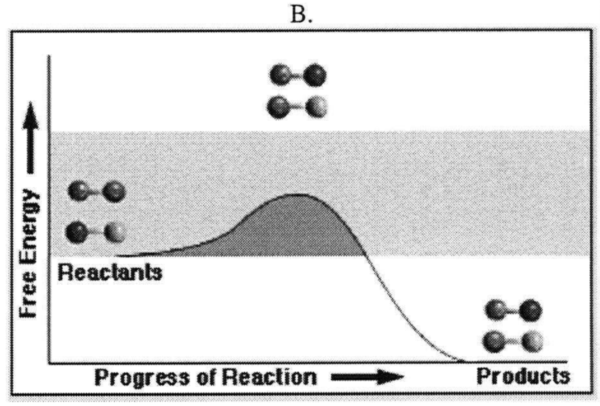
4. What is the amount of energy needed for the reaction to occur called?

5. What critical role do enzymes have in living organisms such as humans?

A.



B.



1. Identify a) the reason for the difference in the appearance of these two graphs, and b) the difference between the reactants at the beginning of the reaction compared to their appearance at the top of the Energy of Activation hump:

Computer Animation/Multimedia Center: Lock and Key Model of Enzyme Action
(from Physiological Concepts of Life Science Video 50 sec - 2 min 19 sec or counter # 0000 - 0091)

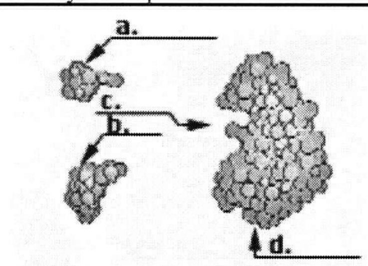
This animation shows the effects of enzymes on their substrates.

Questions:

1. What changes occur to an enzyme during an enzyme catalyzed reaction?

2. Describe one possible change that occurs to the substrates of an enzyme catalyzed reaction.

3. Identify the representations in the following diagrams:

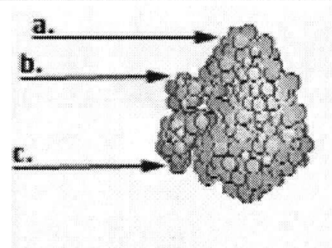


a. ______________________

b. ______________________

c. ______________________

d. ______________________



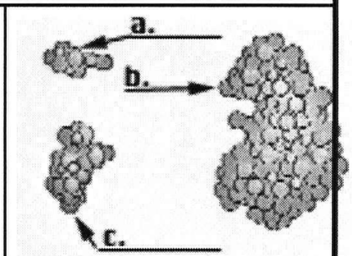
What is the name of the above structure?

____

a. ______________________

b. ______________________

c. ______________________



a. ______________________

b. ______________________

c. ______________________

Computer Tutorial: Enzymes
View scenes # 8 - 10
(from Cyber Ed CD series)

Instructions:

1) Click on continue/start/presentation/manual/select location/OK
2) Enter the scene number (scene # 8) you wish to jump to by clicking on the correct digits/click on "go to"

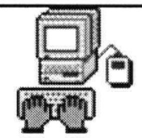
Questions:

1. What is the role of an active site?

2. In the lock and key model, which participant can be called the lock and which is the key? Why? (Note: you are not responsible for induced fit model.)

3. What does the enzyme substrate complex consist of?

Enzymes are____________for one type of reaction only because the substrates fit on the enzyme the same way a key fits in a _________. Because of this exact fit, this is known as the _______ and _________ theory of enzyme action.



Computer Animation/Multimedia Center: Enzymes and Energy Cycles
(from Biology Life on Earth Laserdisc Side 1)

Search Frame 12851

This animation introduces the two energy classifications for chemical reactions and demonstrates the effects of enzymes.

Questions:

1. What does term metabolism mean?

2. Describe and give an example of an exergonic reaction:

3. Describe and give an example of an endergonic reaction:

4. What is activation energy?

5. What is the role of enzymes in regards to activation energy?

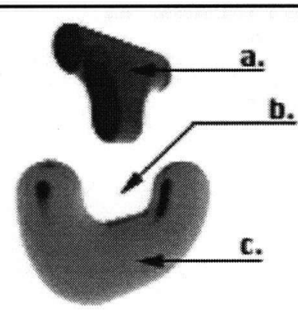
6. List four ways enzymes accelerate chemical reaction to occur:

7. Identify features a, b, & c in the following diagram:

a. ______________________________________

b. ______________________________________

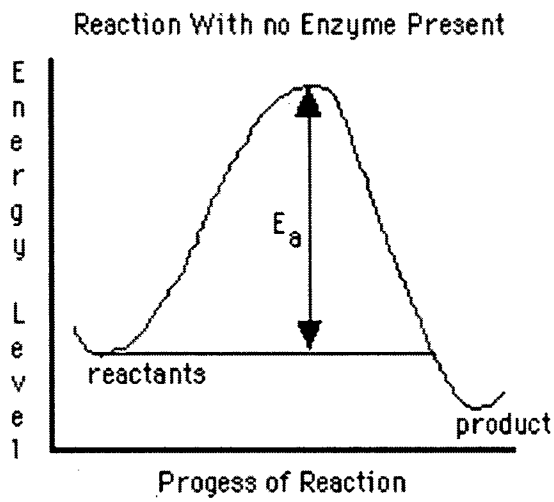
c. ______________________________________



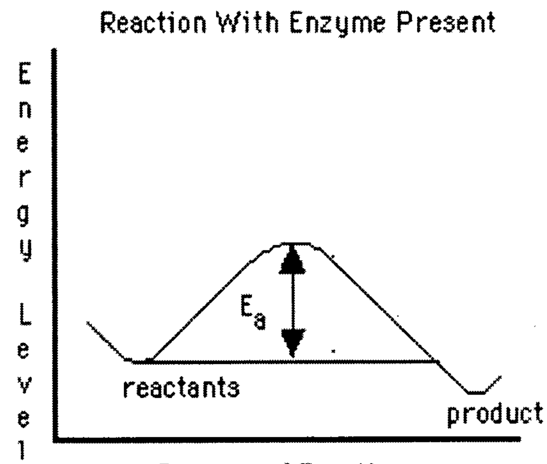
8. IB/Enrichment Question: Describe the features of competitive and allosteric inhibition:

Enzymes speed up reactions by lowering the E_a (energy of activation). Study the two following graphs & see Audesirk & Audesirk Pg. 64 - 65.

A.

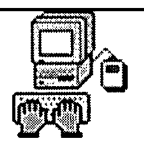


B.



The presence of a specific enzyme for a reaction lowers the activation energy for the reaction. In graph A. the Ea is _______________ compared to graph B. Enzymes lower the _____________ ____________ by binding with their __________________ in such a way that the reaction can occur ________________ .

Enzymes are specific to only one reaction, and enzymes are reusable.



Computer Tutorial: Enzymes
View scenes # 14 - 19
(from Cyber Ed CD series)
Shows the effect of temperature/substrate concentration/enzyme concentration on enzyme catalyzed reactions.

Instructions:
1) Click on continue/start/presentation/manual/select location/OK
2) Enter the scene number (scene # 14) you wish to jump to by clicking on the correct digits/click on "go to"

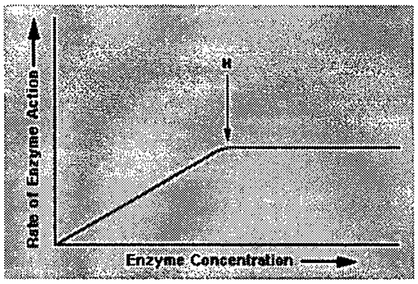
Questions:
1. How does temperature affect enzyme catalyzed reactions?

2. Why is the optimum temperature for human enzymes 37° C?

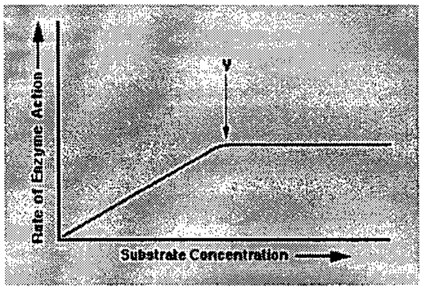
3. Why does the rate of enzyme action begin to decline with higher temperature?

(continued on next page)

5. Explain why the graph below levels off at X.



6. Explain why the graph below levels off at Y?



7. What is the optimum pH for pepsin? Why is this the optimum pH for pepsin?

8. Why was the Danish "bogman" so well preserved?

9. What kind of compound is a cofactor? What is the role of a cofactor?

10. What kind of compound is a coenzyme? What is the role of a coenzyme?

Coenzymes

Besides the protein portion of an enzyme (known as the ______________), there may also be a non-protein

portion (the coenzyme). Coenzymes often require ________________ in order for the body to produce them, or may be partially made of ________________ . This is the only function for many ________________ in the body.

Coenzymes participate in reactions by serving as carriers for __________________.

Experiment

Laboratory Experiment: The Effects of Temperature on an Enzyme Catalyzed Reaction
Obtain a copy of the Student Lab Instructions from your Teacher. **NOTE: WEAR SAFETY GOGGLES WHILE CONDUCTING THE EXPERIMENT!**

Hand in the Experiment Separately to your teacher.

STUDENT

Interactive Test...
Test your progress on the computer. Take the test "**Cellular Metabolism**".

Your test will be marked automatically; print the results and hand them into the teacher.

Compare Your Quiz Scores to Your Goal...

Goal Achieved!

file your work and move on...

Continue with the next topic... Energy Transfer.

Corrective Assignments:
Audesirk & Audesirk: Review Questions Page 72 # 3,4,5.
or
Mader (7th): Study Questions Page 81 # 5,6,7,8.
Complete these questions and hand in to your teacher on a separate piece of paper.

STUDENT

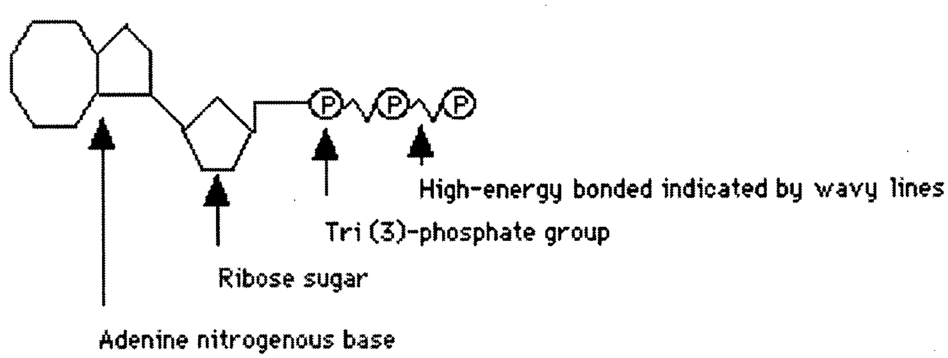
Interactive Test: Cellular Metabolism Re-Test

Test your progress on the computer. Take the retest "**Cellular Metabolism ReTest**". Your test will be marked automatically; print out the results and put them in your folder.

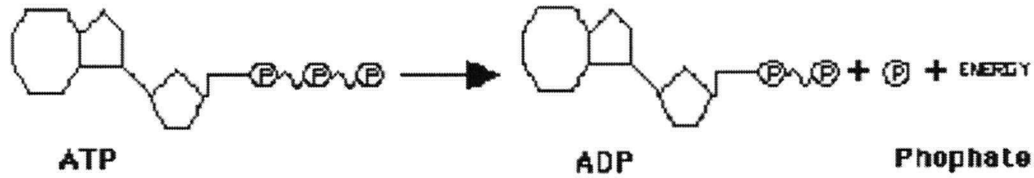
Text References:
Audesirk & Audesirk
68 - 70
Mader
7th. Pg. 74 - 75

Energy Transfer

ATP (adenosine triphosphate) is the energy currency of the cell. A molecule of ATP is shown below:



When the cell requires energy- for things such as active transport, muscle contraction, endocytosis, etc. the ATP molecule is broken down as follows:



ADP is adenosine diphosphate, and as you can see it now contains only 2 phosphate molecules, one of the phosphate molecules was removed to produce energy (about 7 kcal/ATP molecule. Check out fig. 5.2 of the 7th ed. on Pg. 75 for some interesting stats on ATP use.

In summary the ATP reaction is: _______ _______ + _____ + energy

Computer Tutorial: Cellular Respiration
View scenes # 4 - 9
(from Cyber Ed CD series)
This animation shows the function of ATP in the cell.

Instructions:
1) Click on continue/start/presentation/manual/select location/OK
2) Enter the scene number (scene # 4) you wish to jump to by clicking on the correct digits/click on "go to"

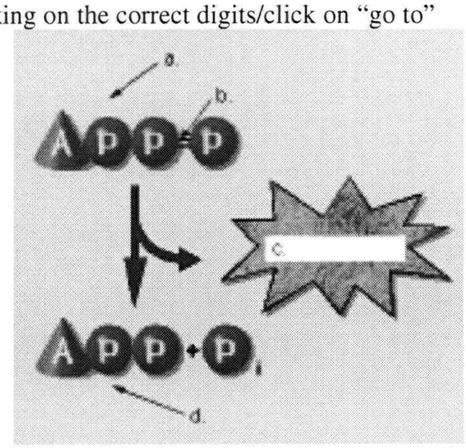
Questions:
1. Identify the labeled structures in following diagram:

a. ________________________________

b. ________________________________

c. ________________________________

d. ________________________________



(continued on next page)

2. Define oxidation:

3. Define Reduction:

OXIDATION & REDUCTION REACTIONS

It will be important for you to be able to tell if a molecule is being oxidized or reduced in the upcoming section. If you use these guidelines, this will be an easy process.

Remember : **LEO** the lion goes **GER**

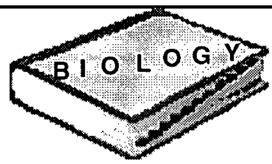
LEO stands for: **Loss of electrons = oxidation**. In other words anytime a molecule or compound loses electrons during a chemical reaction, it becomes oxidized.

- Oxidation reactions <u>release</u> energy.

GER stands for: **Gain in electrons = reduction**. In other words if a molecule or compound picks up more electrons during a chemical reaction, it is being reduced.
- Reduction reactions <u>require</u> energy.

i.e.
$NAD^+ + 2e^- + 2H^+ \text{---->} NADH + H^+$
In the above reaction NAD^+ has become ______________ during the reaction to become NADH.

Conversely, if the reverse reaction were to occur: $NADH + H^+ \text{---->} NAD^+ + 2e^- + 2H^+$; NADH would be ______________ during the reaction to become NAD^+.



Text References:
Audesirk & Audesirk
Pg. 140 - 156
Mader
7th. Pg. 90 - 102

<u>Cellular Respiration</u>

Cellular Respiration are metabolic processes occurring in cells where ______________ is oxidized and the energy released is used to produce ____ ATP molecules.

ATP is the molecule that cells use for energy.

The overall **net reaction** of cellular respiration is:

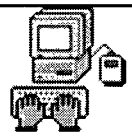
$C_6H_{12}O_6 + \_\_O_2 \text{---->} \_\_CO_2 + \_\_H_2O$ + energy (in the form of ___ ATP)

Cellular Respiration consists of

1) Glycolysis
   - occurs is the cytoplasm of the cell
   - Oxygen is not required
   - can lead to either aerobic or anaerobic respiration (fermentation)

2) Aerobic Cellular Respiration
   - occurs in the mitochondria of the cell.
   - Oxygen is required
   - consists of 3 subpathways: Mitochondrial matrix reaction, Kreb's (citric acid) Cycle, & Respiratory Chain (Electron transport system).

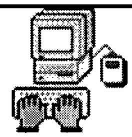
1) Glycolysis

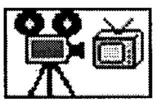


Computer Tutorial: Cell Structure and Function
View scenes # 29 - 30
(from Cyber Ed CD series)

Instructions:
1) Click on continue/start/presentation/manual/select location/OK
2) Enter the scene number (scene # 29) you wish to jump to by clicking on the correct digits/click on "go to"

Questions:
1. What is the mitochondrion capable of?





Computer Animation/Multimedia Center: Cellular Respiration
(from Biology Life on Earth Laserdisc Side 1)

Search Frame 38958

This animation shows a tour of a cell undergoing cellular respiration.

Questions:
1. How do cells acquire energy?

2. What is the first part of the pathway called and where does glycolysis occur?

3. What occurs during glycolysis and what are the products?

4. If anaerobic conditions (no Oxygen available) exist, what products are made in animals? In Yeast?

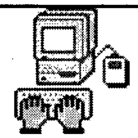
5. What is the name of the process that produces the above molecules?

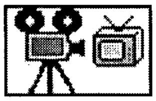
6. What kind of conditions are necessary for cellular respiration to occur?

7. In the Kreb's cycle what occurs to pyruvic acid?

8. What other molecules are produced in the Kreb's Cycle?

9. How many ATP are produced by the electrochemical gradient created by the electron transport system?





Computer Animation: Glycolysis & Fermentation
(from Visualizing Cell Processes Laserdisc Side 1)

Search Chapter 15

An animation showing the metabolic subpathway of glycolysis.

Questions:

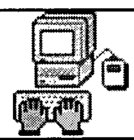
1. What is glycolysis?

2. Where does glycolysis occur in the cell?

3. How many steps are involved in glycolysis? Note: you do not have to know the details of each step - just the beginning reactants and final products.

4. Describe how molecules of NAD+ are transformed into NADH.

5. What is the net gain of glycolysis?



Computer Tutorial: Cellular Respiration
View scenes # 14 - 20
(from Cyber Ed CD series)
Shows the subpathway known as glycolysis.

Instructions:

1) Click on continue/start/presentation/manual/select location/OK
2) Enter the scene number (scene # 14) you wish to jump to by clicking on the correct digits/click on “go to”

Questions:

1. What is glycolysis?

2. Where does glycolysis occur in the cell?

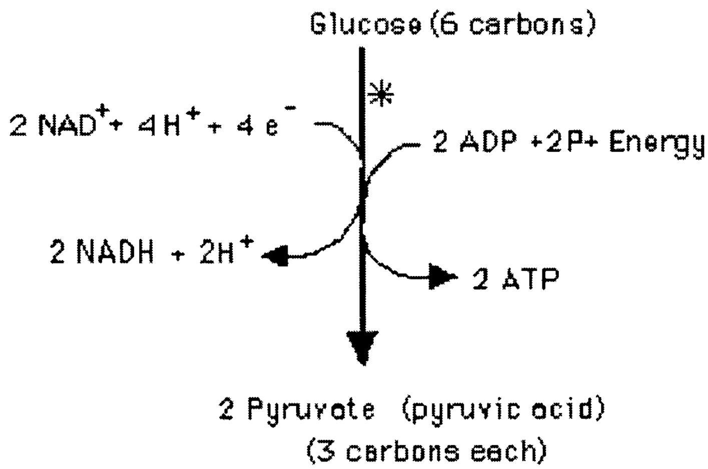
3. What is the substrate of glycolysis?

4. How many ATP are produced during glycolysis?

5. What molecule picks up the hydrogen atom from PGAL?

6. When NAD gains H+ is it being oxidized or reduced? (NOTE: the reaction is $NAD + e^- + 2H^+ \rightarrow NADH + H^+$)

1) Glycolysis



✳ this is actually a nine step process- but you only need to know the above

Fill in your own notes on glycolysis here:

Location: ______________________

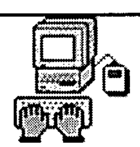
# of NADH Produced: ______

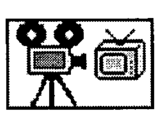
# of ATP produced: ______

Substrate: ________________

Products: _________________________

2) Acetyl Coenzyme A formation





Computer Animation/Multimedia Center: Mitochondrion Structure
(from Visualizing Cell Processes Laserdisc Side 1)

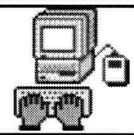
Search Chapter 16

An animation describing the metabolic reaction forming Acetyl Coenzyme A.

Questions:

1. What is the energy released from pyruvic acid used to produce?

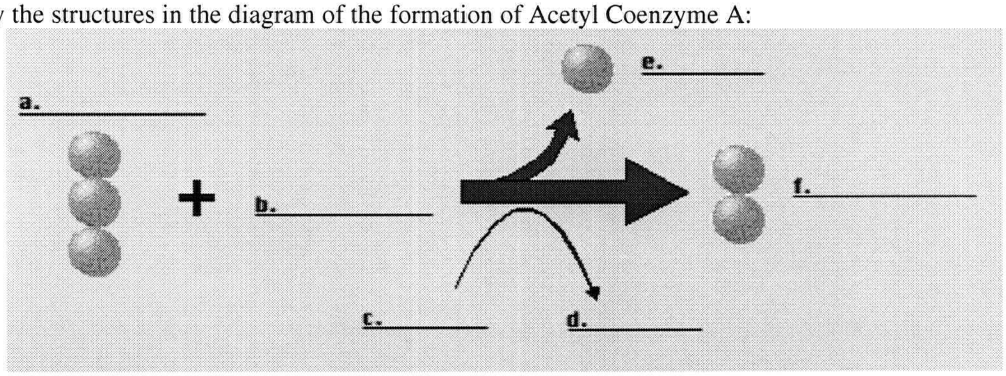
2. What waste molecule produced diffuses out of the mitochondrion?



Computer Tutorial: Cellular Respiration
View scenes # 31 - 32
(from Cyber Ed CD series)

Instructions:
1) Click on continue/start/presentation/manual/select location/OK
2) Enter the scene number (scene # 31) you wish to jump to by clicking on the correct digits/click on "go to"

Questions:
1. Identify the structures in the diagram of the formation of Acetyl Coenzyme A:

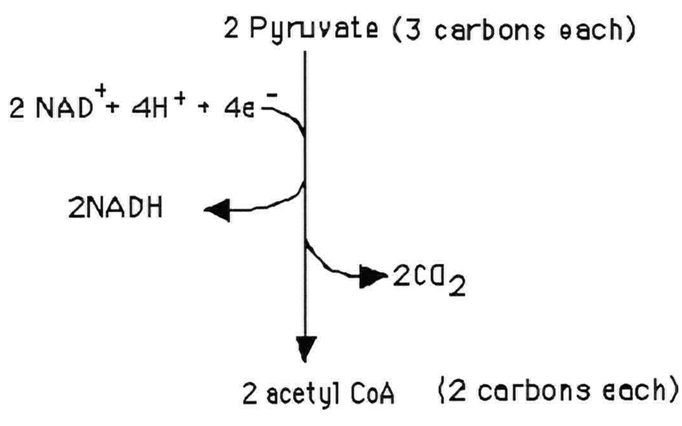


2. How many carbons are in a molecule of pyruvic acid, how many are in Acetyl-CoA?

3. What has happened to the carbon that left pyruvic acid during this reaction?

Acetyl CoA formation

- Occurs in the matrix of the ___________________ .
- First step of ________________ cellular respiration.

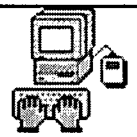


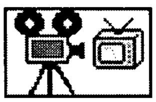
Fill in your own notes on Acetyl CoA formation here:
Location: ____
# of NADH produced: ____
# of ATP produced : ____

other product(s): ________________

Substrate: ______________________

3) Citric Acid (Kreb's) Cycle





Computer Animation: Kreb's Cycle
(from Visualizing Cell Processes Laserdisc Side 1)

Search Chapter 18

This animation shows the cyclic nature of the Kreb's (citric acid) cycle.

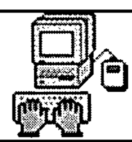
Questions:

1. What does the Kreb's Cycle do?

2. How many NADH are formed during the Kreb's Cycle? How many $FADH_2$ are formed?

2. Why is Kreb's Cycle called a cycle?

3. How many Acetyl CoA enter the Kreb's cycle /molecule of glucose entering glycolysis?



Computer Tutorial: Cellular Respiration
View scenes # 33 - 35
(from Cyber Ed CD series)

Instructions:

1) Click on continue/start/presentation/manual/select location/OK
2) Enter the scene number (scene # 33) you wish to jump to by clicking on the correct digits/click on "go to"

Questions:

1. How many Acetyl-CoA enter the cycle per rotation of the Kreb's Cycle?

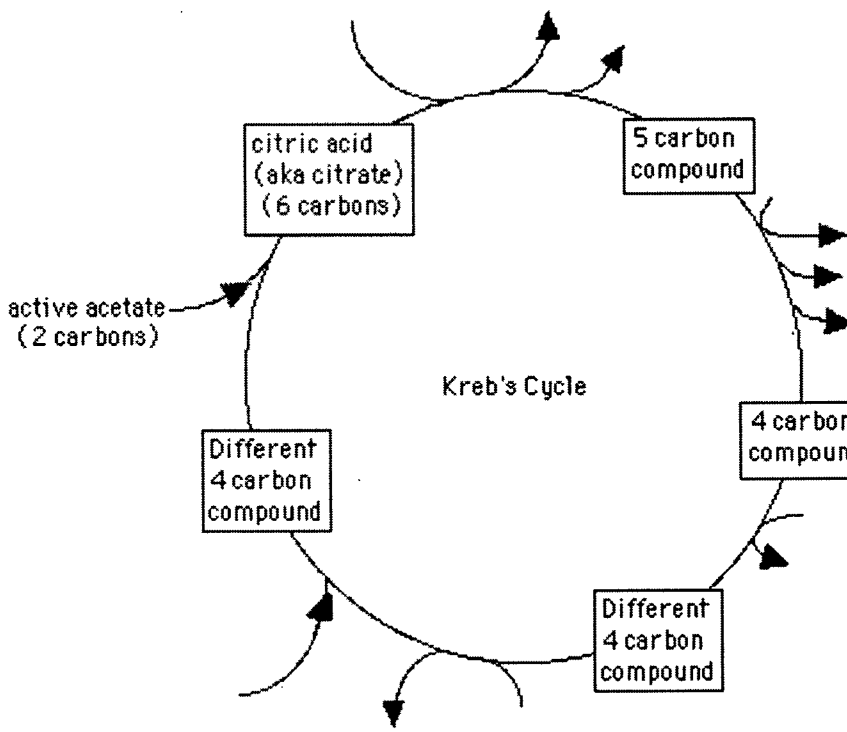
2. List the products of the Kreb's Cycle: # Produced Name of Compound

Citric Acid (Kreb's) Cycle

- occurs in the mitochondrial ______________ .
- carbon to carbon bonds within molecules are broken
- the broken bonds release energy (therefore involves ________________________)

- the energy is used to produce ATP, NADH, $FADH_2$
- a.k.a.: oxidative decarboxylation (means:)
- consists of a cycle which uses ______________________ from Acetyl CoA formation.

Fill in the blanks in the following diagram of the Citric Acid (Kreb's) cycle:



NOTE: for every 1 glucose molecule the cycle goes around twice
Write your own Kreb's Cycle notes here:

four things removed from the substrates: __________, ___________, ___________, &

___________ .

For every 1 glucose:

Substrate: _______________

Products: _____ CO_2

_____ ATP

_____ NADH

_____ $FADH_2$

CO_2 is a _________ product, however, ATP, NADH, & $FADH_2$ provide energy to the following, and final, step.

4) Electron Transport System (Respiratory Chain)

Computer Tutorial: Cellular Respiration
View scenes # 36 - 43
(from Cyber Ed CD series)

Instructions:
1) Click on continue/start/presentation/manual/select location/OK
2) Enter the scene number (scene # 36) you wish to jump to by clicking on the correct digits/click on "go to"

Questions:
1. Identify the structures shown in the following diagram:

a. ____________________________________

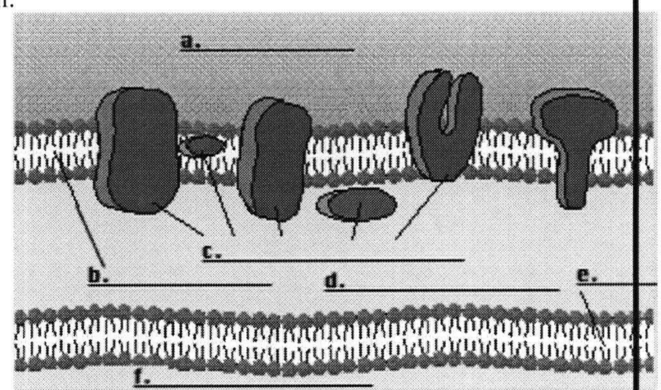
b. ____________________________________

c. ____________________________________

d. ____________________________________

e. ____________________________________

f. ____________________________________



2. What two molecules bring electrons to the electron transport chain?

3. Write the reaction showing the oxidation of NADH:

4. What is the energy of the electrons used for?

5. What chemical reaction occurs after the hydrogen ions have left the intermembrane space?

6. What is the function of ATP Synthase?

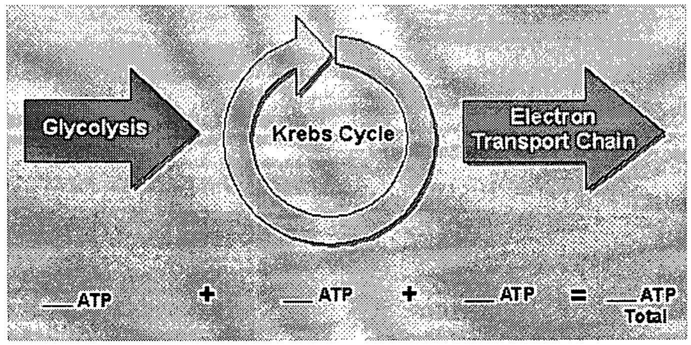
7. Why do H^+ ions want to leave the intermembrane space?

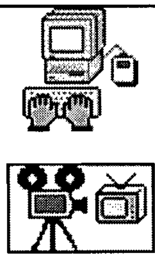
8. How many ATP's are formed by the arrival of NADH at the electron transport chain? How many by $FADH_2$?

(continued on next page)

9. Why does $FADH_2$ result in fewer ATP than NADH?

10. Fill in the following summary of ATP production:





Computer Animation: Electron Transport System
(from Visualizing Cell Processes Laserdisc Side 1)

Search Chapter 19

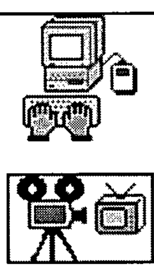
An animation depicting the final step of cellular respiration.

Questions:

1. What can the energetic electrons be compared to?

2. What does the height of the hill represent in the "rolling ball" analogy?

3. What chemical reaction occurs at the end of the process?



Computer Animation/Multimedia Center: ATP Synthesis
(from Visualizing Cell Processes Laserdisc Side 1)

Search Chapter 20

An animation showing how ATP is generated using the movement of hydrogen ions.

Questions:

1. What provides the energy for ATP synthesis?

(continued on next page)

2. What does ATP synthase look like?

3. Where is ATP synthase located in a mitochondrion?

Electron Transport System (Respiratory Chain)

- located on mitochondrial ____________ .
- consists of a series of carriers (cytochromes) that pass ____________ on from one carrier to another.
- leads to _____ production.
- uses ATP, NADH, & $FADH_2$ from Kreb's cycle to supply the energy to produce ______.

Each NADH arriving at the respiratory chain produces ____ ATP

Each $FADH_2$ arriving at the respiratory chain produces ____ ATP

Make your own notes on the respiratory chain here:

Source of high energy electrons: _________ & __________ .

Function of the cytochromes: ____.

Source of energy for ATP production:____

____

Total NADH produced in cellular respiration:

____ from glycolysis

____ from Acetyl CoA formation

____ from Kreb's Cycle

Total = ____ NADH

Total $FADH_2$ produced in cellular respiration

____ from Kreb's cycle

Total = ____ $FADH_2$

Therefore ATP formed in Respiratory Chain:

____ NADH x ____ $\frac{\text{ATP}}{\text{NADH}_2}$ = ____ ATP

____ $FADH_2$ x ____ $\frac{\text{ATP}}{\text{FADH}_2}$ = ____ ATP

Total = ____ ATP

Now let's figure out how many ATP molecules are produced per Glucose molecule entering into cellular respiration:

____ from glycolysis

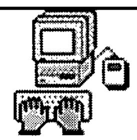
____ from Acetyl CoA formation

____ from Kreb's Cycle

____ from Electron Transport

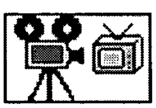
Total = ____ ATP / Glucose

4) Review of Aerobic Cellular Respiration



Computer Animation/Multimedia Center: Cellular Respiration
(from Biology Life on Earth Laserdisc Side 1)

Search Frame 34830



This animation provides a good summary of cellular respiration.

Questions:

1. What are "anaerobic conditions"?

2. What are the "reduced electron carriers" produced in the Kreb's cycle called?

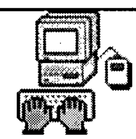
3. What is the role of the reduced electron carriers?

4. What is the role of the energy donated by the high energy electrons in the electron transport system?

**Please fill in the following table based on the ATP output of mammalian (e.g. human) heart or muscle cells - see Audesirk & Audesirk Pg. 155 TABLE 8-1 for an explanation.

Name of Subpathway	Location in Cell	Substrate(s)	Products	# of ATP Produced
Glycolysis				
Acetyl CoA formation				
Kreb's Cycle				
Electron Transport System				

Anaerobic Respiration (Fermentation)



Computer Tutorial: Cellular Respiration
View scenes # 11 - 13, & 23 - 27
(from Cyber Ed CD series)

Presents the process of anaerobic cellular respiration.

Instructions:
1) Click on continue/start/presentation/manual/select location/OK
2) Enter the scene number (scene # 11) you wish to jump to by clicking on the correct digits/click on "go to"

Questions:
1. What does the term Anaerobic mean?

2. Name two organisms that rely on anaerobic respiration?

3. What conditions must be present in order for human muscle cells to conduct anaerobic respiration?

4. Why is aerobic respiration more efficient than anaerobic respiration?

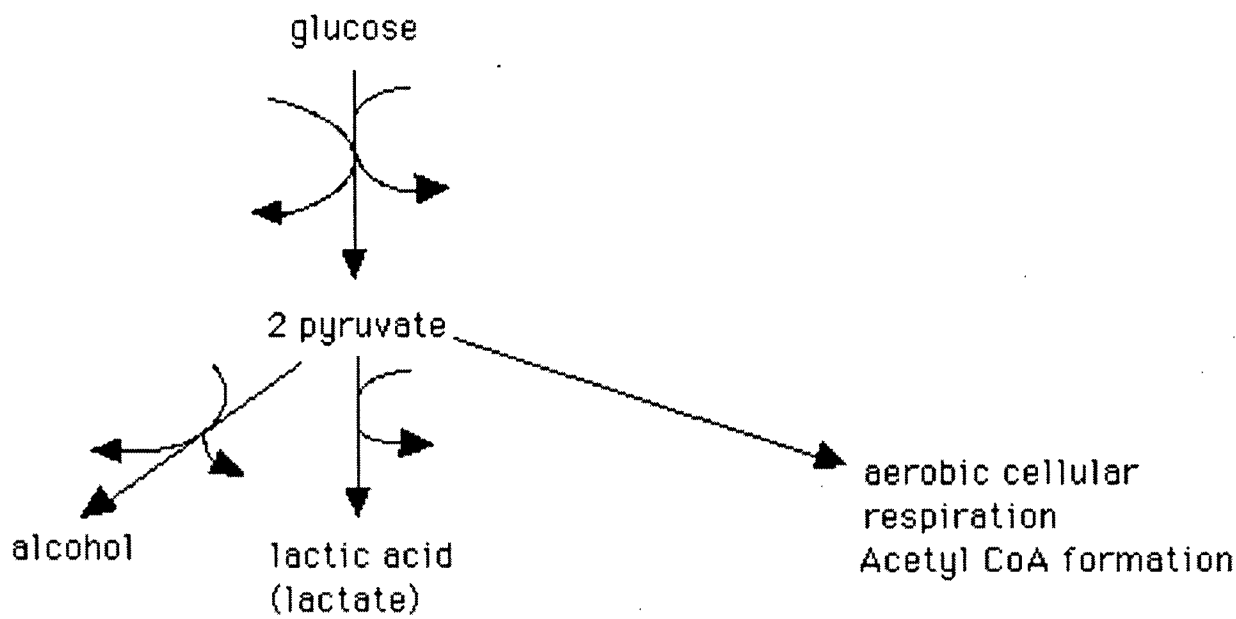
5. Name two possible products from anaerobic respiration and the organisms that produce them.

6. Is glycolysis aerobic or anaerobic?

ANAEROBIC RESPIRATION (Fermentation)

Glycolysis is _______________ because it can proceed with or without oxygen. Anaerobic respiration or fermentation consists of glycolysis plus one other reaction. The products of this process may vary depending on the type of organism it is occurring in. i.e.

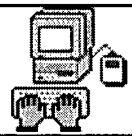
(continued on next page)



Occurs in __________ ________________ ___________________

In humans anaerobic respiration (fermentation) occurs only in ____________ muscle cells. The purpose is to recycle __________ to allow ______ ATP to be produced - which is better than nothing.

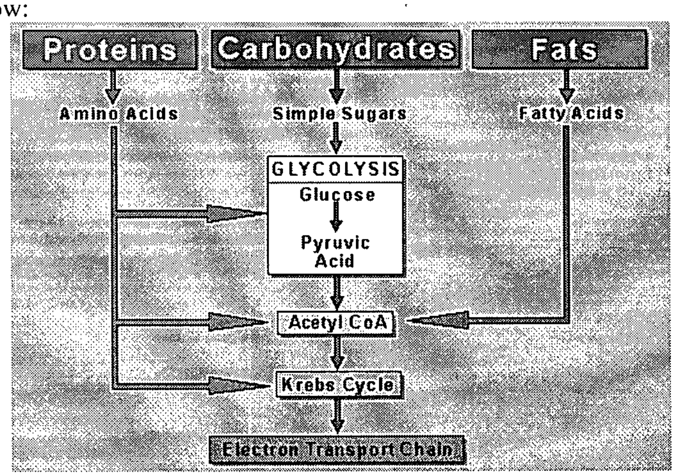
(continued on next page)



Computer Tutorial: Cellular Respiration
View scenes # 44
(from Cyber Ed CD series)

Instructions:
1) Click on continue/start/presentation/manual/select location/OK
2) Enter the scene number (scene # 44) you wish to jump to by clicking on the correct digits/click on "go to"

Questions:
1. Study the diagram below:



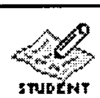
Indicate typical food sources for:

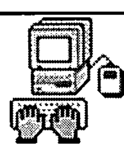
Proteins:

Carbohydrates:

Fats:

2. Where would you have to add arrows to indicate how a person gains weight?

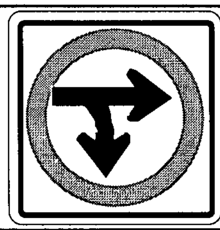




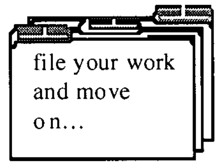
Interactive Test...
Test your progress on the computer. Take the test "**Cell Respiration**".

Your test will be marked automatically; print the results and hand them into the teacher.

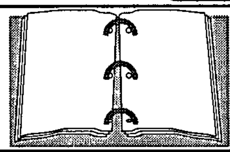
Compare Your Quiz Scores to Your Goal...



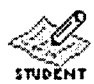
Goal Achieved!

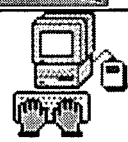


Continue with the next topic... <u>Photosynthesis</u>.



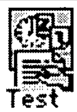
Corrective Assignments: Cellular Respiration:
Audesirk & Audesirk: Review Questions Page 155 # 1,2,3,4,7.





Interactive Test: Cell Respiration Re-Test

Test your progress on the computer. Take the retest "**Cell Respiration ReTest**". Your test will be marked automatically; print out the results and <u>hand them into your teacher</u>.



<u>Cell Ultraprocesses: Unit Exam</u>

Review your study guide to this point; refer to your "Learning Outcomes" accompanying this study guide and your assignments to direct your studies.