MULTIPLE INTELLIGENCE THEORY IN BIOLOGY 2D03 LABORATORIES

MULTIPLE INTELLIGENCE THEORY IN THE REVISION OF BIOLOGY 2D03 LABORATORIES

By

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Abstract

The laboratory curriculum and assessment of the course Biology 2D03, The Plant Kingdom, was revised in 1998. In part, the revision was due to the need to update the laboratory manual to reflect a new edition of the text book. Also revision to condense three chapters into two to accommodate a shorter than usual term and to include a chapter on the fungi was done. Assessment was revised in response to student suggestions and comments taken from course assessments. Key to these revisions was incorporating Multiple Intelligence theory into curriculum and assessment.

A new form of assessment, mini-laboratory practicals, was devised replacing quizzes and one laboratory examination. The mini-laboratory practicals utilized visual-spatial, bodily-kinesthetic, naturalist intelligence, verbal-linguistic and mathematical-logical intelligences. Intrapersonal intelligence was implemented with an essay assignment which required students to reflect on how plants were important to their personal lives. Musical-rhythmic intelligence was implemented by playing classical music with nature sounds (to enhance the naturalist intelligence) in the laboratory classroom. Two laboratory sections requested that the music be played during test situations while six sections did not.

There were few unintended side effects of the revisions. The essay was more of a feminine exercise and male students had difficulty in relating personal experience. Revision of assessment procedures did not affect grade means or distributions. Assessment methods

required some memorization but also required thinking and application of knowledge. A large proportion of students found that the combination of assessment methods (mini-laboratory practicals, laboratory examination and final examination) best tested their knowledge. The majority suggested that the new revision scheme be retained. The use of classical music with nature sounds resulted in a more relaxing, soothing learning environment but there was no evidence of a "Mozart effect".

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At this time I wish to thank those women who have been my mentors over the years. Dr. Louise Barber and Dr. Irene Ockenden of McMaster University have always been there when I needed friendship and encouragement. My mother-in-law, Margaret Joyce Leech, has had an enormous influence on my life. She has shown me that learning in life-long and one is never too old!

On a personal note, I thank Fred Leech for his support on the home front. I also wish to dedicate this project in the memory of my father-in-law, Russell Edward Leech.

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Chapter 1.

Introduction

Biology 2D03, The Plant Kingdom is a second level course offered in the fall term at McMaster University by the Department of Biology. The course description of 2D03 states that it provides an overview of major groups of green plants with an emphasis on growth and development of vegetative parts and mechanisms of reproduction. It is a required course for biology degrees offered at McMaster and is a pre-requisite for higher level botany courses. At the end of each term, course evaluations are completed by the students. Overall, the evaluations have been favourable. In 1996, 80% of responding students indicated that the course material seemed valuable to them and 74% indicated that they found the course material interesting. Fifty-four per cent of responding students indicated that they found the laboratory component of the course to be very valuable. Only 4.5% indicated negative remarks about the laboratories. Over the years these evaluations have had the following common suggestions, comments or observations which could lead to improvement of the course:

- That there be a formal laboratory manual.
- That the assessment methods used in 2D03 be revised to eliminate or reduce in value the laboratory examinations.

- That the curriculum and assessment in 2D03 decrease an emphasis on memorization of material and instead encourage thinking and problem solving.
- While students find the curriculum in the Plant Kingdom course to be interesting, they fail to see any relevance to their life. As a consequence, few students go on to take higher level plant courses.

In response to the first comment, a laboratory manual was developed in 1992 and since then it has undergone yearly revision in response to students' feedback through course evaluations and surveys, changes in the text book, new scientific developments and development of new laboratory exercises. In 1998, a major revision of the laboratory was planned for the following reasons:

- To incorporate revisions due to a new edition of the text book.
- To condense three laboratory manual chapters into two to accommodate a shorter than usual fall term in 1998 caused by a late Labour Day holiday.
- The development of a new chapter and associated exercises on the fungi, a group of organisms that has not been part of the 2D03 curriculum prior to 1998.

While revising the laboratory manual, it was decided to address the issues of assessment and relevance of the 2D03 curriculum in response to points 2, 3, and 4.

One of the most contentious issues between student and teacher is that of assessment. The university system requires instructors to quantify the learning of students in their courses. Grades at McMaster university are quantified on a scale ranging from "0" (equal to a failing grade or F) to "12" (which is equivalent to an

A+). Assessment in university courses not only informs students how they are doing in a course and how much they have learned but determines their academic programme and future career. Each academic year, a cumulative average is calculated and used by McMaster University to determine the student's placement at university and future academic career potential in the following fashion:

- On a scale ranging from "0 - F" to " 12 - A+", a cumulative average (CA) of 6.0 is required to enrol in an Honors B.Sc. programme
- An honours student with a CA ranging from 5.5 - 5.9 is put on probation for one year
- A B.Sc. student with a CA ranging from 3.5 - 5.4 is enroled in a three year B.Sc. programme
- A student with a CA ranging from 3.0 - 3.4 is on probation for a three year B.Sc. for one year.
- A student with a CA less than three is not eligible to continue at McMaster.
- Restricted enrolment in Biology programmes requires a higher CA for enrollment in those courses than is required to enroll in the programme.
- In order to graduate, a three year B.Sc. requires a minimum CA of 3.5 while an Honors B.Sc. requires a minimum CA of 5.5.
- A CA of 9.5 or greater is required to qualify for the Dean's Honour List and graduation with distinction.
- Admission to Graduate Studies requires a minimum CA of 8.5.

- Admission to professional schools (medicine, dentistry, chiropractor college, law), which are in high demand, may require a CA of 11 or 12.

The guidelines for ethical principles in university teaching written by Murray et al (1996) for the McMaster University Society for Teaching and Learning in Higher Education state: "Given the importance of assessment of student performance in university teaching and in students' lives and careers, instructors are responsible for taking adequate steps to ensure that assessment of students is valid, open, fair, and congruent with course objectives." They go on to elucidate that the teacher should be aware of research on the advantages and disadvantages of alternate methods of assessment. Based on this knowledge, the teacher selects assessment techniques that are consistent with the objectives of the course and at the same time are as reliable and valid as possible. The challenge in revising assessment in Biology 2D03 is to ensure that the assessment methods meet the last statement.

Chapter 2a.

History of Assessment in Science Classes and in Biology 2D03 Prior to 1998.

Traditional Laboratory Assessment Methods:

The introductory general biology courses, Biology 1A03 and 1AA3, rely on traditional laboratory assessment and curriculum. In each laboratory the students perform "experiments" and are required to write formal laboratory reports which are modelled on scientific papers. In some laboratories, the first year students are required to produce formal scientific line drawings of organisms which follow strict protocols. The drawbacks to this type of laboratory assessment are listed below:

- The experiments are not experimental. They are tried and proven exercises which demonstrate known principles and are considered a success if the students produce the "correct" results. By this standard, the discovery of penicillin by Sir Alexander Fleming was a failure.
- Laboratory reports from previous years are freely available on campus so academic dishonesty is a concern.
- Scientific publications no longer rely on formal line drawings. Black and white or colour photographs and micrographs are now regular features in scientific journals. In requiring students to produce line drawings, they are being taught an out-dated technique. This form of assessment relies strongly on drawing and

drafting ability, which not all students are gifted in or have been trained in.

- Laboratory curriculum and assessment tend to be considered separate from the lecture material.

Assessment Methods Used in 2D03 Prior to 1998:

Biology 2D03 has never used laboratory reports or line drawings for assessment. Students are referred to illustrations in their text book and if they make drawings, the drawings are for their own study purposes and are not marked. Some laboratory exercises are performed, but they are not experimental and students do not write up laboratory reports. The purpose of the exercises was to demonstrate known principles and to teach laboratory techniques. Questions regarding the exercises appeared on quizzes and examinations. In Biology 2D03, there has been no separation between laboratory and lecture curriculum. Lectures and laboratories have followed the same topic schedule and the purpose of the laboratories has been to illustrate and enhance the lecture material with live plants materials, dissections, slide preparations and micrographs. There has been an emphasis on using native Canadian plant material to illustrate lecture topics. Prior to 1998, assessment in 2D03 was as follows (value of assessment as a per cent of the final grade is given in brackets).

A. Slides and Dissections performed in the laboratory (4%):

Slides and dissections were marked as a means to ensure that students actually did the required work. It also allowed the graduate student teaching assistants to check that students have observed what they are supposed to, to question the students

about what they have observed, and to increase the amount of interaction between students and their teaching assistants. It should be noted that almost 100% of the class do their slides and dissections and obtain a perfect grade for this part of the course. Many students comment on course evaluations that doing the slides and dissections were a waste of time but the instructors feel that they are valuable in teaching laboratory skills and ensuring interaction among students, teaching assistants and the instructors.

B. Weekly laboratory quizzes (16%)

The purpose of the weekly quizzes was to force the students to review each week's material. Each quiz was worth a small portion of the final grade but collectively they totaled 16%. Biology 2D03 is an intensive course and if students do not review weekly, the amount of material to be reviewed before each laboratory examination can be overwhelming to some students. While many students commented that weekly testing was too frequent and required too much work for so little marks, the instructors felt that the weekly quizzes were fulfilling their intended function. Grades on weekly quizzes were generally high (mean of 78% and median of 81% in 1997). Weekly quizzes were strictly pen and paper assessment and tested memorization skills and understanding of plant development/reproductive processes. As students have access to previous years' quizzes, by studying all the previous year's quizzes, they knew what to expect on the quizzes.

C. Laboratory Examinations (45%):

Two laboratory examinations were held at the middle and end of the term. Most of the negative comments made by students on course evaluations refered to the laboratory examinations. In this type of examination, the students moved from station to station, answering questions at each station. Stations may have had plants, microscope slides, micrographs or diagrams present on which the questions were based. Some recall of facts was required but the student was also required to interpret the material presented at each station. For example, students would be asked to list essential botanical errors present in diagrams taken from text books. Each station must be completed within a time limit of three minutes. Educationally, the laboratory examination was a valid assessment tool. They had some aspects of real life situations in that the students are confronted with real plants, electron micrographs and slides. The time limit increased anxiety for the students but in real life they would find themselves in situations such as job interviews or meetings with employers/clients/patients/students where they would be asked a question and would have to formulate a coherent answer in much less than three minutes. The students however have made the following complaints[1]:

- The time limit creates too much stress. "Lab exam (time) limit creates stress, panic, confusion." "The lab exam was too rushed, considering the amount of

[1] Comments selected from 1992-1997 course/laboratory evaluations.

material, the little amount of time you had, not to mention the stress you were under."

- The time limit is too short "Practicals are unfair. Questions such as "why" and "explain" are not suitable for practicals!!! These require thinking which is tough to do under a 2.5 minute time limit." "I felt that the Bell Ringer Lab exams were worth too much because they did not test my knowledge, they tested how fast I could read and write and think. My intelligence is not as low as my speed reading and writing abilities." "Some or most of the testing for major marks has a strong bias towards reaction time and discriminates to a large degree against adult learners. These require thinking which is tough to do under a time limit."

Student perceptions of the laboratory examination may be discouraging students from taking Biology 2D03 or from taking the plant sciences stream. The instructors would like to retain at least one laboratory examination in 2D03 but wanted to develop other assessment tools which may use the same physical aspects of laboratory examinations but eliminate the stress caused by the time limit.

D. Final Examination (35%)

The final examination was given after the course evaluations were completed so there has been no student feedback regarding this form of assessment. It was a two hour examination administered by the university registrar. Analysis of class statistics has shown that there is a strong correlation (Pearson Coefficient +0.8 in 1996, +0.9 in 1997) between how students perform on the second laboratory examination and the

final examination. These figures demonstrate that while students may complain about the laboratory examination format, the results obtained by the laboratory examination were correlated with how they perform on other, pen and paper assessment tools.

Chapter 2b.

Review of Authentic Assessment and Multiple Intelligence Theory in Biology 2D03

It is difficult to separate development of curriculum and assessment. Both are intertwined as one cannot change the curriculum without making corresponding changes to the assessment procedures used. If the main focus of 2D03 laboratory curriculum is to allow students to observe, dissect and section plant material then the assessment should not rely on pen and paper tests. In this project, the decision to revise assessment in 2D03 lead to a corresponding revision of the laboratory curriculum.

Student complaints that most assessment in 2D03 was based on memorization and did not assess intelligence or critical thinking skills questioned the "authenticity" of the assessment procedures. A cynic might observe that to some students, a assessment device is only valid or authentic if that particular student does well. So what is "authentic assessment"? Baron and Boschee (1995) and Armstrong (1994) concur that authentic assessment allows students to show what they have learned in a setting that closely matches the environment in which they would be expected to show that learning in real life. Multiple choice tests and quizzes based on facts, principles and terms demonstrate that the students have memorized the material but

often do not demonstrate that the students can apply their knowledge in a real life situation. Newman and Archbald (1994) state that authentic assessment requires students to produce knowledge that has value in their lives beyond proving their competence in school. Or as Baron and Boshee (1995, 3) stated, "The purpose of education is to prepare students to complete life's **relevant** tasks and to use academic skills in concert to complete those tasks." The key here is the word "relevant". Many students do not see the relevance of plant sciences to their current or future lives or the relevance of the assessment procedures to their lives (the fourth observation taken from course evaluations). Biology 2D03 has a enrolment that varies from 180 to 200 students. Many hope to be accepted by a medical school but others have alternate career aspirations. The challenge is to make the curriculum and assessment procedures relevant to a variety of careers and personal lives. Showing the students the relevance of plant sciences in their lives may ultimately be more important than the course content.

Leithwood (1986) and Miller & Seller (1990) discuss three curriculum orientations, the transmission, transaction and transformation orientations. Traditional university curricula are based on the transmission mode in which as Miller and Seller (1990, 5) states "the function of education is to transmit facts, skills, and values to students". The professor is considered to be the master of the subject and presents facts and concepts which the students passively absorb during lecture. A metaphor for this type of learning is the filling of an empty bucket. This is particularly true in the

first two years of university education when students take required core courses which lay the background information needed for higher level courses. When female students were surveyed in 1995 (T. Setterlund Leech, unpublished study), many commented that the feature they liked least about their first two years at McMaster University was the amount of memorization required. While the purpose of university education is not to prove that students can memorize large amounts of material, the curriculum and assessment procedures used in the lower levels tend to emphasize memorization.

Leithwood (1986) and Miller and Seller (1990) describe two other curriculum orientations, transaction and transformation. The proposed revision of Biology 2D03 curriculum and assessment would incorporate facets of both transaction and transmission orientations. The aim of transaction orientation is to develop rational intelligence in general and complex solving skills (Miller and Seller, 1990). Students focus their learning on what they need to do well on tests, that is to succeed at assessment. If assessments focuses on memorization and regurgitation of facts, students will focus their learning on memorizing those facts. Without opportunity and reward for developing and using complex solving skills, students will not develop these skills. While students would still have to know facts, the assessment in Biology 2D03 was to be more inquiry oriented and problem solving oriented.

Lazear (1999, 5) describes both old and new assessment paradigms. The old paradigm, which is still evident in lower level university courses, states, "There is a

clearly defined body of knowledge that students must master in school and be able to reproduce on a test." This paradigm in concordance with transmission curriculum orientation. The new assessment paradigm as described by Lazear (1999, 5) is in accordance with transaction orientation in that "the teaching students how to learn, how to think, and how to be intelligent in as many ways as possible (that is creating lifelong learners) is the main goal of education." While it is still the function of lower level university courses to provide the necessary background for higher level courses, this should be combined with the goals of the new assessment paradigm.

Many students in 2D03 do not see the relevance of plant sciences to their current or future lives. The modern world is facing a potential mass extinction of species due to human overpopulation, loss of habitat, global warming and pollution that is on the order of the last great extinction 65 million years ago which wiped out the dinosaurs. It is the aim of the instructors in Biology 2D03 is to make the students aware of the great biodiversity that exists today and the rapid rate of extinction of species. Today's students will have to face the effects of and hopefully minimize or prevent the next great extinction. While many students may not realize the importance of plants in their lives, it is one of the aims of Biology 2D03 to raise their awareness of the importance of plants. While most students are aware of extinction threats to animals, they are unaware of the effect that plant extinction would have on the entire ecosystem. By emphasizing personal relevance and social change in the 2D03 curriculum, the curriculum orientation borders on the transformation orientation as

described by Leithwood (1986) and Miller & Seller (1990). Rather than molecular learning, learning in Biology 2D03 should be holistic in which the students see relationships between themselves, their environment and their curriculum.

How could the 2D03 laboratory curriculum be reformed towards a greater transaction and/or transformation orientation with less emphasis on transmission orientation? The answer lies in Howard Gardner's eight multiple intelligences or Multiple Intelligence (MI) Theory. Numerous authors have published books with practical applications of MI theory (Armstrong, 1994, Campbell, 1998 and Lazear, 1991, 1994). The key to multiple intelligences is that students learn in different ways. University lectures and traditional laboratories appeal mostly to the verbal-linguistic intelligence in which students learn through listening to the lecturer or doing "safe" experiments in which there are no surprises. If there is interpretation of data, the laboratories involved some use of the logical-mathematical intelligence. Although we, the 2D03 instructors, have (up to now) been unaware of Howard Gardner's theories on multiple intelligences, the laboratory curriculum in Biology 2D03 brings in several other intelligences. Table 1 briefly summarizes each type of intelligence with an explanation of how certain intelligences were already part of the 2D03 curriculum prior to 1998.

Table 1. Summary of Howard Gardner's Eight Multiple Intelligences or Ways of Knowing and Application in Biology 2D03 Prior to 1998.

Type of Intelligence	Description of each intelligence as described by Lazear (1999, 4):	Application in Biology 2D03 prior to 1998
Visual-Spatial	"The knowing that occurs through seeing both externally (with the physical eyes) and internally (with the mind's eye)"	Students saw slides after lecture and in laboratories live plant material, real electron micrographs and live plant cells and tissues in their own hand sections.
Bodily-Kinesthetic	"The knowing that occurs through physical movement and performance (learning by doing)."	Students learned by doing, ie. preparing their own hand sections, dissecting flowers, practising asceptic techniques in tissue culture
Verbal-Linguistic	"The knowing that occurs through written, spoken, and read aspects of language as a formal system."	Students learned a foreign language, the language of science and botanical terms. A great deal of the memorization required in 2D03 is the memorization of botanical vocabulary.
Logical-Mathematical	"The knowing that occurs through the process of seeking and discovering patterns through problem solving."	Students were required to develop scientific reasoning and pattern recognition.

Type of Intelligence	Description of each intelligence as described by Lazear (1999, 4):	Application in Biology 2D03 prior to 1998
Naturalist	"The knowing that occurs through encounters with the natural world that involves appreciation for and undertanding of the various flora and fauna, recognition of species membership and the ability to relate to living organisms."	The primary objective of the 2D03 instructors was invoking this intelligence.
Intrapersonal	"The knowing that occurs through introspection, metacognition (thinking about thinking), self-reflection and 'cosmic questioning'."	As students often commented that while 2D03 is an interesting course but they did not see how it is relevant to their life, this intelligence was lacking in the curriculum.
Interpersonal	"The knowing that occurs through person-to-person relating, communication, teamwork, and collaboration."	Students in 2D03 work alone, so there was no teamwork involved however informal collaboration between students occurred while doing laboratory tasks.
Musical-Rhythmic	"The knowing that occurs through sound, vibrational patterns, rhythm, and tonal patterns ... It utilizes such tools as singing, musical instruments, environmental sounds ..."	Not applicable to 2D03 laboratories prior to 1998.

Revision of Biology 2D03 Curriculum and Assessment:

The proposed revision of the 2D03 laboratory curriculum and assessment for 1998 was to accomplish the following items:

- Incorporate intrapersonal and musical-rhythmic intelligences into the laboratory curriculum and to revise the assessment procedures to utilize as many intelligences as possible. As Lazear (1999) states, "The lines between the curriculum and assessment are blurred; that is assessment is always occurring in and through the curriculum and daily instruction." (5) While several different types of intelligences were already part of the 2D03 laboratory curriculum, much of the assessment relied on only the verbal-linguistic and logical-mathematical intelligences.
- To condense three laboratory manual chapters into two, in order to accommodate a shorter term length and to include a fungi laboratory.
- The laboratory manual was to be revised to include a new unit on the fungi, a group of organisms that had been ignored by the biology curriculum. This new unit was to be developed with an emphasis on as many intelligences as possible.
- While teamwork is an essential skill for students to develop, interpersonal intelligence was not included in this current phase of curriculum and course revision, but may be developed at a later date. Informal collaboration between students occurred as laboratory partners share slides and help each other to perform laboratory tasks and exercises. Another second year biology course,

2B03 - Cell Biology, already requires students to work in problem based learning teams so this intelligence is not entirely lacking in the second year biology curriculum.

The benefits of adding intrapersonal and musical-rhythmic intelligences to the 2D03 curriculum and assessment are as follows:

A. Benefits of Intrapersonal Intelligence:

A common comment gleaned from 2D03 course evaluations from years 1992 to 1997 was "Why is it (2D03) required?". Another frequent comment is "While I didn't want to take this course, the instructor made it interesting but I can't see me taking more plant courses." While it seemed obvious to the instructors and Biology Undergraduate Curriculum Committee that at least one course in the plant sciences is required for a well rounded biology programme, the students failed to see the relevance of this course to their academic careers or personal lives. What was missing is intrapersonal intelligence. The students were not reflecting on what the curriculum of 2D03 means to them and failed to see how it affected their lives. The curriculum did make references to the economic, medical, and ecological importance of plants which does increase student interest but it was not enough. Assignments requiring students to reflect on the plant sciences would incorporate intrapersonal intelligence.

B. Benefits of Musical-Rhythmic Intelligence:

While music was not part of the biology curriculum it can be used to set the mood or create atmosphere. Playing classical music tapes with natural sounds (ocean waves, loons calling, bird calls and wolf howls) would enhance the naturalist intelligence in the laboratory by creating a "natural" sound environment. Students also find test situations very stressful. Soothing music played before and after tests may create a more relaxed atmosphere. Students also identify strongly with their own music. Allowing students to bring their own biology-related music and researching such music on their own could bring new understanding and give them ownership of their time spent in laboratory classes.

Chapter 3

Practical curriculum and assessment revision in Biology 2D03 with a more transaction orientation with overtones of transmission orientation.

A. Revision of laboratory manual and development of a new study unit on the fungi.

1. Although one week of laboratory examinations was to be deleted from the curriculum, a late Labour Day in 1998 and adding a new unit on the fungi meant that the fall term would be one week shorter than normal. This required some consolidation of laboratory units. It was decided to combine the root and stem material into one week's unit. Details of xylem and phloem tissues; basic structures, secondary growth and modifications of root and stem systems were included in this unit. Adaptations to growth in wet environments of stems, roots and leaves was included in the leaf laboratory as all tissues have the same adaptations in wet environments (namely development of aerenchyma tissue, reduced vascular tissue). Root-fungi symbiotic relationships, called mycorrhizae previously placed in the root laboratory, were moved to the fungi unit.

2. Unit on the Fungi

The fungi are not really plants as they are not found in the kingdom Plantae but are their own kingdom. Clumping the fungi with plants goes back to Linnaes who divided the world into three categories; mineral, animal and vegetable. As fungi are not animals or minerals, Linnaes grouped them as vegetable. Actually, the fungi are

more closely related to animals. Comparisons of small subunit ribosomal RNA sequences suggest that fungi and animals share a common flagellated protist ancestor. Despite this, modern texts such as Raven *et al* (1999) that are used by Biology 2D03 include a chapter on the fungi. As no other course at McMaster covered the fungi it was decided to include the fungal kingdom with the plant kingdom. The unit on the fungi was scheduled to come late in the term, after the lower non-vascular, spore-bearing plants and before the algae. It was hoped that after studying numerous spore bearing plant groups such as the Hepatophyta and Bryophyta, the students would be familiar with spore-bearing nomenclature which would make the group easier to understand. The fungal kingdom includes four different phyla, the Zygomycota, Basdiomycota, Ascomyta and Deuteromycetes. Each phylum has unique life cycles, asexual and sexual spores. The nomenclature can be overwhelming so it was decided to cover the basics of each phylum but to simplify the life cycles and the amount of terminology required to memorize. Listed below are features of the fungi which were stressed in the fungal unit:

- Their importance to the ecosystem as decomposers.
- Locally occurring mushrooms and toadstools. Some information on edible and poisonous mushrooms was included as well as the contamination of food crops by mycotoxins produced by fungi.
- Their importance as plant pathogens, using examples of historical importance such as wheat rust or local interest such as tar spot disease on maple leaves.

- Their prevalence in our lives by exposing plates of media to classroom air and examining the fungal cultures that grew from air borne spores.
- Their recently developed importance as human pathogen. Historically fungi have not been common human pathogens. The fungi are now important pathogens infecting humans with immune systems compromised by organ transplant anti-rejection drugs, HIV infection, or steroid drug therapy. Also covered was diseases caused by mycotoxins such as aspergillosis and *Stachybotris* infestation of local school portables.
- The importance of the fungi as an agricultural crop, and of fungi or fungal products in food production.
- The importance of the fungi as sources of pharmaceuticals such as penicillin, cyclosporin, anti-migraine drugs, and the use of fungi in wound dressings to speed heeling.

The unit on the fungi is included in its entirety in Appendix A, pages 84-98.

B. Incorporation of Musical-Rhythmic Intelligence in 2D03 Curriculum

While musical-rhythmic intelligence was not incorporated into the assessment procedures in 2D03, it was incorporated into the laboratory environment. Recordings of natural sounds superimposed on classical music were played during the laboratory classes (list of recordings in Appendix B, page 99). The students were invited to bring in tapes on their own music, provided that the music had a nature component. The purpose of introducing music with nature sounds into the laboratory was to

accomplish the following:

- Enhance the learning environment with the addition of music.
- Reduce the stress some students experience during laboratories by playing soothing classical music.
- Reduce stress during mini-laboratory practicals by playing soothing classical music. All students in a laboratory section would have to agree to the playing of music during a test situation.
- Enhance the naturalist intelligence by using music with nature sounds.
- Give the students some ownership of their learning environment by allowing them to bring in their own music.

C. Revised Laboratory Assessment for Biology 2D03 for 1998 (value of assessment as a per cent of final grade given in brackets):

i. Slides and Dissections (5%)

The marking of slides and dissections by teaching assistants was retained with no change in number other than to add fungal slides to be marked in the fungi laboratory and to compensate for the addition of fungal slides with the deletion of some slides required for the root and stem units.

ii. Essay on the Personal Importance of Plants (5%)

Students were to find an article on some aspect of plant science and write a short, 500-750 word essay, describing their article and relating on how the topic of

their article applied to their personal life. The essay was to bring intrapersonal intelligence into the 2D03 assessment as it required introspection and self-reflection about some aspect of plant science. The student's assignment was to find a paper, web site, magazine article about a plant or plant product that had importance in their own life. The importance could be to them personally, to a relative or to them as a member of the human race (global significance).

iii. Mini-Laboratory Practicals (35%)

One mid-term laboratory exam and the weekly pen and paper quizzes were eliminated and replaced with seven mini-laboratory practicals which were worth five per cent each. In these practicals, the students were to be given whole or pieces of plants to observe, dissect and/or section. The plant material chosen for each practical was not necessarily identical to the material presented in each laboratory but would be similar in structure and growth pattern. Students would be asked to draw their test material and to label certain structures. A list of structures that may be present was given on each practical so that students were not required to memorize the spelling of each new term. This represented a reduced emphasis on verbal-linguistic intelligence. Students were expected to recognize which structures on the list were present and which were not. While the assessment required some drawing ability, formal line drawings were not required and only rudimentary drawing ability was necessary. Electron and light micrographs were included in the practicals. Students would be expected to identify features of the micrographs or processes that occur in

structures shown in the micrographs. Whenever possible students were asked to justify their answer by stating what was the evidence in their plant sample or the micrographs for their answer. Samples of mini-laboratory practicals are located in Appendix C, pages 100 - 112.

iv. Laboratory Examination (20%)

One musical chairs type of laboratory examination with a time limit of three minutes per station was retained. It was scheduled at the end of the term, in the last week of classes. In format it remained the same as previous laboratory examinations but content now covered the entire term. A laboratory examination was retained for the reasons listed below:

- To force students to attend laboratory classes. If laboratory material is not to be directly examined, students tend to skip classes entirely or only do a huried examination of laboratory material.
- To force students to interrelate different parts of the course.
- Make students study the material in a more comprehensive way.

v. Final Examination (35%)

The final examination format was left unchanged. This M.Sc.(T.) project did provide an opportunity to survey students about the final examination after the course was completed.

D. Evaluation of M.Sc.(T.) Project:

Evaluation of the M.Sc.(T.) project involved determining the success of the alternate curriculum and assessment, drawbacks of the same and unintended side effects. Student and instructor views on these factors may differ. Evaluation was based on the four following items:

- Instructor's observations on the implementation of new curriculum and assessments.
- Comparison of grades and grade distribution in 1998 and previous years.
- Reviewing responses and comments qualitatively and quantitatively on the formal course evaluations and comparing these responses and comments to previous evaluations. As the principal 2D03 instructor, Professor J.N.A. Lott, was on sabbatical leave in 1997, course evaluations taken in 1995 and 1996 will be considered, but not the 1997 evaluations.
- Surveying the students specifically about the innovations in 2D03 after the course is fully completed. Review by the President's Committee on Ethics of Research on Human Subjects was required and obtained. A copy of the survey is located in Appendix D, pages 113-116. The completed surveys were analyzed qualitatively and quantitatively.

i. Statistical analysis of data:

All statistical analyses were carried out using the following Quattro Pro 8 statistical functions:

- Pearson product-moment correlation coefficient. The Pearson coefficient applies to most continuous measures, does not have many restrictions (Youngman, 1979) and is frequently used in such fields as psychology, education and sociology (Welkowitz *et al*, 1991). It was used to calculate the correlation of grades of one type of test with another.
- F-test of homogeneity between samples with unequal numbers. Comparison of course grades involved samples with unequal numbers (n) so an F-test was used instead of a t test (Steel & Torrie, 1960).
- Chi square (χ^2) test. Grade distributions, course evaluations and the survey sent out to students produced frequency data. With this type of data, the researcher needs to determine if the differences between the observed frequencies and the frequencies expected if the null hypothesis is true can be attributed to random sampling fluctuations. The statistic used to determine the validity of the null hypothesis is the Chi square test (Welkowitz *et al*, 1991).

ii. Evaluating the outcome of the project:

When evaluating the outcome of the project, the following questions (as taken from Baron and Boschee, 1995) were addressed:

- Did the new assessment procedures and breakdown of grades have positive consequences or were there potentially unintended side effects? How do the grades obtained with the new assessment compare with those obtained in previous years?
- Did the assessment procedures used in 2D03 take into account students' cultural backgrounds?
- To what extent do results of one form of assessment (eg. mini-laboratory practicals) transfer to other tasks (laboratory and final examinations)? Correlations between grades obtained for different types of assessment were calculated.
- Did the assessment procedures used require the students to use complex thinking and problem solving skills?
- Was the content selected for assessment in 2D03 representative of the best current understanding of the field?
- Did the students find the assessment tasks realistic and meaningful?
- Was the information about students gathered by the assessment methods used in 2D03 worth the time and effort required to obtain it?

Chapter 4

Results and Discussion of Implementation of Multiple Intelligence Theory into Biology 2D03 Laboratory Curriculum and Assessment.

A. Revision of Laboratory Manual.

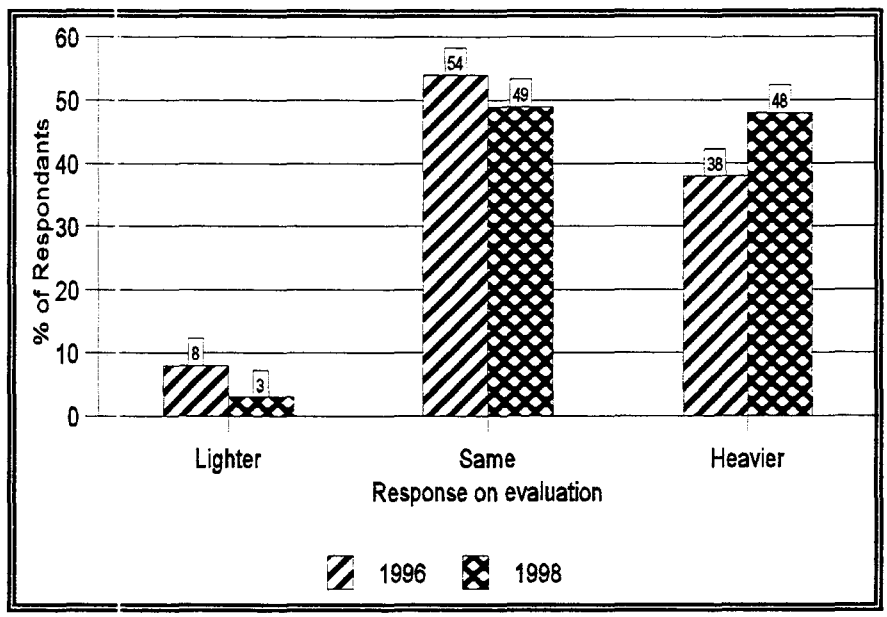
Combining the stem and root material into one laboratory unit created a heavy work load for the students. The combined root and stem units plus laboratory tissue culture exercises and the loss of twenty minutes of class time to the first practical, meant that there was a lot of material to cover and activities to accomplish in three hours. Future fall terms, if they have an early Labour Day date would be able to split the roots and stems back into separate laboratory units. Also the number of activities and slide preparations could be reduced in future years.

The fungal unit was also very heavy. Although the life cycles were simplified, the amount of material presented and activities to be done need to be simplified further. The life cycle of wheat rust, although simplified for this unit, was still too complicated for the allotted time period. The number of slides prepared from fresh fungal material such as *Aspergillus* and *Penicillium* could be replaced with demonstrations of prepared slides. These two slides required a fair amount of time for the students to locate the desired features. The slide of fresh portobello mushroom gill

tissue did show basidia and basidiospores and was simple to prepare. It should be retained. Fresh mushrooms were collected in the fall of 1998 and preserved for use later in the term. The preservative, formaldehyde/acetic alcohol, bleached the bright colours out of the mushrooms and fumes from the preservative caused some physical discomfort for some students. In the future, a variety of mushroom forms could be demonstrated with edible mushrooms purchased from local grocery stores.

In past course evaluations the students tended to indicate that the course load of Biology 2D03 was either the same or heavier than their other courses. More students in 1998 than in 1996 indicated on the course evaluation that the course had a heavier workload than their other courses (Figure 1) but the difference in response between the two years was not statistically significant. A Chi square test produced a value of 0.016 with 2 degrees of freedom. For this value to be statistically significant at the 0.05 level, it must be equal to or greater than 5.99 (Charles, 1988). Thus the null hypothesis, that there was no significant difference in student response between 1996 and 1998, is true. Students have consistently indicated on course evaluations that the workload of Biology 2D03 tends to be the same or heavier than other courses so the workload could be lessened somewhat. As noted above, both the root and stem plus the fungi chapters could be reduced. A longer fall term with an earlier Labour Day would allow the splitting of root and stem material back into separate laboratory manual chapters.

Figure 1. Comparison of workload in 2D03 with other university courses as taken from 1996 and 1998 course evaluations.



B. Implementation of Musical-Rhythmic Intelligence

The primary benefit of introducing music into Biology 2D03 laboratories was to create a more pleasant and less stressful learning environment. The meta-analysis conducted by Watkins (1997) reports that slow, quiet, non-vocal, harmonious music reduces patient anxiety in clinical settings. Physiological evidence of reduced patient anxiety expressed as lowered blood pressure and heart rate was also reported by Watkins. Many students found music in the laboratory environment soothing and relaxing. One student, after completing his weekly practical, called out for relaxing music to be played in the laboratory. One tape of classical music with wolf calls had

to be retired from the repertoire as the students found the wolf calls to be too discordant and threatening. Songbird, loon and whale calls, rain falling, waves crashing and storm sounds all superimposed on classical music were acceptable. Students from other courses, when visiting the laboratory would comment on how nice and relaxing the music was. A few students suggested that more contemporary and upbeat music should be played in the laboratories. Only two students throughout the entire term brought in their own music. One of the recordings supplied by a student was a song called "Johnny Appleseed" which was appropriate for a botany class.

Sound quality was a problem, the cassette players provided by audio-visual for this study produced low volume, poor quality sound. The music seemed to be more of an asset in the laboratory sections with fewer students and less background noise. The larger sections were noisier and the music was harder to hear. These factors may have influenced student response music in the laboratory. One student in response to the survey commented, "I really didn't notice the music because it was on so low and everyone was talking." Other, more favourable comments taken from the survey were:

- "The music made the lab experience more enjoyable and therefore encouraged students to do better work. In addition (to me anyway) music significantly helps my concentration. I always play music while studying because if I don't, I easily become bored & lose track of what I am reading."

- "Not necessarily relaxing, but it was nice to have background music and the nature sounds were appropriate. I say stick with it."
- "GOOD! Very relaxing and peaceful."
- "Very nice, keep playing music from Romantic era (Chopin, Schumann & Liszt)."
- "I did like the music. I felt more relaxed and the stressful atmosphere usually present in the lab was removed."
- I loved the music (emphasis is the student's) ... I personally work better with music, it did keep the atmosphere relaxed in fact overall, I really enjoyed the labs."

The literature contains conflicting references about the beneficial effects of music on learning. Evidence of a so called "Mozart effect" of music on learning and test performance is not conclusive. Some researchers (Collier, 1999; Cockerton *et al*, 1997; Rideout and Taylor, 1997; Abikoff *et al*, 1996; Rauscher *et al* 1993) have reported improved learning and test scores when students are exposed to Mozart or harmonious soothing music. The meta-analysis conducted by Steele *et al* (1999) showed that more recent studies failed to find any statistically significant improvement of test scores due to music exposure. Sousous (1997) demonstrated that music affects mood but does not enhance recall of facts. While it was not part of this project to prove or disprove the Mozart effect, two laboratory sections did have music played while they wrote their mini-laboratory practicals. The mini-laboratory practical mean

for those two laboratory sections was 76.5% which was not a statistically significant difference from the mean for the seven sections which had no music during tests. When the grades for the laboratory sections with music played during mini-laboratory practicals were compared to those without music, an F value of 0.002 was calculated. With 156 and 41 degrees of freedom, an F value equal to or greater than 1.39 was required for the difference to be statistically significant.

Given the positive feedback from the Biology 2D03 students, it would be worthwhile to continue providing classical music with nature sounds in Biology 2D03 laboratories if a better audio system than the one provided by audio-visual services could be provided or purchased.

C. Changes in Assessment in Biology 2D03.

The major changes in assessment were to replace the weekly quizzes with mini-laboratory practicals, to implement an essay and to reduce the number of laboratory examinations to one held at the end of term, eliminating the midterm laboratory examination.

i. Mini-laboratory Practicals

Instructor's Observations:

The mini-laboratory practicals were easier to implement than weekly quizzes and midterm laboratory examination which they replaced. A laboratory examination takes two instructors the better part of a day to set up. Five different versions of the

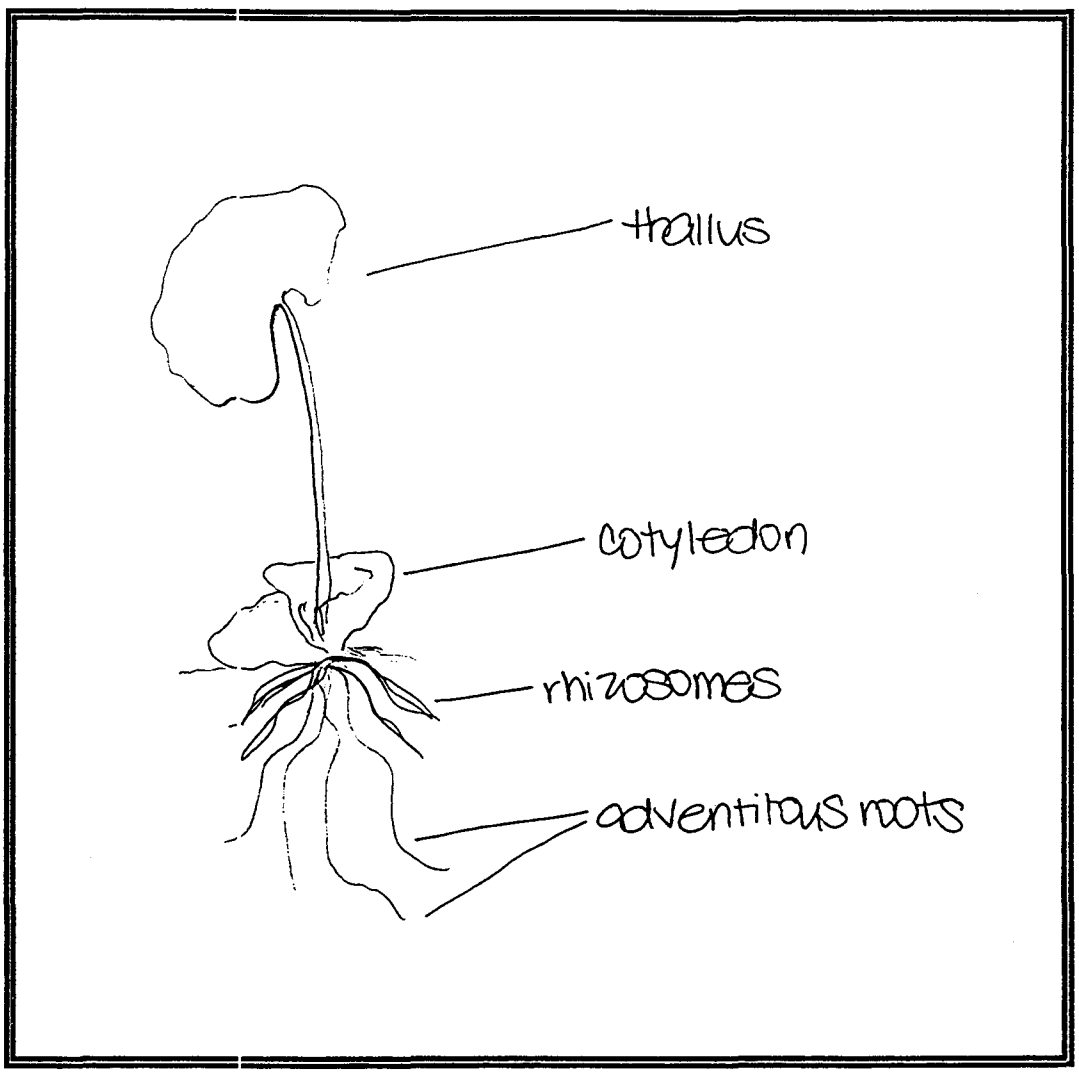
weekly quizzes had to be created each year, a different one for each laboratory day. In the mini-laboratory practicals, one template test was created. The same questions could be asked on each laboratory day but by changing the plant material, a totally different test was given. It did not matter if the students knew what the questions were in advance, they had no idea of what material they would be examined on.

The biggest drawback from an instructor's point of view in implementing the mini-laboratory practicals was grading the papers. Most of the graduate students assigned to Biology 2D03 in 1998 did not have a strong background in botany. The decision was made for one instructor, T.G. Setterlund Leech, to grade all mini-laboratory practicals for the term. This eliminated potential difficulties in variation in grading between different markers but created a heavy workload for the instructor. However, it was instructive in informing the instructor on how the students were doing with the new form of assessment. Now that the instructor has experience with the mini-laboratory practicals, producing a marking scheme for teaching assistants would be possible. Also, hand sections of a variety of plant tissue could be photographed during the summer months in preparation for Biology 2D03 in the fall term. With photographs of the tissue, even inexperienced teaching assistants could mark the mini-laboratory practicals.

A potential weak point with the practicals was the reliance on students' drawing ability to illustrate what they found in their plant tissue. While the technology exists to collect images from microscopes and transfer it to computer files

or video tapes, this technology was not available for teaching undergraduate laboratories. Students had to draw what they observed in their tissue and label their drawings. Formal scientific line drawings were not expected, any reasonable effort to illustrate their tissue was acceptable. Student drawings did accurately portray the material they were working with. At times, students would accurately draw the tissue but misinterpret and mislabel their diagram. Figure 2 shows a sample of a student's drawing of a fern gametophyte with a young sporophyte. The drawing clearly illustrates that the student accurately observed his/her plant sample but she/he has completely mislabeled the structures present. This student would receive marks for observation and producing an accurate drawing even though the labels were incorrect.

Figure 2. Sample of a student's drawing and labeling of a fern gametophyte with a young sporophyte.



In cases of mark dispute with the mini-laboratory practicals, students were given the opportunity to section or dissect the plant material after the marked papers were returned. If they could demonstrate that the disputed material was present, they would be given the mark. Very few students took advantage of this opportunity.

The mini-laboratory practicals were designed to incorporate several multiple intelligences in an effort to get away from strictly pen and paper tests. The application of multiple intelligence theory into the practicals is summarized in Table 2.

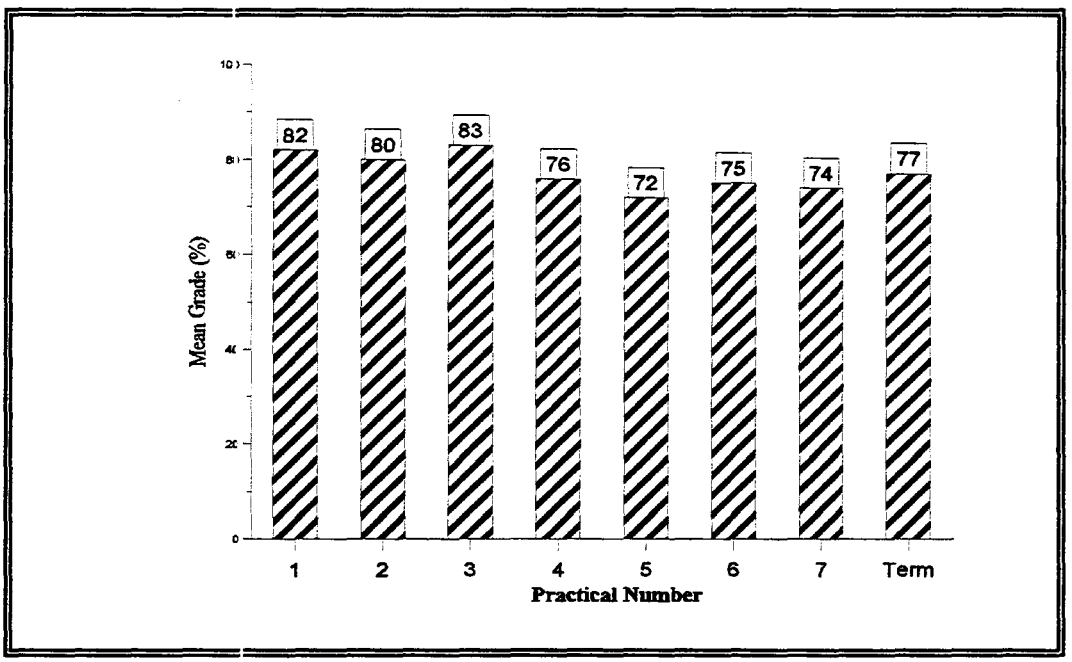
Table 2: Multiple Intelligences Used in Mini-Lab Practicals (1998)

Type of Intelligence	Description of each intelligence as described by Lazear (1999, 4):	Application in Mini-Lab Practicals
Visual-Spatial	"The knowing that occurs through seeing both externally (with the physical eyes) and internally (with the mind's eye)."	Students looked at and observed plant material and micrographs.
Bodily-Kinesthetic	"The knowing that occurs through physical movement and performance (learning by doing)"	Students dissected and sectioned their plant material, set up and used two types of microscopes. Assessment was based to some degree on technical skills developed in 2D03.
Verbal-Linguistic	"The knowing that occurs through written, spoken, and read aspects of language as a formal system."	The practicals reduced the emphasis of verbal-linguistic intelligence by providing a list of tems on every test paper. The students were expected to know what terms meant and to read questions carefully.
Logical-Mathematical	"The knowing that occurs through the process of seeking and discovering patterns through problem solving."	Questions regarding the plant material and micrograpahs required students to see and discover patterns.
Naturalist	"The knowing that occurs through encounters with the natural world that involves appreciation for and understanding of the various flora and fauna, recognition of species membership and the ability to relate to living organisms."	Recognition of different plant groups, appreciation of and understanding plant tissues and taxonomic groups were part of assessment.

Grade Statistics for Mini-Laboratory Practicals:

The seven mini-laboratory practicals accounted for a cumulative 35% of the students final grade. Grade statistics for 1998 showed a mean test score of 77% for all seven practicals. The mean grade for weekly quizzes and a midterm laboratory examination, which the mini-laboratory practicals replaced, in 1996 was also 77%. The first few practicals had higher mean scores than the later practicals (Figure 3) but the variation between practicals was not statistically significant. A Chi square (χ^2) test involves comparing the actual observations, in this case the individual mini-laboratory practical means, against what the researcher expected (in this case the mean for all mini-laboratory practicals). The calculated χ^2 value was 1.41 with 6 degrees of freedom. For this value to be statistically significant at the 0.05% level, a χ^2 value equal or greater to 12.59 was required (Charles, 1988). Thus the null hypothesis, that the individual practical means did not significantly vary from the mean for all the mini-laboratory practicals, was true. Some students felt that incorporating technical skills into assessment was unfair but the statistics show that it did not adversely affect the grades as mini-laboratory practicals that required the most technical skill had slightly higher means from the later mini-laboratory practicals which relied on photographs and micrographs which were given to the students..

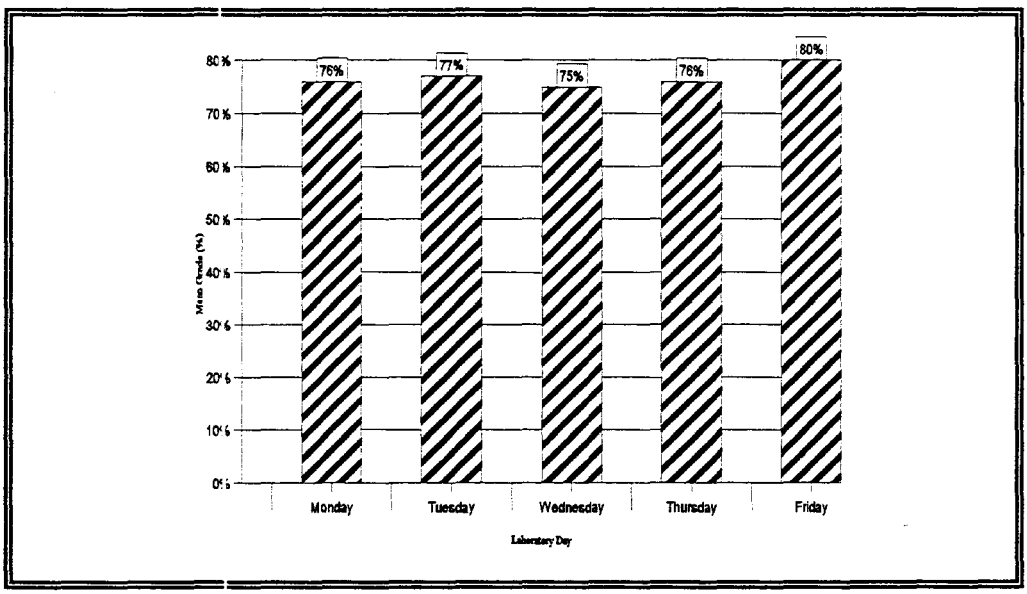
Figure 3: Mean test scores of mini-laboratory practicals for Biology 2D03 1998 (204 students).



There were student complaints that the plant material used on one day on the mini-laboratory practicals was "easier" than another and therefore unfair. While on specific practicals there may have been variation in the practical means from day to day, at term's end all laboratory days demonstrated comparable means (Figure 4). Once again, the class mean for all the mini-laboratory practicals was assumed to be the expected observation when calculating a χ^2 value. A χ^2 of 0.14 with 4 degrees of freedom was calculated. To be significant at the 0.05% level, a χ^2 value of 9.49 was required (Charles, 1988). Thus the null hypothesis must be true that there was no significant difference between the observed day to day mini-laboratory practical means

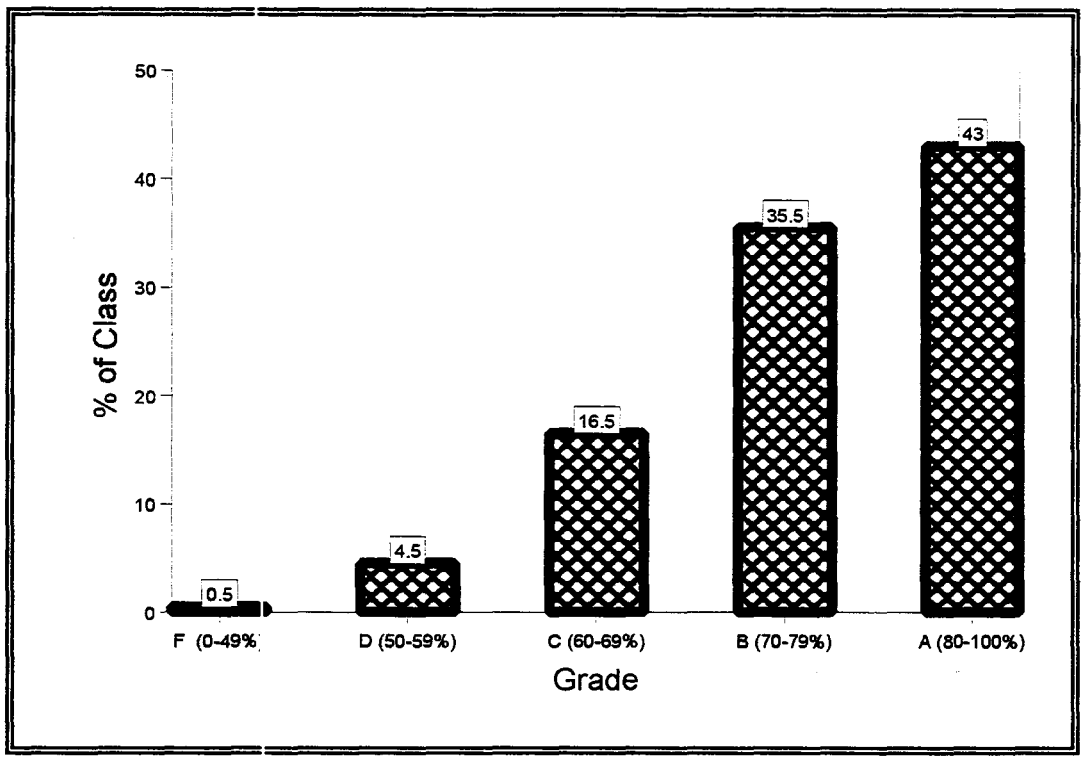
did not statistically vary from the class mean.

Figure 4. Comparison of Biology 2D03 (1998) mean grades per laboratory day on mini-laboratory practicals.



The grade distribution for the mini-laboratory practicals resembles a "J" curve more than a bell-shaped normal distribution (Figure 5). Seventy nine per cent of the students achieved a grade above 70% or a B-. One of the requirements for an honours degree program is to achieve a grade average equal to or greater than 70%. It is apparent that most students achieved success with this form of assessment.

Figure 5: Grade distribution of Biology 2D03 1998 mini-laboratory practicals.



Students response and comments regarding mini-laboratory practicals:

Student response and comments regarding the assessment used in Biology 2D03 was obtained from course evaluations distributed at term's end and a survey sent out to the students in the 1999 winter term. Formal course evaluations were administered before the students wrote their laboratory examination and final examination hence the assumption can be made that responses regarding assessment apply solely to the mini-laboratory practicals. Out of a class of 204, 186 students completed the course evaluation at term's end (91% response). Multiple answers are

possible for most questions on the evaluation. Student responses to the questions regarding testing in 2D03 in 1998 are summarized in Table 3. The 1998 evaluations asked slightly different questions regarding tests than the 1996 evaluation. In 1996, student responses regarding assessment on the evaluations would be based on the weekly quizzes and midterm laboratory examination. The 1996 responses are summarized in Table 4.

Table 3: Quantitative student responses to 1998 course evaluation questions regarding tests.

Favourable Response		Unfavourable Response	
Aspect of tests	% of respondants	Aspect of tests	% of respondants
Appropriate number	31	Too many	22
Appropriate level of difficulty	26	Tests too difficult	18
Challenged students to think	33	Not asked	
Good coverage	35	Tests not related to course material	3
Fairly/clearly graded	27	Not fairly graded	5
Well supervised	22	Not well supervised	3

Table 4: Quantitative student responses to 1996 course evaluation questions regarding tests.

Favourable Response		Unfavourable Response	
Aspect of tests	% of respondants	Aspect of tests	% of respondants
Sufficient number	30	Not enough Too many	1 9
Good coverage	27	Tests not related to course material	5
Fairly marked	21	Not fairly marked	3
Grading well explained	12	Grading not well explained	1
Well supervised	11	Not well supervised	1

Although the course evaluations had a 91% response rate, the majority of responding students did not answer the questions regarding assessment. For example in Table 3, 30% of the students responded that the tests were of sufficient number while 22% indicated that there were too many. Therefore, a larger proportion (47%) did not answer this question. There were two major complaints about tests in the 1998 evaluations:

1. That there were too many tests.
2. Tests were too difficult.

More students in 1998 indicated that tests were too frequent than in 1996 although the difference in response between the years was not significant. A χ^2 test was conducted by comparing the observed frequencies with expected frequencies

calculated using the formula provided by Welkowitz *et al*, 1991. A χ^2 value of 0.35 with 3 degrees of freedom was calculated. At the 0.05 level, a χ^2 value of 7.81 was required . Thus the null hypothesis that there was difference in response between the two years was accepted. Previously, there were 5 quizzes and a midterm laboratory. On the 1998 evaluations, students suggested that the mini-laboratory practicals be held every two weeks throughout the term. Over a twelve week term, holding seven mini-laboratory practicals averaged at a test being held every 1.7 weeks. In reality, tests were held weekly for the first five laboratories and two tests were held in the last month of term. This created a very test intensive first month of laboratories and as noted earlier, the laboratory curriculum during this period of time had a heavy workload. One way to decrease the workload in the first month of laboratories would be to decrease the number of mini-laboratory practicals held during this period.

Frequent testing with the mini-laboratory practicals was deliberate. One aspect of authentic assessment is that assessment be more like a season of games and are not one-shot deals. Assessment should have multiple validations which recur so they are worth practicing for and retaking until success is achieved (Baron and Boschee, 1995). A series of low value tests meant that assessment was not based on a single event. If a student was having an "off" day, a busy week or experiencing stress in their personal life, these factors could result in poor performance on one test. With multiple testing over the term, the repercussions of having an "off" day for taking tests would not be serious. Tests worth 5% would be less stressful to take than a single

midterm examination worth 35%.

A drawback to having frequent, low value practicals was that some students tended to not apply themselves as the practical was not worth much. If other courses had a higher value test that week then studying for the plant mini-laboratory practical suffered. Unfortunately for these students, when the practicals were added up they equaled 35% of their final grade.

The second major complaint, that the tests (mini-laboratory practicals) were too difficult was not substantiated by the grade statistics. A mean of 77% and the grade distribution seen in Figure 5 do not indicate that this form of assessment was too difficult for the majority of students.

One student was most virulent in his/her opposition to the new testing procedures in 2D03 and wrote the following on his/her course evaluation:

> The practicals are shit! ... Majority of material we get tested on, I HAVE NEVER SEEN BEFORE!...Marking should be consistent from year to year. If I had this caurse (sic) last year I would have got a guaranteed 10, know (sic) may only get an average mark. This f...g class may have screwed up all my future plans just b/c you people had to change the layout of the practicals.

This student was obviously upset. One unintended outcome to the mini-laboratory practicals was the hostility of students who failed to do well or did not do as well as they expected. If most of the class excelled at the practicals, students who did not were very hostile. Students may enter the course expecting to do well if they

memorize the previous year's versions of the tests. As the mini-laboratory practicals were new, there were no previous tests to memorize. This student felt that it was unfair to be given something he/she had never seen before and be asked to analyze it. The material chosen for the mini-laboratory practicals was similar in growth or structure to material presented in the lab. The point was not whether the students had for example, memorized the growth patterns and structures of pea seedlings, but if they were given a sweet pea seedling which was similar, could they recognize it and answer questions about it? The high marks for the practicals demonstrate that the majority of students could. Actually, this student's very negative comments proved the success of the mini-laboratory practicals in switching from memorization to application of knowledge.

Results of student survey on assessment changes in Biology 2D03:

Sixty-three students out of 204 responded to the survey sent out during the 1999 winter term, representing a 30% response rate. Response rates for self administered questionnaires vary from 10% to 50% (Wiesberg *et al*, 1996). Although personal and telephone interviews have a higher response rate (greater than 60%) the decision was made to use a self-administered questionnaire which was handed out to students and sent out by electronic mail. The President's Committee on Ethics of Research on Humar. Subjects was concerned that the students might feel coerced to participate in the survey if it was administered directly by their instructors through personal or telephone interview. Also, the students might feel compelled to respond

with what they thought their instructors wanted to hear, rather than give a frank response. Self-administered questionnaires which could be returned anonymously avoided any coercion of the students to respond and ensured frank, unconstrained responses.

Objective results from the survey regarding the mini-laboratory practicals involved comparison of the practicals with other forms of assessment. These results are given in a later section of this project. Students did provide subjective comments regarding the mini-laboratory practicals. Previous comments about Biology 2D03 complained about the amount of memorization required. It was not the intention of assessment revision in Biology 2D03 to totally eliminate memorization. Biology 2D03 is a lower level course in which students learn background material required for higher level courses. Students would still have to know their facts in order to apply their knowledge. While forty-nine per cent of the responding students in their comments on the survey noted that memorization was required, more students indicated that the practicals also tested application of their knowledge. Selected student comments are as follows:

- "Since we were subject to live specimens on the practicals I was forced to apply my knowledge, not just assign a name to a drawn structure."
- "While memorization was obviously an important part of the course, I think that we were always obliged to apply our knowledge."
- "Well done. Since it was an introductory course memorization was required

to respond intelligently with the new lingo. Also it was a great practical and knowledge based test."

- "Really good test of understanding, think & apply."
- "Memorization was needed but comprehension was used because test plants were new to our experience."

General comments regarding the practicals were favourable. Some students appreciated that frequent testing required them to review each week's material throughout the term. Constant review made preparation for the laboratory examination and final examination easier. As one student commented;

> I liked having many smaller tests, as opposed to a few large tests. However, when work from other classes outweighed the practicals (which was fairly often since the practicals weren't worth much) I tended to ignore them & my marks on a few practicals suffered as a result.

Another student complained that preparation for a mini-laboratory practical based on the previous week's work meant that he/she was less prepared for the current laboratory. A few students complained that the practicals required technical skills. A student that was not skilled at sectioning, dissection or proper use of a microscope would be at a disadvantage with this type of test. However, the sectioning and dissection skills required to perform the practicals were very basic and within the capabilities of second year university students. These skills were in constant use during the laboratories and there was ample opportunity to practise these skills.

Certainly students aspiring to a medical career would require technical skills more advanced than those required in the practicals.

ii. Essay on the personal importance of plants.

Instructor's Observations:

The essays on the importance of plants was also graded by T. G, Setterlund Leech. Although this also created a heavy workload, the essays were a joy to read. It was apparent from reading the essays that many students had been unaware of how plants affected their lives until they took Biology 2D03. The essay in particular seemed to bring a strong personal relevance of plants to most students. The professor, Dr. Lott, also found this approach lead to more positive interactions with students as they asked for literature resources or their essay topic.

Essay topics were as varied as the students in Biology 2D03. The instructors expected a plethora of medicinal plants as they have the impression that most students aspire to medical studies. Table 5 summarizes essay topics.

Table 5: Summary of topics for the personal importance of plants essay in Biology 2D03, 1998.

General categories	Specific topics (numbers of essays per topic given in brackets)
Health/Medicine (89)	Naturopathy/herbal medicine (37), taxol (13), *Ginkgo* (9), *Echinacea*(7), phytoestrogens (5), digitalis (3), allergies (3), opiates & addictions (3), *Aloe* (2), essiac (2), malaria (1), selenium in plants (1),
Environment/Ecology (48)	Forestry (15), organic farming (7), hemp farming (5), global warming (4), famine (4), purple loostrife (3), phytomining (2), Green Revolution (2), plant diseases (2), space exploration (1), cyanobacteria (1), use of aquatic plants to clean sewage (1), aquatic vegetation (1)
Plants As Food (37)	Rice (4), ginseng (4), garlic (3), herbal/health food (2), herbal junk food (2), kava (2), broccoli (2), carrots (2), olives (2), carrots (2), gluten (1), pineapples (1), onions (1), *Stevia* (1), tomatoes (1), date palm (1), nuts (1), soybeans (1), rhubarb (1), vegetarianism (1), saffron (1), cayenne (1)
Molecular Biology (12)	Transgenic plants as food (6), vaccines produced by transgenic plants (6)
Stimulants (11)	Tea (4), coffee (3), *Ephedera* (2), tobacco (1), betel nut (1)
Personal Issues (7)	Forensics & pollen analysis (3), roses & romance (1), tulips & Dutch heritage (1), birch bark canoes (1), wood for drumsticks (1)

As expected, the largest group of topics dealt with plants and medicine. What was unexpected was the emphasis on alternate medicine such as naturopathy. Students related how they or relatives used various herbs to treat medical conditions or improve cognition or mental health. Some student related how they were treated

by their grandparents or parents with ethnic herbal remedies. One student told the story of how his grandfather in India was murdered with herbal medicine! The next largest group was the use of plants as food. Students would describe the cultural significance of certain foods or their consumption of foods for phytochemicals which would affect their health. Ecology topics involved local issues such as purple loosestrife and more global issues such as the Green Revolution. The Green Revolution was big news twenty years ago when most of the Biology 2D03 students were born. One student explained how her uncle, a government official in India, was in charge of implementing the Green Revolution. Her grandfather, an experienced farmer, accurately predicted the failure of the Green Revolution. Essays based on transgenic plants were split between students that wrote about the controversy of transgenic foods and those who wrote about the use of transgenic plants to produce medicines. Biology 2D03 is a required course for the Molecular Biology programme, so it was encouraging for some students to find relevance of the course to their future studies. Students' use of stimulants included the expected tea and coffee but also reflected their ethnic origins with topics such as the use of betel nut in India. Personally important plants make up the last essay topic category. Plants that signified romance (roses), ethnic heritage (tulips, birch bark canoes) and future careers in forensics are included in this category. Two students wrote about the use of pollen analysis in forensic science to determine the time of death for soldiers in East Germany that were murdered by Russians. One of these students hoped to pursue a

career in forensic science and had never thought that the study of plants was required for her career. She also discussed her topic with her grandparents, who fled Europe at the time of the murders. Her topic not only applied to her future career but to her family history as well.

The essays were a success not only in invoking intrapersonal intelligence but also allowed the students to bring their varied cultural backgrounds into the exercise. This is one of the principles in evaluating assessment put forth by Baron and Boschee (1995).

A frequent criticism of conventional testing procedures is that they are biased towards males. When assigning the essay, it was not realized that it had a feminine bias. The female students loved being asked to relate their personal relevance or feelings to their university curriculum. One female student commented that she could not believed that she was asked what her feelings about the material she studied were. Male students on the other hand had difficulty discussing their feelings. Some male students were more matter of fact about the personal relevance and this tended to be the weaker part of their essay.

Grade statistics on the essays:

The purpose of the essay was to aid the students to use their intrapersonal intelligence by finding some facet of plants that was important to their lives. Grading of the essays was qualitative rather than quantitative as it was difficult to place a grade mark on personal feelings. For example, is relating the story of the use of tamoxifen,

(an anti-cancer drug derived from conifers) to treat a mother's breast cancer worth more marks than a students's use of *Echinacea* to prevent colds? The essays were all excellent so a simplified marking scheme was adopted. Students were assigned a grade of 9 out of 10 if they did an adequate job of describing a plant topic and its relevance to their personal lives. Papers that demonstrated excellence in originality, description of relevance or relating how something they had learned in Biology 2D03 helped them to understand their topic were given a grade of 10. Forty-nine per cent of the essays were assigned a grade of nine while 51% received a grade of ten. Such high grades were awarded as the essays succeeded in bringing relevance of plants into the students' personal lives. One paper in which the student did a poor job in describing a topic and related no personal relevance, received a grade of 5 out of 10. This student represented 0.5% of the class and did not significantly affect the course statistics for the essay. The greatest benefit of the essay was what they taught the instructor about biology students. Second year biology classes tend to be large with enrollments in the hundreds. Biology 2D03 in 1998 had an enrollment of 211. With such large class sizes, it is difficult to view the students as individuals. The greatest benefit of the essay is what they taught the instructor about the students.

Student comments about essay as taken from survey:

Forty-three students or 68% of the survey respondents wrote comments regarding the essay. The remaining students did not comment about the essay assignment. The comments were overwhelmingly in favour of the essay. Eighty-six

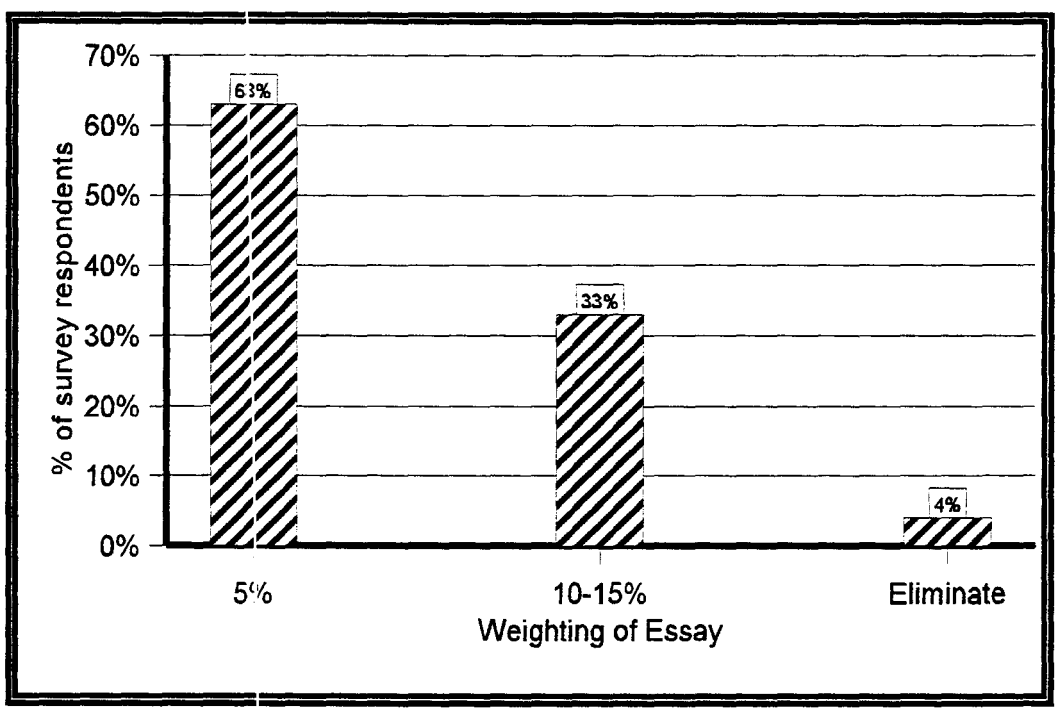
per cent of the comments stated that the essay did make plant curriculum more relevant. Selected comments taken from the survey are:

- " YES! I learned a lot about how the course material could be applied to other interesting subjects and how plants have influenced my life."
- " Yes! I thought it was a very good part of the course and the easy marking turned it into a fun learning experience instead of torture."
- "Allowed us to see various ways in which plants play a role in our lives and why plants are important to our daily lives."
- "Forced students to look for importance of plants in life, very relevant to the course."
- "Yes, it gave me a chance to research into plants with regards to their medicinal (pharmacological) uses."

Both the instructors and students found the essay to be a worthwhile exercise. Few (eight or 13%) students made suggestions to change the essay assignment. In the survey, the students were asked if the essay weighting of 5% was right or whether it should be worth more, less or eliminated. The students responses are presented in Figure 6. A χ^2 test was conducted by comparing the observed frequencies with expected frequencies calculated using the formula provided by Welkowitz *et al*, 1991. A χ^2 value of 52.8 with two degrees of freedom was calculated. This χ^2 value greatly exceeds the value required (5.99) for the differences in responses was statistically significant at the 0.05 level(Charles, 1988). Thus the null hypothesis that there was

no difference between the three responses is rejected. The majority of students responded that the weighting of the essay was right. Some suggested that it be worth more but none suggested that it be worth less. A handful responded that the essay should be eliminated.

Figure 6: Student response on the survey regarding weighting of the essay in Biology 2D03, 1998.



The instructor observed that after marking the essays that the essay could involve the Biology 2D03 curriculum more strongly. This could be accomplished by requiring the students also write how something they learned in class helped them to

understand their topic. For example one student wrote about how different types of wood are used to make different sounding drumsticks. This essay could have been taken further by discussing the different forms of cells that make up woody tissue and how cell types would affect wood density and the resulting sound.

iii. Term end laboratory examination:

The term end laboratory examination retained the same format as previous laboratory examinations (as discussed in assessment previous to 1998, page 8). The assessment revision in Biology 2D03 changed the content of the laboratory examination to cover an entire term's work. This made the examination content more general than when there were two laboratory examinations. Grade comparisons between the laboratory examination and other forms of assessement are discussed later in this project.

Sixty per cent of the students responding to the survey wrote comments regarding the laboratory examination. Stress of the examination, mostly imposed by the three minute time limit at each station, was mentioned by forty per of the students that commented on the laboratory examination. This was to be expected as the stress imposed by the time limit of the laboratory examinations was a frequent feature in previous years. Forty two per cent of the comments stated that the laboratory examination relied mostly on memorization while eight per cent felt that the laboratory examination required application of knowledge. A further eight per cent

of the students commented that it required both memorization and knowledge application. Some of the comments were:

- "Tests how you cope with stress rather than knowledge."
- "Stations were so fast, you didn't have time to think about the questions so if you didn't have everything memorized you had no chance."
- "Relied heavily on memorization but was not as stressful since I was forced to study for lab practicals and the information was retained."
- "Definitely challenged students to think, a good coverage however it was a speed test."
- "Application of knowledge was essential."

These comments regarding the stress of the laboratory examination format were expected since the examination format was similar to previous laboratory examinations. The change was the reduction of number and grade value of laboratory examination.

iv. Final Examination:

The format of the final examination was not changed but the survey done in the winter of 1999 was the first opportunity the instructors have had to get student feedback regarding the final examination. Forty students or 64% of the respondants commented on the final examination. Sixteen students (or 40% of the student comments) commented that the final examination required both memorization and application of knowledge. Twelve students (30%) commented that it required mostly

memorization while seven students (18%) commented that it required mostly application. Generally, the comments regarding the final examination were favourable:

- "Wrapped up course really well, more applicable, a little bit of everything."
- "Application of knowledge to each question, here there was enough time to think about the problems and they were set so that knowledge and thinking and understanding were required."
- "Very good. Maybe I just studied the right things but I thought it was very fair and a good way to test our knowledge."

v. Course Grade Statistics and Distribution with New Assessment Procedures:

Although Lazear (1999) criticizes the old assessment paradigm for its emphasis on the Bell curve, and sorting students into categories of successful, average, and failing students; sorting of students is part of assessment at universities. Realistically, students vary in academic ability, perseverence and dedication to their studies. The students are not equal and they must attain certain standards to qualify for their degrees, future studies or employment. The new assessment procedures for Biology 2D03 must have statistics and sorting of the students that is acceptable to McMaster University.

If grades were high in the mini-laboratory practicals and essays, were these forms of assessment not challenging the students or did the student achieve similar

levels in other forms of assessment? How did the final course statistics work out? Table 6 summarizes the statistics for the mini-laboratory practicals, the laboratory examination and the final examination in 1998. The data for the essay and marked slides/dissections have been excluded as all students achieved a high mark in these two forms of assessment.

Table 6: Statistics for major forms of assessment in Biology 2D03 1998.

Statistics	Form of Assessment			
	Mini-laboratory Practicals	Laboratory Examination	Final Examination	Course Final Statistics
Mean grade	77%	74%	72%	76%
Median grade	78%	74%	73%	76%
Maximum grade	100%	100%	97%	100%
Minimum grade	48%	39%	40%	14%*
STD	9.2	13.2	11.2	10

* Grade obtained by a student who did not complete some course assignments.

Interestingly, the final examination had more favourable comments on the survey than the practicals and laboratory examination although it had a lower class median and mean. A χ^2 test was conducted by comparing the observed frequencies with expected frequencies calculated using the formula provided by Welkowitz *et al*,

1991. A χ^2 value of 0.27 for the mean grades for all three forms of assessment was calculated. With two degrees of freedom, a value of 5.99 was required for there to be a statistical difference between the means (Charles, 1988). Thus the null hypothesis that there was no difference between the means was accepted. Students on the other hand would find a five per cent difference highly significant. Possible correlations between one form of assessment with the others was calculated using a Pearson Coefficient and summarized in Table 7. Pearson Coefficients vary from a value of zero to one. A value of zero indicates an absence of relationship while a value of one indicates the existence of a perfect relationship (Charles, 1988).

Table 7: Correlation of grades among mini-laboratory practicals, laboratory examination and final examination in Biology 2D03, 1998.

	Mini-laboratory Practicals vs Laboratory Examination	Mini-laboratory Practicals vs Final Examination	Laboratory Examination vs Final Examination
Pearson Coefficient	0.5	0.5	0.8

One facet of authentic assessment is to what extent results of one form of assessment transfer to others (Baron and Boschee, 1995). A Pearson Coefficient Student of 0.5 between the performance in the mini-laboratory practicals with performance in the laboratory examination and the final written examination indicates a moderate correlation. The strongest correlation lay between the laboratory

examination and the final examination which had a Pearson Coefficient of 0.8. This is to be expected as a short period of time (less than two weeks) divided these two forms of assessment. Students who knew the course material for the term-end laboratory examination would be well prepared for the final examination. In past course evaluations and surveys students complained that the time limit in the laboratory examination was unfair, adversely affecting their performance and resulting grade. These statistics show that grades achieved on the term-end laboratory examination could be correlated with performance on the written final examination.

vi. Comparison of 1995, 1996 and 1998 Final Grade Distributions in Biology 2D03

The 1998 grades of Biology 2D03 were compared to those of 1996 and 1995. The data from 1997 was excluded as the principal Biology 2D03 instructor, Professor J.N.A. Lott was on sabbatical leave and did not teach that year. Figure 7 shows the grade distribution pattern for 1995, 1996 and 1998, while the final grade averages are listed in Table 8.

Figure 7: Final Grade Distributions in Biology 2D03, 1995, 1996, 1998.

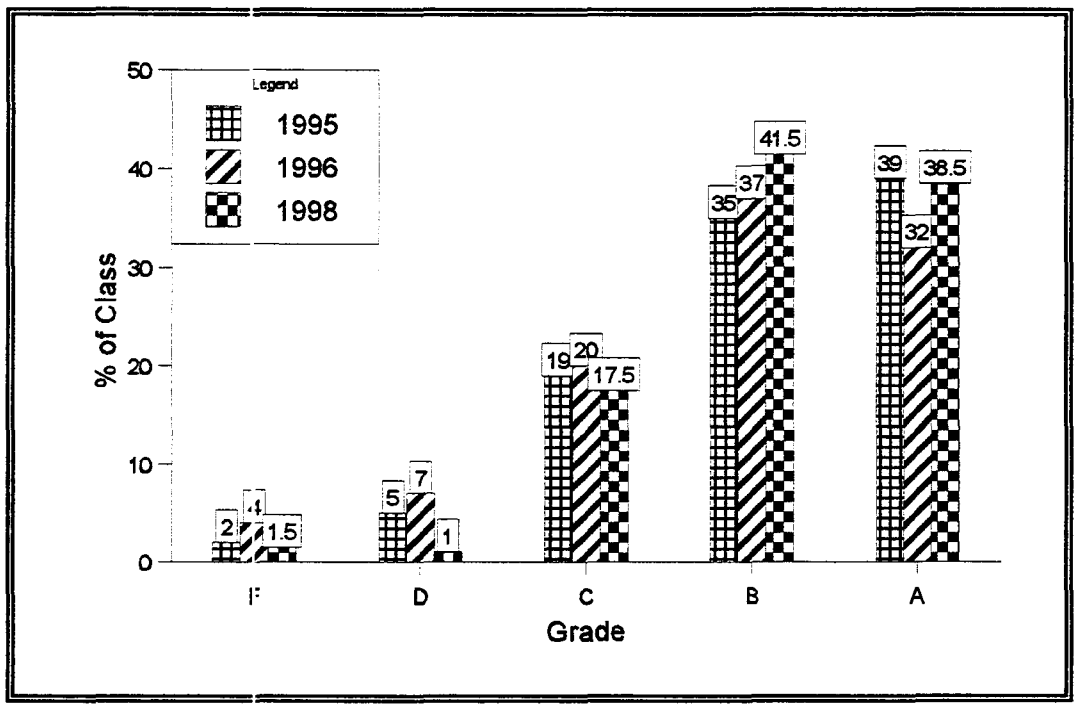


Table 8: Mean final grades for Biology 2D03, 1995, 1996, 1998.

Year	1995	1996	1998
Mean Grade	75.7%	73.6%	75.9%

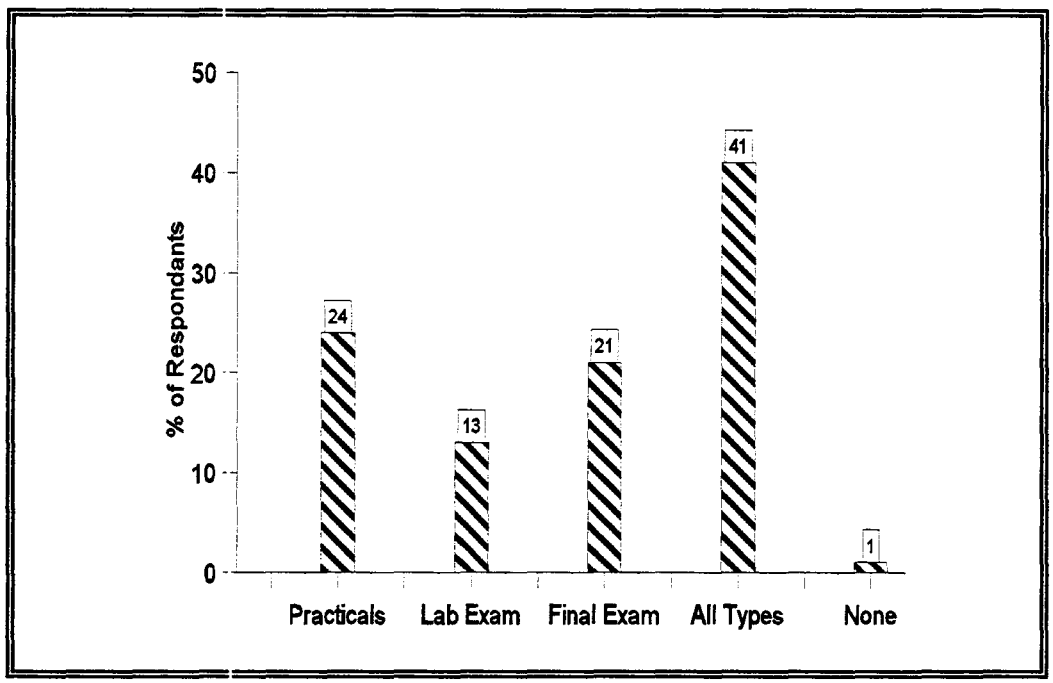
Comparison of course grades from 1998 to previous years involved samples with unequal numbers (n) so an F-test was used. The year 1998 had a mean grade nearly identical to 1995. For there to be a statistically significant (0.05 level) between the mean for 1998 and the means for 1995 and 1996, an F value greater than one was required (Steel and Torrie, 1960). The F value for comparing the 1998 mean with the

1996 was 0.08 (with 204 and 186 degrees of freedom). When the 1998 mean was compared with 1995, an F value of 0.50 (with 204 and 192 degrees of freedom) was calculated. Thus the null hypothesis that there was no difference between the 1998 course mean and the means for 1996 and 1998 was accepted. The grade distribution of 1998 was similar to that of 1996 and 1995 (Figure 7). A χ^2 test was conducted by comparing the observed frequencies with expected frequencies calculated using the formula provided by Welkowitz *et al*, 1991. A χ^2 value of 0.50 with 6 degrees of freedom was calculated. A χ^2 value of 12.59 was required for there to be a statistical difference at the 0.05 level between the three grade distributions (Charles, 1988). From the data, it appears that revising assessment in Biology 2D03 did not significantly change the course statistics.

vii. Results of Student Survey Regarding Assessment Changes in Biology 2D03.

Student responses to the question, which form of assessment best tested their knowledge is presented in Figure 8. A χ^2 test was conducted by comparing the observed frequencies with expected frequencies calculated using the formula provided by Welkowitz *et al*, 1991. The χ^2 test of the differences between responses calculated a value of 30.63 with four degrees of freedom. A value of 13.28 indicates significance at the 0.01 level (Charles, 1988). Thus the null hypothesis that there was no difference between the responses is rejected. A quarter of the respondents thought that the mini-laboratory practicals best tested their knowledge. Forty per cent of the respondents indicated that all the types of assessment used tested their knowledge. No one assessment method is perfect and complete on its own. The intention of revising assessment and using multiple testing methods in Biology 2D03 was to reduce the emphasis on just two (verbal-linguistic and mathematical-logical) intelligences. That forty per cent of the students felt that all forms of assessment in 2D03 best tested their knowledge indicated that the assessment on the whole, and not just one method was successful.

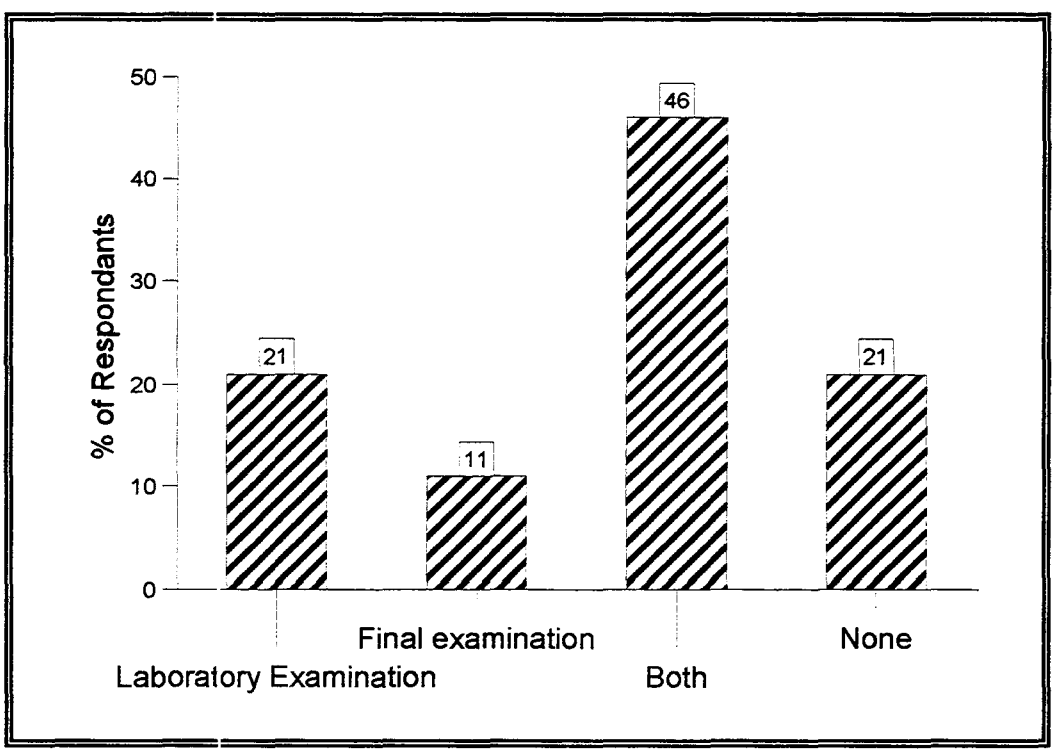
Figure 8: Student responses to which type of testing procedure used in 2D03, 1998 best tested their knowledge.



If the mini-laboratory practicals were a valid form of assessment, they should have helped prepare the students for other forms of assessment. While statistical analysis showed a moderate correlation between grades obtained on the min-laboratory practicals with the other forms of assessment (Table 7), what was the students' perception? The data shown in Figure 9 demonstrates that most of the students thought that the practicals helped them prepare for at least one type of assessment, with 46% responding that the practicals helped prepare them for both the laboratory and final examinations. An appreciable number of students (20%), did not find the practicals helpful in preparing for other examinations. A χ^2 test was

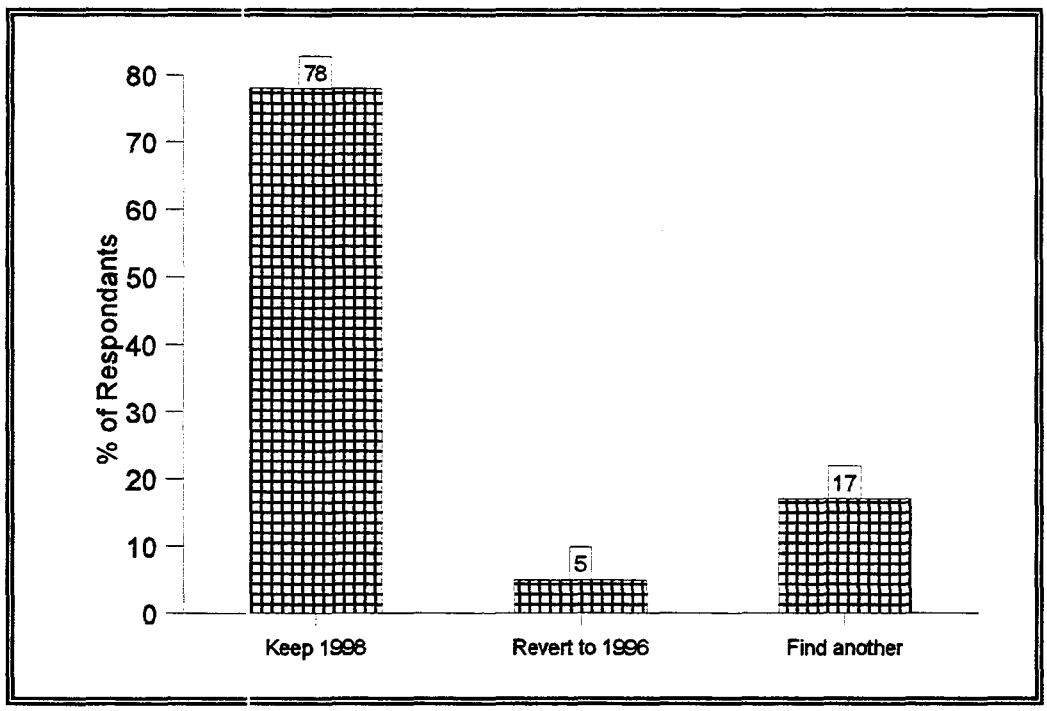
conducted by comparing the observed frequencies with expected frequencies calculated using the formula provided by Welkowitz *et al*, 1991. A χ^2 value of15.22 with three degrees of freedom was calculated for the responses shown in Figure 8. A χ^2 value of 11.345 at the 0.01 level indicates significance between the responses. Thus, the null hypothesis that there was no difference between the responses was rejected. It can be concluded that the indication that the mini-laboratory practicals helped most students to prepare for all types of testing used in Biology 2D03 in 1998 was statistically greater than the other responses.

Figure 9: Student responses the question regarding which type of Biology 2D03, 1998 test did the mini-laboratory practicals prepare students for.



While the one student quoted from course evaluations (page 48) had virulent remarks about the laboratory practicals, the students responding to the survey were overwhelmingly in favour with their retention (Figure 10). The differences between responses was highly significant. A χ^2 test was conducted by comparing the observed frequencies with expected frequencies calculated using the formula provided by Welkowitz *et al*, 1991. A χ^2 value of 56.0 with two degrees of freedom was calculated. A χ^2 value of 9.21 with two degrees of freedom is significant at the 0.01% level. The majority of respondents thought that the assessment procedures used in 1998 should be retained while a minority felt 2D03 should go back to two laboratory examinations as in 1996. A very small proportion of students thought that there should be another (unspecified) form of assessment used in 2D03.

Figure 10: Student responses to the question should the Biology 2D03 1998 assessment procedures be retained.



vii. Student subjective comments on survey regarding all assessment in 2D03:

It was not the intention of assessment revision in Biology 2D03 to totally eliminate memorization. Biology 2D03 is a lower level course in which students learn background material required for higher level courses. Students would still have to know their facts in order to apply their knowledge. Students replying to the survey made the following comments:

- "All (tests) required thought and tested different things. They were an EXCELLENT way to test us on all the info."

- "Since we were subject to live specimens on the practicals I was forced to apply my knowledge, not just assign a name to a drawn structure."
- "While memorization was obviously an important part of the course, I think that we were always obliged to apply our knowledge."
- "Well done. Since it was an introductory course memorization was required to respond intelligently with the new lingo. Also it was a great practical and knowledge based test."
- "Really good test of understanding, think & apply."
- "Memorization was needed but comprehension was used because test plants were new to our experience."

These comments demonstrate that the mini-laboratory practicals were successful in assessing not only the memorization of facts but the application of botanical knowledge.

Chapter 5

Conclusions

The laboratory curriculum and assessment of Biology 2D03, The Plant Kingdom were revised in 1998 for several reasons. The revision was in part due to the need to update the laboratory manual to reflect a new edition of the textbook by Raven *et al*, 1999; to condense three laboratory units into two in order to accommodate a shorter term and to develop a chapter on the fungi. In response to comments made by students on past course evaluations, it was decided to revise assessment. The goal was to make assessment procedures more "authentic", authentic assessment being defined as allowing students to show what they have learned in a setting that closely matches the environment in which they would be expected to show their learning in real life (Baron and Boschee, 1995 and Armstrong, 1994). Assessment should also be consistent with the objectives of the course (Murray *et al*, 1996). Students in past course evaluations complained that assessment often only tested their ability to memorize and regurgitate facts. It was never the objective of Biology 2D03 to prove that students can memorize. Assessment was revised to incorporate some facets of inquiry and problem solving. This would fit in with Lazear's (1999) new assessment paradigm in which students are taught how to learn, how to think and how to be intelligent in as many ways as possible.

The key to curriculum and assessment revision in Biology 2D03 was Howard Gardner's Multiple Intelligence theory. Several intelligences were already part of 2D03

curriculum (as outlined in Table 1, p. 16-17). Previously, assessment in the form of pen and paper weekly quizzes were strong in verbal-linguistic and mathematical-logical intelligences. Students had in the past complained of the stress of the time limit imposed in the laboratory examinations. A new form of assessment, periodical mini-laboratory practicals were implemented and one midterm laboratory examination was eliminated. The mini-laboratory practicals utilized visual-spatial, bodily-kinesthetic and naturalist intelligences. This was in keeping with Murray *et al* (1996) that assessment methods at McMaster University should be consistent with course objectives. Intrapersonal intelligence was successfully implemented with an essay assignment. The students wrote short essays on how plants were personally important to their lives. Musical-rhythmic intelligence was incorporated into the Biology 2D03 laboratories by playing recordings of classical music combined with nature sounds. The music contributed to a more soothing, relaxing learning environment. There was no evidence of a "Mozart effect" or an improvement in test scores in response to music. The nature sounds enhanced the naturalist environment of the laboratories. The students generally liked the nature sounds but one recording with wolf howls had to be withdrawn from the repertoire as some students found wolf howls threatening. Overall, student response to the music in the laboratory was favorable. The exception was in laboratory sections with too many students. In that case, the background noise from the students made the music hard to hear. Most students appreciated the selection of classical music although there were some requests for contemporary music with an upbeat rhythm.

Evaluation of the changes in Biology 2D03 curriculum and assessment were to be

based on the seven questions taken from Baron and Boschee (1995) and listed on page 29.

1. Did the curriculum and assessment revisions have unintended side effects?

With the implementation of a new assessment procedure, the Biology 2D03 instructors were concerned that there may be several unintended side effects. On the most part, their concerns may be expressed by what did not happen. A radical change in course grade statistics could have been an unintended side effect of the assessment revision. The grade distribution of the mini-laboratory practicals resembled a "J" curve more than a normal distribution (Figure 5, page 44) but the mean term grade for the mini-laboratory practicals did not differ statistically from the mean term grade from a previous year (1996). In a course that tends to be dominated by honours students, a large proportion of B's and A's would be expected. The course grades obtained in 1998 were comparable to course statistics (mean, grade distribution) from previous years (Figure 7, page 65). The grade distribution of 1998 was almost identical to that of 1995. Some technical skill was required for the first few mini-laboratory practicals which some student thought was unfair. However, these mini-laboratory practicals had higher means than the mini-laboratory practicals that did not require technical skills. The reliance on students drawing abilities could have affected grades but as shown in Figure 2 on page 38, only rudimentary drawing skills were necessary.

The only unintended side effect of revising Biology 2D03 was that the instructors did not realize that the personal essay was such a feminine exercise. Male students had more difficulty relating personal information in their essays and tended to get lower marks on this portion of their essay. Female students did a better job of describing the personal relevance

and several expressed the opinion that they appreciated that their instructors actually wanted to know how they felt about what they had learned at McMaster University.

2. Did the new curriculum and assessment take into account student cultural backgrounds?

The essay on the personal importance of plants was a form of assessment that allowed some students to relate their cultural background with the 2D03 curriculum. Some students discussed their essay topics with their parents or grandparents and included family or cultural history in their essay.

3. To what extent did the results of one form of assessment (mini-laboratory practicals) transfer to other tasks (laboratory examination and final examination)?

In the survey, students responded that the mini-laboratory practicals prepared them for other forms of assessment. Forty-six per cent of survey respondents felt that the mini-laboratory practicals prepared them for both the laboratory examination and final examination (Figure 9, page 69). Others responded that the mini-laboratory practicals prepared them for either the laboratory examination or the final examination. Only a minority of 21% felt that the mini-laboratory practicals did not prepare them for other forms of assessment. A common complaint on the course evaluations was that there were too many tests in Biology 2D03. However, in the survey one student responded that the laboratory examination was less stressful due to the his/her previous studying for mini-laboratory practicals meant that he/she already knew the information required to answer questions.

Statistical analysis showed that there was no significant difference between the mean grades for all three forms of assessment (Table 6, page 62). There was a moderate positive correlation between mini-laboratory practical grades with laboratory examination and final examination grades (Pearson Coefficient of 0.5) (Table 7, page 63). There was a strong positive correlation (Pearson Coefficient of 0.8) between laboratory examination and final examination grades (Table 7, page 63). These grade statistics indicated that results from one type of assessment did carry over to other forms of assessment in Biology 2D03.

4. Did the assessment procedures require the students to use complex thinking and problem solving skills?

Mini-laboratory practicals required application of facts, involving problem solving and thinking skills. While memorization was not eliminated, many survey respondents commented that the mini-laboratory practicals required them to apply their knowledge and were a good test of comprehension. Twenty-four per cent of the survey respondents felt that out of all the assessment procedures used in Biology 2D03, the mini-laboratory practicals best tested their knowledge (Figure 8, page 68). While students still complained of the stress factor imposed by the time limit associated by the laboratory examination, they also commented that it challenged them to think and apply their knowledge. A good proportion of survey respondents also indicated that the final examination required application of knowledge. Most encouragingly, 41% of the survey respondents felt that all forms of assessment used in 2D03 best tested their knowledge (Figure 8, page 68). As no one assessment method is perfect for all individuals, a combination of assessment methods may be a more a valid or

authentic test of knowledge than one method alone.

5. Was the content selected for Biology 2D03 curriculum and assessment representative of the best current understanding of botany?

Updating the laboratory curriculum to reflect a new edition of the text meant that the 1998 curriculum was representative of the current understanding of the field. The Fungi, a kingdom previously not part of the second level biology curriculum, was now included in the Biology 2D03 curriculum. Although strictly speaking the Fungi are not plants, they have historically been included in botany curriculum and text books. These changes were also incorporated into all forms of assessment used in Biology 2D03.

6. Did the students find assessment tasks in Biology 2D03 realistic and meaningful?

On the course evaluation, a larger proportion of respondants indicated positive responses about tests (i.e. mini-laboratory practicals) than negative responses (Table 3, page 45). In summary, they indicated that tests were at an appropriate level of difficulty, challenged them to think, had good coverage, fairly and clearly graded and well supervised . The two main student complaints regarding tests in Biology 2D03 were that there were too many tests and tests were too difficult. A series of frequent but low value tests was deliberate so that assessment would based more on "a series of games" rather than be based on a single event. The class mean for the mini-laboratory practicals did not significantly differ from the term mean from a previous year (1996). Almost half of the survey respondents (41%) felt that all forms of assessment in Biology 2D03 best tested their knowledge (Figure 8, page 68). Less

than 1% responded that none of the assessment methods used in 2D03 tested their knowledge. Overwhelmingly, 78% of students responding to the survey felt that the new assessment methods should be retained (Figure 10, page 71). Few (5%) wanted to revert to the previous methods and 17% indicated that an alternate method should be found. It is not likely that any assessment scheme will achieve 100% approval from students.

The essay was not a large part of the assessment in biology 2D03. Sixty-three per cent of survey respondents felt that the value of the essay (5% of their final grade) was right (Figure 6, page 58). Some students felt that it should be worth more. A few students responded to the survey that they thought the essay was a waste of their time and 4% of respondents felt that the essay assignment should be eliminated. However, having read all the essays submitted, the instructor is of the opinion that the essays were a worthwhile endeavor to bring personal relevance into the curriculum.

7. Was the information about students gathered by the assessment methods used in Biology 2D03 worth the time and effort required to obtain it?

Implementing new assessment procedures, namely mini-laboratory practicals and essays, required an enormous amount of time and effort on the part of T. Setterlund Leech. The teaching assistants assigned to Biology 2D03 in 1998, were not particularly strong in botany studies. Due to the open-ended nature of the material used in the mini-laboratory practicals, it was not feasible to expect the assigned teaching assistants to mark them. Marking an entire class load of seven mini-laboratory practicals and personal essays by one person required great effort and time. However, as both were new forms of assessment, it was

invaluable for T. Setterlund Leech to do this marking in order to determine how successful the assessments were and how to improve them. With the experience gained in 1998 in marking all mini-laboratory practicals, marking schemes that future teaching assistants could follow can be created. Teaching assistants stronger in botany studies could be hired in future years by hiring senior undergraduate students who are former Biology 2D03 students instead of graduate students with little botanical background.

Previously, it required great creativity to create five versions of the weekly quizzes for each laboratory day. The mini-laboratory practicals were somewhat easier to create as the same questions could be used each laboratory day. By changing the plant material, a new test was created for each day (despite using the same questions). It was challenging to T. Setterlund Leech's creativity to find different plant material for each day. Economics were also a concern as the cost of some plant material (e.g. flowers) and of photocopied micrographs had to be kept withing the course budget.

In conclusion, the following recommendations for Biology 2D03 curriculum and assessment can be made:

- The Fungi be kept as part of the curriculum but that the amount of work required be decreased and the life cycle details be further simplified.
- The combining of three chapters into two at the start of the term also imposed a heavier work load on the students and should be revised to lessen the amount of work required.
- Music in the laboratory environment should be retained but sound systems better than

the equipment supplied by the audio-visual department be purchased.

- The mini-laboratory practicals be retained as a form of assessment and only one laboratory examination be retained.
- Imaging equipment (digital camera, link of camera to microscope, computer and printer) could be purchased for the mini-laboratory practicals. With such equipment, the students could take digital images of their best plant sections, print out their image and label it. This would remove the reliance on student's drawing skills to accurately portray what they observe. Imaging equipment could also be used to prepare marking schemes for the teaching assistants.
- If the graduate students available for teaching assistant positions lack a strong botany background, senior undergraduate students who have taken Biology 2D03 and higher level plant courses offered at McMaster University should be hired as Biology 2D03 teaching assistants.
- The essays should be retained but their scope should be expanded. In addition to describing their topic and relating their personal experiences, students could also describe how something they learned in Biology 2D03 (or any other McMaster University course) helped them to understand their topic.

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Appendix A

The Fungi

Text reference: 306-346

What are fungi? The fungi are not really plants as they are not found in the kingdom Plantae but are their own kingdom, the Fungi. Clumping the fungi with plants goes back to Linnaes who divided the world into 3 categories; mineral, animal and vegetable. As fungi were not minerals or animals, Linnaes classified them as vegetables. This tradition continues today as you find a chapter on the fungi in your 2D03 text. Actually, the fungi are more closely related to animals than plants. Comparisons of small subunit ribosomal RNA sequences suggest that animals and the fungi have a common ancestor that was a flagellated protist similar to today's choanoflagellates.

The fungi are important ecologically, economically and medically. Many fungi are saprophytic, deriving nutrients from dead and decaying matter. They are important in the recycling of nutrients in the environment. Others form symbiotic relationships with other organisms such as plant roots and algae. Mushrooms are an important food for humans and mushroom farming is a big industry in Ontario. In 1996, 75.5 million pounds of mushrooms were grown in Ontario. The value of this crop to the farmer was $104 million. Some fungi are important plant pathogens. Plant diseases caused by fungi can result in economic loss and famine. The potato famine in Ireland during the 1840's resulted in millions dying and millions

emigrating to North America to escape the famine. Secondary metabolites called mycotoxins produced by fungi have resulted in poisoning of humans and animals. In recent times with an increase in people with immune deficiencies due to AIDS, organ transplants and drug treatments, fungal diseases of humans have become more prevalent and important. Some fungi also produce important drugs such as penicillin and cyclosporine.

Station 1 Fungal growth

Most of the time, fungi grow from a spore, produced either through asexual or sexual reproduction. Spore germination lead to the growth of a germ tube which develops into the basic fungal unit, a hyphae. A clump of hyphae is called mycelia (although some mycologists also call hyphae (singular) mycelium). When grown on agar medium in a petri plate, hyphae grow and branch to form circular colonies. Hyphae may be divided into sections or cells by partitions called septae. The pores in the septae may be large enough for nuclei to pass through and there may be connection between vacuoles through the pore. In most fungi the hyphal wall is composed mainly of chitin although in some fungal groups the wall may also contain chitosan, beta glucan or mannan. All growth occurs at the hyphal tips where the wall is still plastic or non-rigid. In this area the cytoplasm is homogenous, lacks vacuoles and septae. Fungal cell membranes have a typical three-layered structure in which the lipid portion has a significant content of free fatty acids, a trait peculiar to the fungi. The fungal nucleus is smaller than that of other eukaryotic organisms. The vacuoles are the site of nitrogen and phosphorus storage, the packaging and secretion of hydrolytic enzymes and the synthesis and secretion of extracullular polysaccharides. Figures 15-4 (p. 310) and 15-5 (p. 311) of your text illustrate the ultrastructure of fungal hyphae. Note the septum and pore

shown in Fig. 15-4.

Examine the hyphae growing in fungal colonies on agar in petri plates. Remove a piece of agar containing hyphae and place on a microscope slide. Stain with analine blue. Cover with a cover slip, pressing down on the cover slip to squash the agar and spread out the hyphae. Examine the hyphal filaments under high power with a compound microscope.

b) Some fungi, like yeasts, do not have hyphal structures. Their cells divide by budding of young daughter cells or by fission. Some fungi in certain environmental conditions may exhibit yeast-like growth while in other conditions may show hyphal growth. Remove a drop of yeast mixture, place on a slide and cover with a cover slip. Examine with the compound microscope for yeast growth. Yeast growth is shown in Figure 15-31 (p. 331) of your text.

c) Examine the diagram showing how the components of the fungal wall are layered. In this fungus, *Candida albicans*, chitan and beta glucan are sandwiched between two mannoprotein layers.

Station 2 Division Basidiomycota

Basidiomycetes include the mushroom and toadstools and probably are what most people think of as fungi. The basidiomycetes have several characteristics which distinguish them from the other fungi.

i. They are septate with a unique pore structure (shown in Fig. 15-20 on p. 322 of your text).

ii. Most basidiomycetes produce one type of spore, the basidiospore, which is formed by structures called basidia. Your text shows basidia and basidiospores

in Fig. 15-19 (p. 321).

iii. After spore germination, basidiomycete mycelia are multinucleate at first but with the formation of septae they are monokaryotic (ie. one nucleus per cell). Eventually two hyphae fuse to form dikaryotic cells. Growth at the hyphal tip requires a special structure called clamp connections to maintain the dikaryotic state. These clamp connections (shown in Fig. 15-21 on p. 322 of your text) are characteristic of the basidiomycetes.

The sexual life cycle of a mushroom is shown in Fig. 15-18 on p. 321 of your text. Dikaryotic mycelia produce the mushroom or fruiting body. Tissue lining the gills of the mushroom develop basidia (spore bearing structures) at the hyphal tips. The two nuclei of the young dikaryotic basidia fuse to form a diploid nucleus. The diploid nucleus promptly undergoes two meiotic divisions to form four haploid nuclei. Four basidiospores bud off the tip of each basidium. The four nuclei migrate into these four basidiospores, one haploid nuclei per basidiospore. The basidiospores are dispersed and germinate into haploid mycelia.

a) Examine the fresh Portobello mushrooms and identify the cap and stalk. On the underside of the cap you will see the gills. Mount a piece of gill tissue on a slide. This tissue does not need to be stained, it can be mounted in water and covered with a cover slip. You should be able to see fresh basidiospores and basidia.

b) A common local mushroom is the "inky cap" or *Coprinus sp.* This mushroom derives its common name from its characteristic of releasing enzymes which digest away the cap into a black slime (hence the name "inky cap"). The slime containing basidiospores is dispersed by insects. Examine the *Coprinus* slides showing sections

through the gills of the mushroom. *Coprinus* gill sections are also shown in Fig. 15-23 on p. 324 of your text.

c) Examine the miscellaneous mushrooms collected earlier this year. Observe the various shapes, sizes, colours andmorphology. In addition to a cap and stipe, some of the mushrooms may have a ring of tissue around the stipe called a volva. There may also be spots of tissue on the cap. Both these tissues are remnants of a membrane that surrounded the young "button" stage mushroom. Some the mushrooms collected may not have gills under their cap but pores. These pores open to tubes where basidiospores are produced. The bracket fungi that grow on tree trunks and rotting logs also have pores leading to tubes producing basidiospores. These three types of basidiomycete fruiting bodies are also shown in Fig. 12-29(a,b.c) on p. 232 of your text.

d) Mushroom or toadstool? Shown here are two mushrooms/toadstools collected locally. Both are white and are very similar in appearance. The Lepiota is an edible mushroom. Ignoring the size difference, this mushroom is very similar to the poisonous "Destroying Angel" toadstool (Amanita virosa). The key identifying feature between the two is the large white bulb or volva at the base of the Destroying Angel stalk.

e) Commercially available edible mushrooms - specimens purchased at local grocery stores and newspaper article.

f) Stinkhorns (preserved specimens). These phallic-shaped "mushrooms" belong to the class Gasteromycetes. An external hymenial layer on the tip of the stinkhorn produces

a smelly, slimy mass of spores. Insects, attracted by the foul odour of the spores, disperse the spores. Stinkhorns are not edible mushrooms.

g) Puffballs. Another type of Gasteromycete which produces spores within the basidiomata. A puffball is shown in Figure 15-27a (p. 326) of your text.

Rusts and Smuts

Since ancient times wheat rust, caused by the basidiomycete *Puccinia graminis*, has been regarded as the most serious cereal disease. It has a complex life cycle with two hosts and five types of spores (an exception to the rule that basidiomycetes have one type of spore). Use Fig. 15-29 on pp. 328-329 of your text to guide you through the life cycle of this fungus. (Note: You do not need to know all the details shown in the life cycle diagram, you are responsible only for the features discussed here.)

h) In late fall, affected wheat stems have black lesions in which dikaryotic (n + n) black spores are produced. Examine the demonstration slide of lesions with spores. In the spring, the nuclei in these black spores fuse forming diploid spores. This is the only diploid stage in the life cycle of this fungus. Meiosis immediately occurs followed by spore germination to form haploid basidia and basidiospores. The basidiospores are carried by wind to barberry leaves.

i) The basidiospores penetrate through the barberry leaf epidermis and infect the barberry. On the upper surface of the barberry leaf, structures producing haploid spores form. Nectar is produced which attracts flies. The flies, as they feed on the nectar, pick up haploid spores and carry the them to other similar structures. If two opposite mating types of haploid spores fuse, dikaryotic mycelia results. The

dikaryotic mycelia grow through the barberry leaf mesophyll and produce another type of spore bearing structure on the lower epidermis where dikaryotic spores are produced. These spores are carried by the wind to wheat plants. Examine the demonstration slides of barberry leaves with both types of spore bearing structures on the upper and lower surfaces.

j) On wheat, the dikaryotic spores from the barberry germinate and the germ tube penetrates through the stomata. Rust coloured lesions (for which the disease is named)appear on the wheat. In these lesions, another type of dikaryotic spores are produced. Dispersed by wind, these spores infect other wheat plants. Examine the demonstration slides of these lesions with dikaryotic spores. In the fall, the rust coloured lesion turn black producing overwintering black spores.

Throughout history red and black rust were thought to be connected but it was not until 1854 that Charles and Louis Rene proved that they were different stages of the same disease. Also throughout history it had been noted that wheat fields near barberry bushes had severe rust. It was not until 1927 that a Canadian researcher, John Hubert Craigie, discovered that barberry was the alternate host to wheat rust. A disease that requires two hosts to complete its life cycle is said to be heteroecious. Control of wheat rust through eradication of the alternate host, barberry has been attempted but was not successful largely because wind currents can carry all types of *Puccinis graminis* spores over extremely long distances. Since the turn of this century, rust resistant wheat cultivars have been bred. Resistance to wheat rust has historically been based on a single gene change. The pathogen, *Puccinia graminis*, through natural mutation develops new strains that can overcome the resistance conferred by

the single resistance gene of the wheat cultivar. Modern plant breeding now attempts to develop new cultivars with multiple gene resistances that may be more difficult for the pathogen to overcome.

k) Corn smut is caused by the fungus *Ustilago maydis* which is closely related to *Puccinia graminis*. Corn smut produces large unsightly galls on stems, leaves, ears and flowers of corn. Masses of black diploid spores are produced in these galls. Examine the preserved specimens of corn smut galls (if available) and the photograph of corn smut galls in Fig. 15-30 (p. 330) of your text.

Station 3 Division Zygomycota

The zygomycetes have coenocytic hyphae, that is the hyphae lack septum so that the cytoplasm and contents are continuous within the hyphae.

a) Examine the life cycle diagram of *Rhizopus stolonifera* in Figure 15-11 on page 316 of your text book. Sexual reproduction in the Zygomycetes results in the production of thick-walled, resistant zygosporangia. Examine the demonstration slides of zygosporangia (also shown in Fig. 15-12(b) on p. 316 of your text). *Rhizopus* is heterothallic in that it requires two different mating types (usually designated as + and - strains) for sexual reproduction to occur. The two strains or *Rhizopus* release hormones into the environment which causes the hyphae of the two strains to grow towards each other. Each strand of hyphae produces a gamatangium which is separated from the hyphae by a septum. Each gametangium is multinucleate. Fig. 15-12(a) (p. 316) of your text shows two gametangia in the process of fusing. Fusion of the two gametangia is followed by fusion of nuclei creating diploid zygotes (the fused

nuclei). The zygosporangium develops a thick dark wall and remains dormant for a period of time. When the zygosporangium germinates, it produces a sporangiophore. Meiosis occurs in the sporagiophore which then develops a globular sporangium and haploid spores.

b) Haploid spores are the main mode of replication for zygomycetes. Examine the cultures of *Rhizopus stolonifera* for the sporangiophores, globular sporangia and spores using a dissecting microscope. **Do not remove the cover off the petri plate.** Sporangiophores occur at intervals along the hyphae. The hyphae between sporangiophores are called stolons for their similarity to stolons in higher plants. Rhizoids anchor the sporangiophores into the growing media. At the apex of the sporangiophore is a globular sporangium which is separated from the sporangiophore by a septum. The

sporangium produces black haploid spores. The spores are disseminated by air and grow to form new haploid colonies.

c) Examine the demonstration slides of *Rhizopus* sporangiophores, sporangia and spores.

d) *Rhizopus* can cause fatal lung infections in people with immunodeficiencies (article).

Station 4 Division Ascomycota

Ascomycetes may have hyphal growth or yeast-like growth. Their hyphae are septate but the septa have pores large enough for nuclei to pass through. Ascomycetes may be saprobes, digesting dead and decaying matter, but many of them are important plant pathogens. A typical life cycle for an ascomycete is shown in Fig. 15-14 (p. 318) of your text. Asexual reproduction occurs by haploid spores called conidia which are produced by special

cells on stalks called conidiophores. You are not responsible for the details of sexual reproduction in the ascomycetes except for the following description. Through sexual reproduction, dikaryotic hyphae are formed by the gametangia. Dikaryotic hyphae proliferate, forming various types of fruiting bodies. Asci, sack like structures that produce the ascospores, are formed in the fruiting bodies. In asci formation, the tip of the dikaryotic hyphae forms a hook. The two nuclei in the tip of the hook fuse (karyogamy) creating a zygote. This is the only diploid stage in the fungus' life cycle. While the zygote undergoes meiosis followed by mitotis the young ascus elongates. As a result of meiosis and mitosis, the zygote produces eight haploid ascospores, 4 of each mating type. Ascopores are dispersed by air. They germinate to start the asexual part of the life cycle with production of conidia.

a) Examine the fruiting bodies of *Peziza* (if available) collected last spring. *Peziza* is very similar to the fungus shown in Fig. 12-10 on p. 216 of your text.

b) Examine the slides showing sections of an ascocarp from the fungus *Peziza.* Observe the ascospores produced in asci.

c) Cultures of *Sordaria* with perithecia and ascospores. The ascomycetes *Neurospora* and *Sordaria* have been used extensively in the study of genetics. In the Biology 1A03 Genetics lab, you observed the results of a cross of a strain of *Sordaria* that produced black ascospores with a strain that produced grey ascospores. Mount a few *Sordaria* perithecia on a slide with a drop of water. Cover with a cover slip. Squash the perithecia slightly (but not too hard or you will discharge the ascospores). Using a compound microscope, observe the black and grey ascospores in the asci (ignore asci with ascospores of one colour).

d) Some ascomycete fruiting bodies are mushroom like. An excellent eating ascomycete is the morel or *Morchella* (magazine article). Morels grow in association with oak trees and are collected in May. Examine the dried morels (note: the stalk has been removed. While morels do grow locally, the locations of where they grow is kept secret.

e) Examine the slides of morel or *Morchella* asci and ascospores. Figure 15-17 (p. 320) of your text shows the hymenial layer, asci and ascospores of *Morchella*.

f) *Erysiphe graminis* causes a plant disease called powdery mildew. The disease is named for the powdery white mycelia that grows on the leaf surface. Examine the herbarium specimens of powdery mildew. Also examine the demonstration slides of conidia and asci of *Erysiphe graminis*. The asci are produced in an round enclosed fruiting body.

g) If plants infected with powdery mildew are available, you will attempt to "lift" the fungus off the leaf surface using the following technique:

Press a piece of clear tape to the leaf surface and peel off the tape. Place the tape (sticky side down) on a microscope slide with a drop of aniline blue. Cover with a cover slip.

You should be able to observe mycelia growing on the surface of the leaf. With luck you may find a specialized, highly branched hyphal structure called a haustorium. Haustoria penetrate into plant cells and remove nutrients from the cell.

h) Examine the maple leaves with "tar spot". In the last few years, the disease "tar spot" has been afflicting maples in Ontario. This disease is caused by an ascomycete,

Rhytisma acerium. Ascospores develop on overwintering infected leaves. Airborne ascospores infect newly developing maple leaves in the spring. Secondary infection by conidia occurs throughout the growing season. Although this disease is unsightly, it is not a serious disease unless enough leaves are infected to defoliate the tree.

i) "Carbon balls". A common ascomycete found locally growing on dead logs.

Station 5 Division Deuteromycota (or Imperfect Fungi)

The deuteromycetes or Imperfect fungi are a miscellaneous group of conidial fungi in which there is no known sexual stage. Sexual reproduction may have been lost during the course of evolution or may occur infrequently and has not been discovered yet. In some common deuteromycetes such as *Aspergillus* and *Penicillium*, the sexual stage is known but taxonomists continue to group them with the deuteromycetes due to their overall resemblance to others of this group. General features such as a single pore septae indicated that many of the deuteromycetes are ascomycetes. Some deuteromycetes have features of the zygomycetes while others have features of the basidiomycetes.

a) *Penicillium* fresh material (use prepared slides if fresh material is not available). Make a fresh mount of *Penicillium* on a slide. Stain with aniline blue and cover with a cover slip. Examine the slide for conidiophores, conidia producing cells and conidia. The chain of conidia are very fragile and many will have broken up but if you search through your slide you should see chains of conidia similar to Fig. 15-34(a) on p. 332 of your text.

Species of *Penicillium* are used in the production of blue cheeses, as well as Camembert and Brie. In 1928 Sir Alexander Fleming discovered that a *Penicillium*

contaminant in a petri plate was inhibiting the growth of the bacterium *Staphlococcus*. The antibiotic penicillin had been discovered. Since then

numerous antibiotics produced from fungi have been discovered and

developed for medical uses. Organ transplants are possible today due to another fungal product, cyclosporine.

b) *Aspergillus* fresh material (use prepared slides if fresh material is not available). Make a fresh mount of *Aspergillus* as you did with *Penicillium*. *Aspergillus* is similar in appearance to *Penicillium*. Both fungi produce conidia in chains. While *Penicillium* has a "brush-like" appearance, *Aspergillus* conidiophores end with a bulbous tip which bears the conidia. As with *Penicillium*, you will have to search through your slide to find intact chains of conidia which resemble Fig. 13-34(b) on p. 332 of your text.

Aspergillus is a very common fungus which may be beneficial or harmful. Species of *Aspergillus* are used in the production of soy sauce, soy paste (miso) and sake (rice wine). Infestation of stored corn, wheat and peanuts by *Aspergillus flavus* and *A. parasiticus* have caused poisoning of humans and animals. This poisoning is due to a mycotoxin called aflatoxin. Mycotoxins are secondary metabolites of fungi, meaning that they are not required for primary growth or development. Aflatoxin was first discovered in the 1960's when turkeys began to die inexplicably. The new disease was called "Turkey X Disease". Later research determined that the turkeys were being poisoned by aflatoxins in their feed. In high doses aflatoxins can cause death but low doses are known to be carcinogenic resulting in liver cancer.

c) *Aspergillus sp.* may also cause a disease known as aspergillosis in humans, especially in those with compromised immune systems (articles). In a 1991 study of hospital-acquired pneumonia in bone marrow transplant patients, one third were caused by the fungus *Aspergillus* and 85% of those cases were fatal.

d) Examine the petri plates you exposed to air in the lab last week. Make slides of any fungi that grow and examine the fungi for conidiophores and conidia.

Station 6 Symbiotic relationships involving fungi.

Mycorrhizae is a mutually beneficial relationship between roots and fungi. The fungus transfers nutrients, especially phosphorus, from the soil to the roots while the plant provides carbohydrates to the fungus. There are two major types of mycorrhizae, **ectomycorrhizae** and **endomycorrhizae**.

a) Ectomycorrhizae. In ectomycorrhizae a hyphae mantle (tubular filaments of fungal tissue) covers the root surface. Hyphal strands extend out from the mantle into the soil. Ectomycorrhizal roots lack root hairs but the hyphae that make up the mantle fill the same function. Some of the fungal hyphae extend into the root cortex and form the interface between the fungus and the plant. The hyphae grow between the cortical cells but do not penetrate the cells. Examine the micrographs for features of ectomycorrhizae. Ectomycorrhizae are also shown in figures 15-43, 15-44 (p. 342) and 15-45 (p. 343) of your text.

b) Endomycorrhizae is the more common form of mycorrhizae. In endomycorrhizae the fungus penetrates into the cortical cells where it forms coils, swellings (vesicles) and minute branches (arbuscles). The fungal hyphae also extends out into the soil.

Examine the micrographs and note the arbuscles within the cortical cells. Endomycorrhizae arbuscles and vesicles are also shown in your text (Fig. 15-41 p. 341).

In the Bryophyta (moss) portion of the Lower Plants lab you observed **lichens** growing among the mosses. Lichens are a symbiotic relationship between ascomycetes and green algae and/or cyanobacteria. The algal portion of the symbiont provides energy-rich carbon compounds through the process of photosynthesis. The fungal partner is thought to protect the algal partner and to provide it with minerals obtained from the environment. Lichens have three growth forms. Foliose lichens are flat and "leafy". Crustose lichens form hard crusty growths on rocks and tree bark. Fruticose lichens are shrubby and were the type you saw mixed in with the mosses.

c) Observe the three growth forms of lichens. Crustose and foliose lichens are shown in Fig. 15-36 (p. 336) and fruticose lichens are shown in Fig. 15-37 (p. 337) of your text.

Appendix B

List of Music Recordings

Baldwin, Robert W. NorthSound Classical Loon Audiotape. NorthWord Press Inc., 1992.

Baldwin, Robert W. NorthSound Classical Loon II Audiotape. NorthWord Press Inc., 1992.

Baldwin, Robert W. NorthSound Classical Nature Audiotape. NorthWord Press Inc., 1992.

Baldwin, Robert W. NorthSound Classical Wolf Audiotape. NorthWord Press Inc., 1992.[1]

Chacra Artists. New Age of Classics Mozart Audiotape. Chacra Alternative Music Inc., 1991

Gibson Dan and Gordon Gibson. Solitudes Great Lakes Suite Audiotape. Solitudes Ltd., 1991.

Gibson Dan and Gordon Gibson. Solitudes Harmony Audiotape. n.d.

Gibson Dan and Gordon Gibson. Solitudes The Classics Audiotape. Dan Gibson Productions Ltd., 1992.

Gibson Dan and Gordon Gibson. Solitudes The Classics II Audiotape. Dan Gibson Productions Ltd., 1991.

Gibson, Gordon. Solitudes Songbirds at Sunrise Audiotape. Solitudes Ltd., 1996

Gibson, Gordon. Solitudes Whispering Woods Audiotape. Solitudes Ltd., 1997

Griswold, Keith G. NorthSound The Natural Harp Audiotape. NorthWord Press Inc., 1994.

Johnson, Ken. NorthSound The Natural Piano Audiotape. NorthWord Press Inc., 1991.

[1]Recording with wolf calls that had to be retired from the repertoire.

Appendix C

Sample of Mini-Laboratory Practicals

NOTE: **Some questions are based on images or micrographs. The students were give photocopies of these images and micrographs. These photocopies have been included in this appendix.**

A. Seeds & Seedlings Practical #1

1. Dissect your seedling, draw a diagram on the back of this page and label the following structures (if present) on your diagram: (9 marks)
   cotyledon(s), scutellum, epicotyl, hypocotyl, primary root, lateral roots, endosperm, primary leaves, coleorhiza, coleoptile, seed coat, seed coat & pericarp

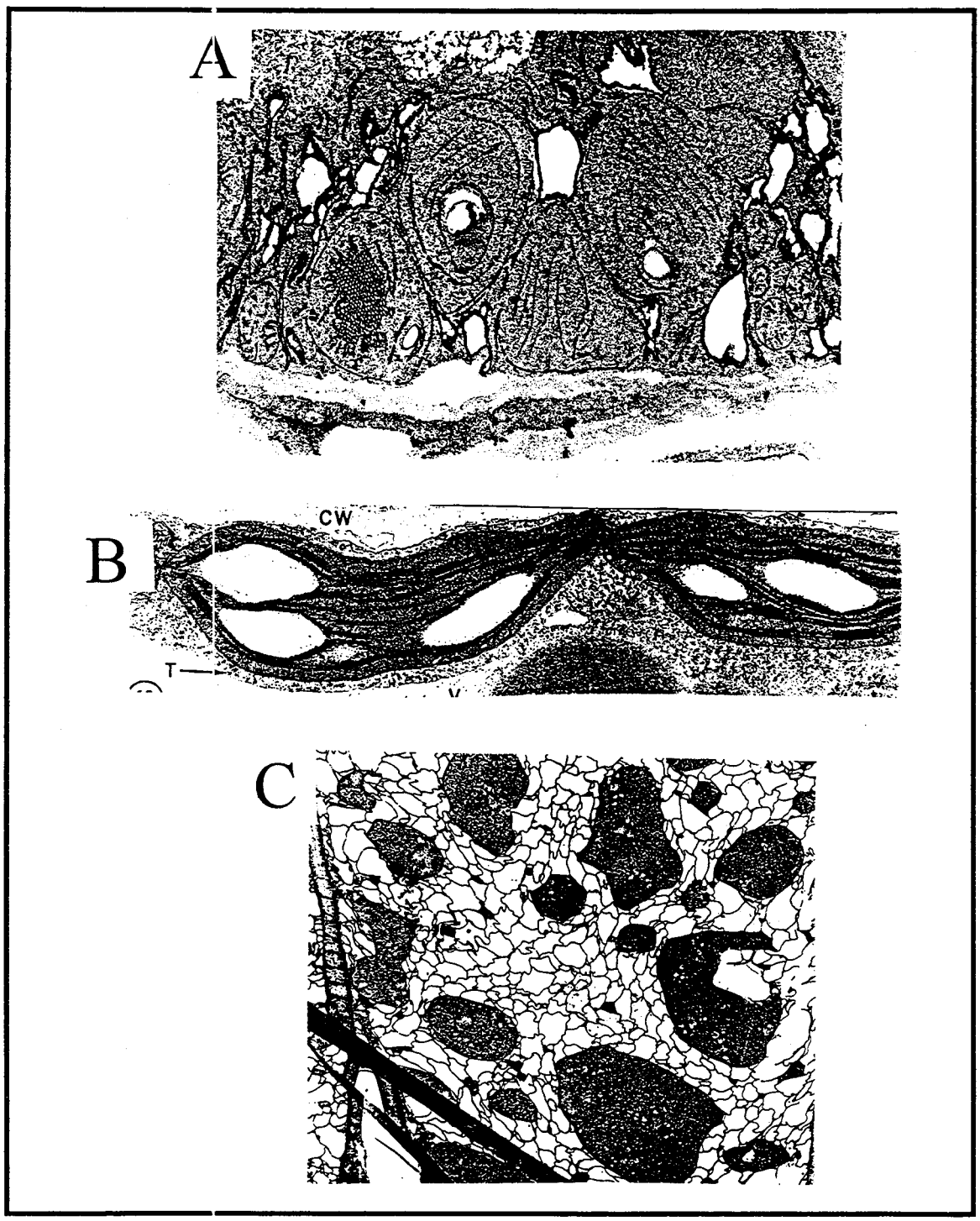
2. Is your seedling a monocot or a eudicot? Indicate on your diagram the features of your seed/seedling that indicate whether it is a monocot or eudicot. (4 marks)

3. Is the growth of your seedling epigeous or hypogeous or a rosette? Explain how you can tell. (4 marks)

4. What is/are the function(s) of the cotyledon(s) of your seedling? Explain how you deduced what the function(s) was/were. (4 marks)

5. Which of the micrographs (A, B, C) depicts a germinated seedling that has been grown in the light? What feature(s) in the micrograph indicates that:
   (a) germination has occurred
   (b) that the seedling was grown in the light

Electron micrographs for question 5:



B. **Roots & Stems Lab Practical #2**

1. Cut a thin transverse (cross) section of your plant tissue, draw a diagram and label the following structures (if present) on your diagram: epidermis, periderm, hypodermis (exodermis), cortex, pith, pith cavity, pericycle, endodermis, stele, vascular bundle, metaxylem, protoxylem, protoxylem lacunae, phloem, fibers, lenticels, vascular cambium, residual procambium, interfasicular region, chloroplasts, starch grains, secondary xylem, secondary phloem. If you find something in your section that is not included in this list, you may add it to your diagram after your TA verifies that it is in your section. Use IKI or toluidine blue if you wish to enhance your section. **(17 marks)**

2. Is your tissue a root or stem? What features seen in the transverse section of your tissue indicates whether is a root or stem? **(4 marks)**

3. Is your tissue from a monocot or eudicot plant? What features seen in the transverse section of your tissue indicates whether it is a monocot or eudicot? **(4 marks)**

C. **Buds, Leaves & Adaptations of Plant Systems Practical #3**

1. Cross section the piece of leaf blade provided, draw a diagram and label the following structures (if present): epidermis, multiple epidermis, mesophyll, spongy mesophyll, palisade mesophyll, intercellular air spaces, guard cells, sclerenchyma strands, sclereids, stone cells, druse crystals, fibers, cuticle, stomata, sunken stomata, veins, trichomes, water storage cells. (15 marks)

2. Indicate on your diagram with a * the tissues/cells you labeled which contain chloroplasts (2 marks).

3. Was the plant your leaf was taken from adapted to growth in a xeric or wet environment? List the features you observed in your leaf that indicate whether it was adapted to growth in a xeric or wet environment. (4 marks)

4. Examine the prepared slide provided. Was it taken from a plant that was adapted to growth in a xeric or wet environment? List the features you observed in the slide that indicate whether it was adapted to a xeric or wet environment. (4 marks)

D. Flowering & Seed Formation Practical #4

1. Observe and dissect the flower/inflorescence provided. On the back of this page draw a diagram or diagrams of the flower/inflorescence and label the following items (if present) on your diagram(s): (13 marks)

sepals	petals	corolla tube		stigma	filaments
ovary/ovaries	anther(s)	styles		ray flowers	
disk flowers	honey guides	pistil(s)		stamen(s)	

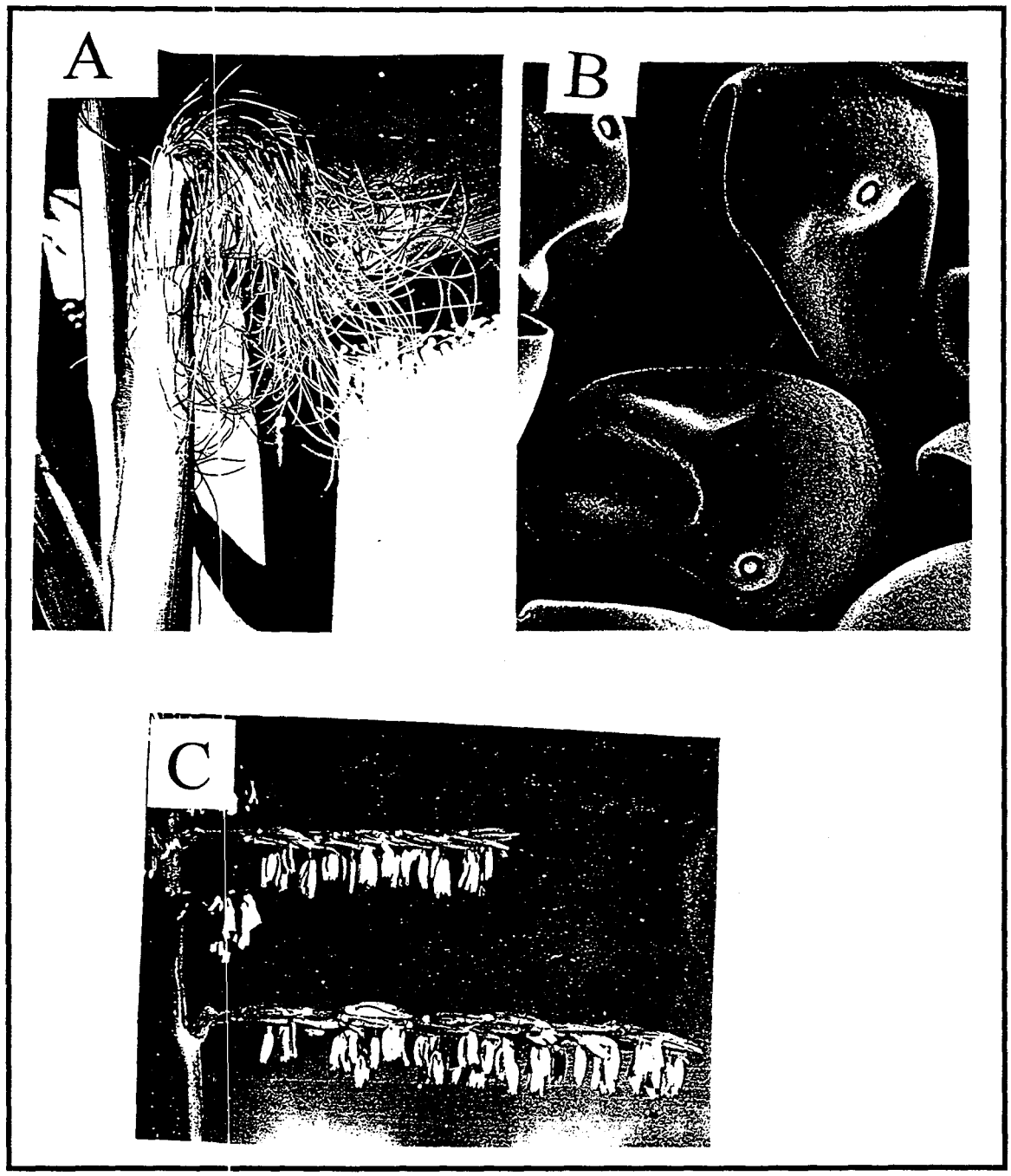
2. Is your flower a monocot or eudicot? What features of your flower/inflorescence indicate whether it is a monocot or eudicot? (3 marks)

3. How do you think your flower would be pollinated? What features of your flower/inflorescence would indicate that this was the pollinator? (3 marks)

4. Is the plant shown in images A, B, & C a monocot or eudicot? What feature indicates whether the plant is a monocot or eudicot? (2 marks)

5. Images A, B & C all come from a plant with what type of pollination? What feature in images A & C tells you that this is the pollination system? (4 marks)

Images for questions 4 and 5:



E. Phyla Coniferophyta, Cycadophyta & Ginkgophyta Practical #5

1. Observe & dissect the tissue provided, draw diagrams on the back of this page and label the following structures (if present): (8 marks)
   needles fascicles ovulate cones staminate cones
   microsporangia winter buds stem arils microsporophylls
   scale leaves ovuliferous scales

2. This diagram was taken from an earlier edition of your text. What error was made in the labeling of this diagram and how would you correct it? (4 marks)

3. What are these objects and what is their function in transmission electron microscopy? (3 marks)

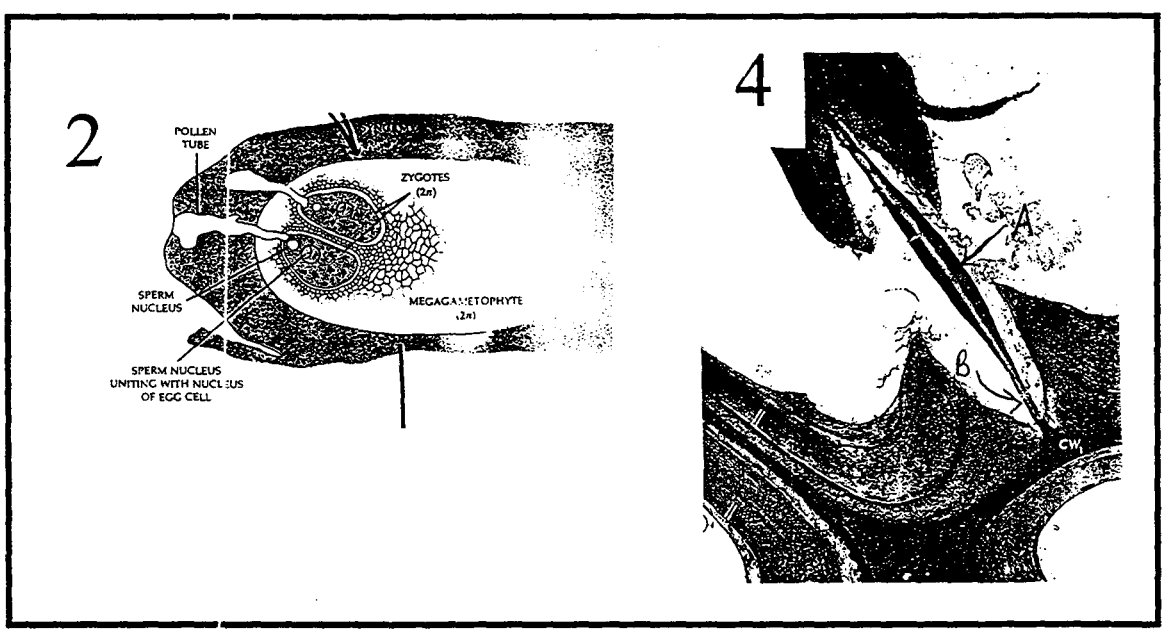
4. The structure labeled A is found in what type of cell? .....

   What is the function of B in a normally functioning cell?

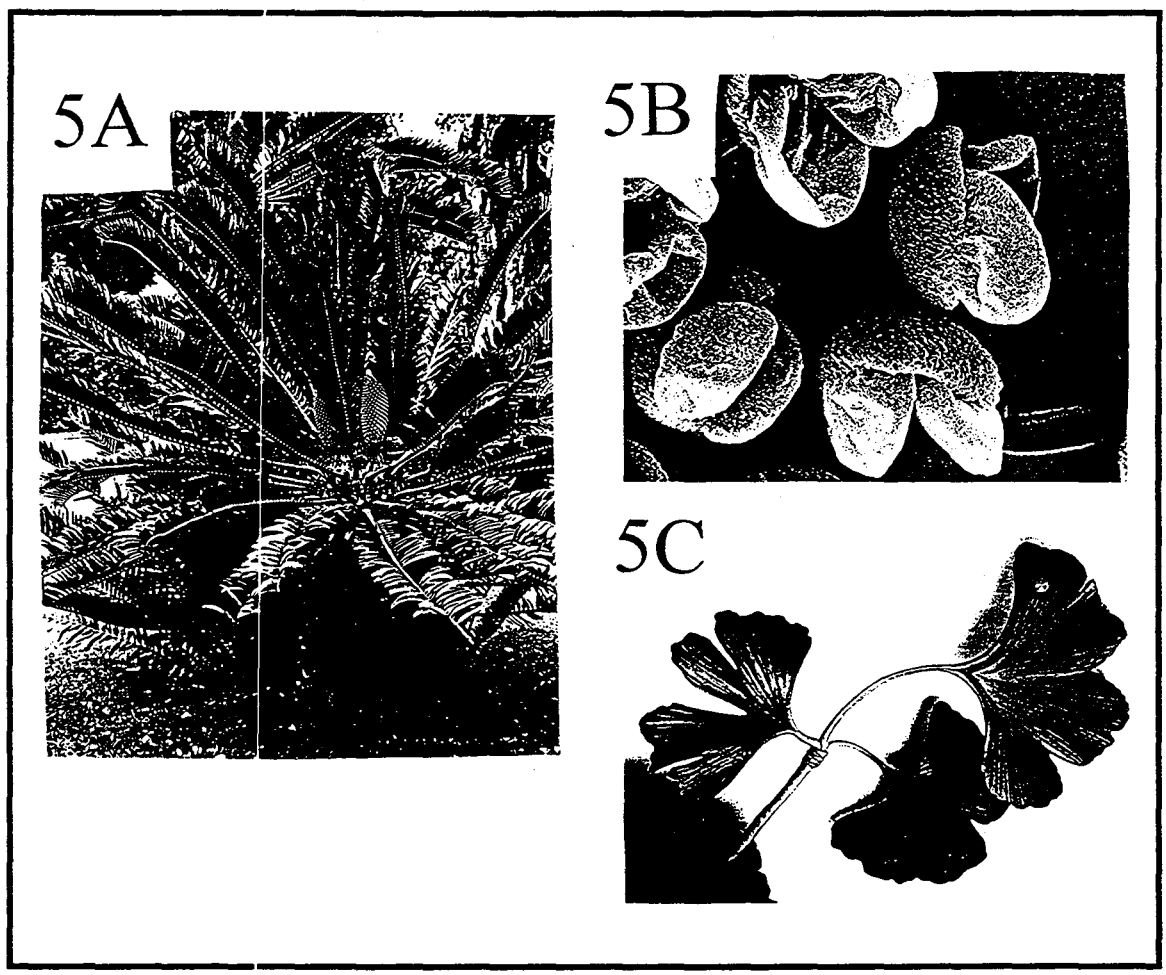
   What is the function of A if the cell is wounded? (6 marks)

5. Which phyla are images A, B, C from? (3 marks)

Images for questions 2 and 4:



Images for question 5:



6. A number of the plants studied in the gymnosperm lab are of medical, ecological, or taxonomic importance. Name one type of gymnosperm (common name or genus) and state what its importance was. (1 mark)

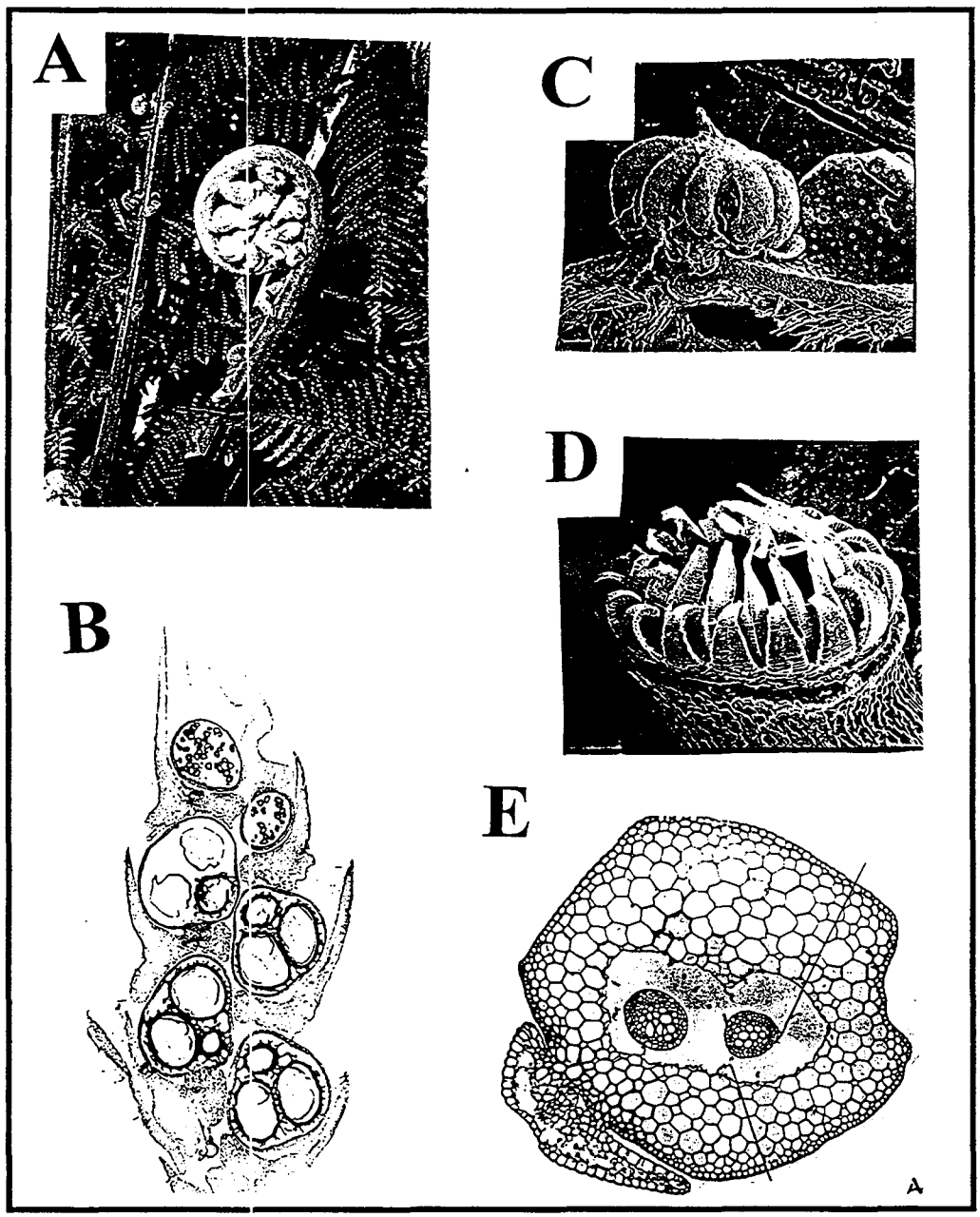
F. Practical #6: Phyla Pterophyta (ferns - leptosporangiate & eusporangiate), Sphenophyta (*Equisetum*), Lycophyta (Selaginellaceae & Lycopodiaceae), Psilophyta (*Psilotum*), Bryophyta (mosses) & Hepatophyta (liverworts or *Marchantia*)

1. Your family received a plant as a gift. They sent you a piece of the plant by mail because they want to know what type of plant it is. They think that the plant must be sick or have bugs because it has brown spots. Observe & dissect the material provided. What phylum (& sub-group if applicable) is it from? How can you tell (be specific, give one feature in your sample that identifies the plant group)? Draw diagrams in the space below describing the brown spots and explain in detail what they are. (9 marks, 2 for phylum & identifying feature, 5 labels on diagram(s) and diagram(s) = 2 marks)

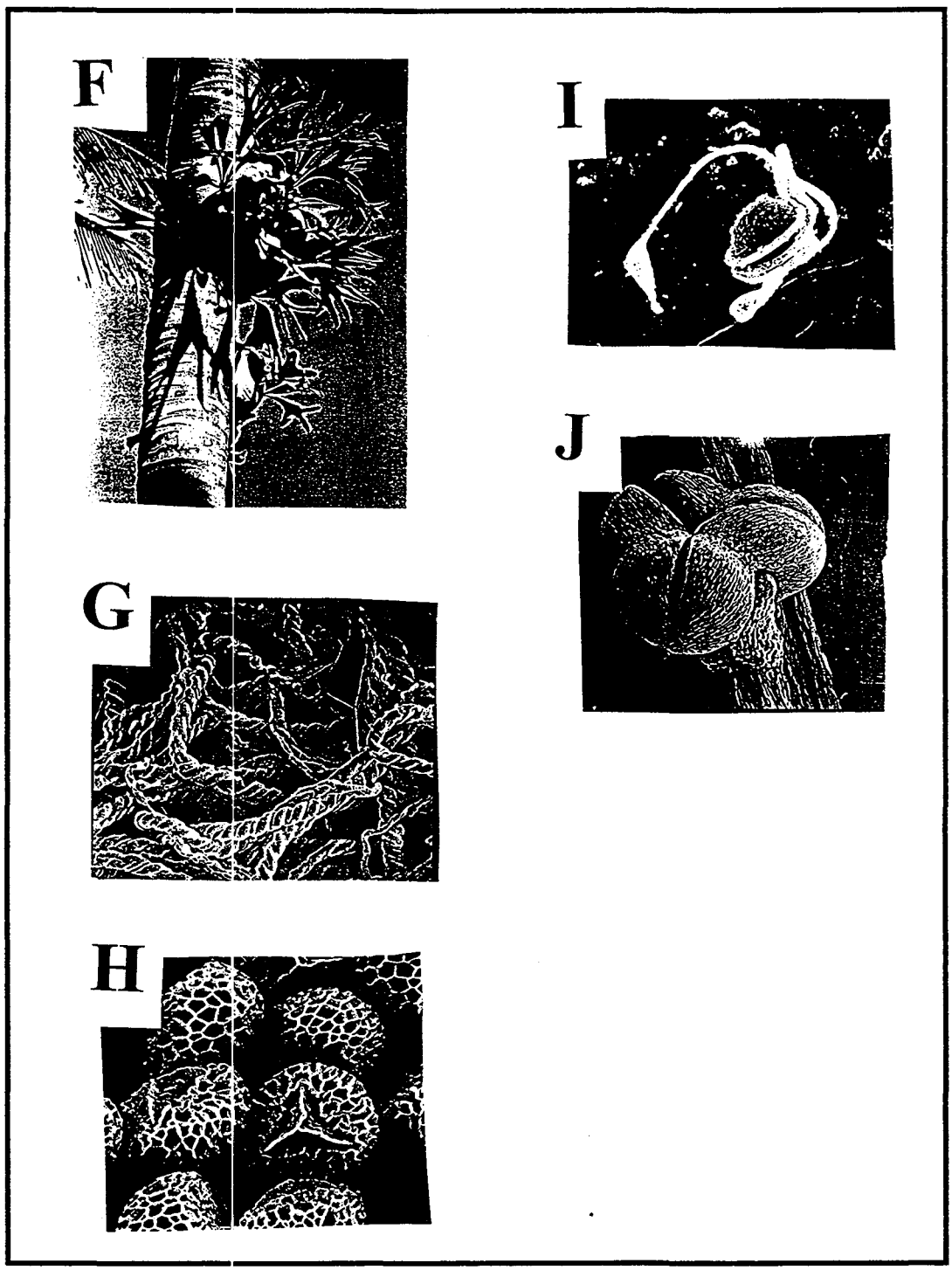
2. Match up the following terms with the images on the handout and name the phylum/phyla (& sub-group if applicable) of each image selected: (Note: Some terms apply to more than one image and phylum) **Phylum must be given in full, short forms or common names will be given part marks.**

TERMS	IMAGE(S)	PHYLUM/PHYLA (plus sub-group if applicable)
Epiphytic fern (plant group not required)		
Trabeculae		
Elaters		
Circinate vernation		
Sporangia in 3's		
Triradiate ridge		
Peristome teeth		
Megasporangia & Microsporangia		
Archegoniophore		

Images A - E for question 2:



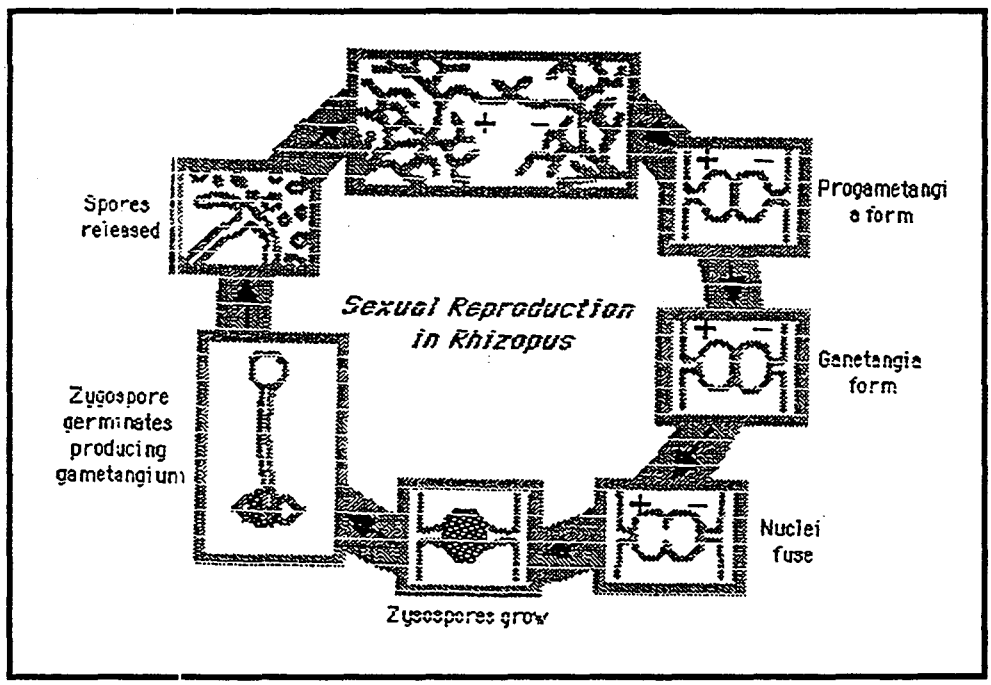
Images F - J for question 2:



G. The Fungi Practical #7

Phyla Basidiomycota, Zygomycota, Ascomycota plus the Deuteromycetes (Imperfect Fungi) and Symbiotic Relationships Involving Fungi (Ectomycorrhizae, Endomycorrhize and Lichens).

1. An error was made in the labeling of this diagram. Identify the error and say how you would correct it. (4 marks).

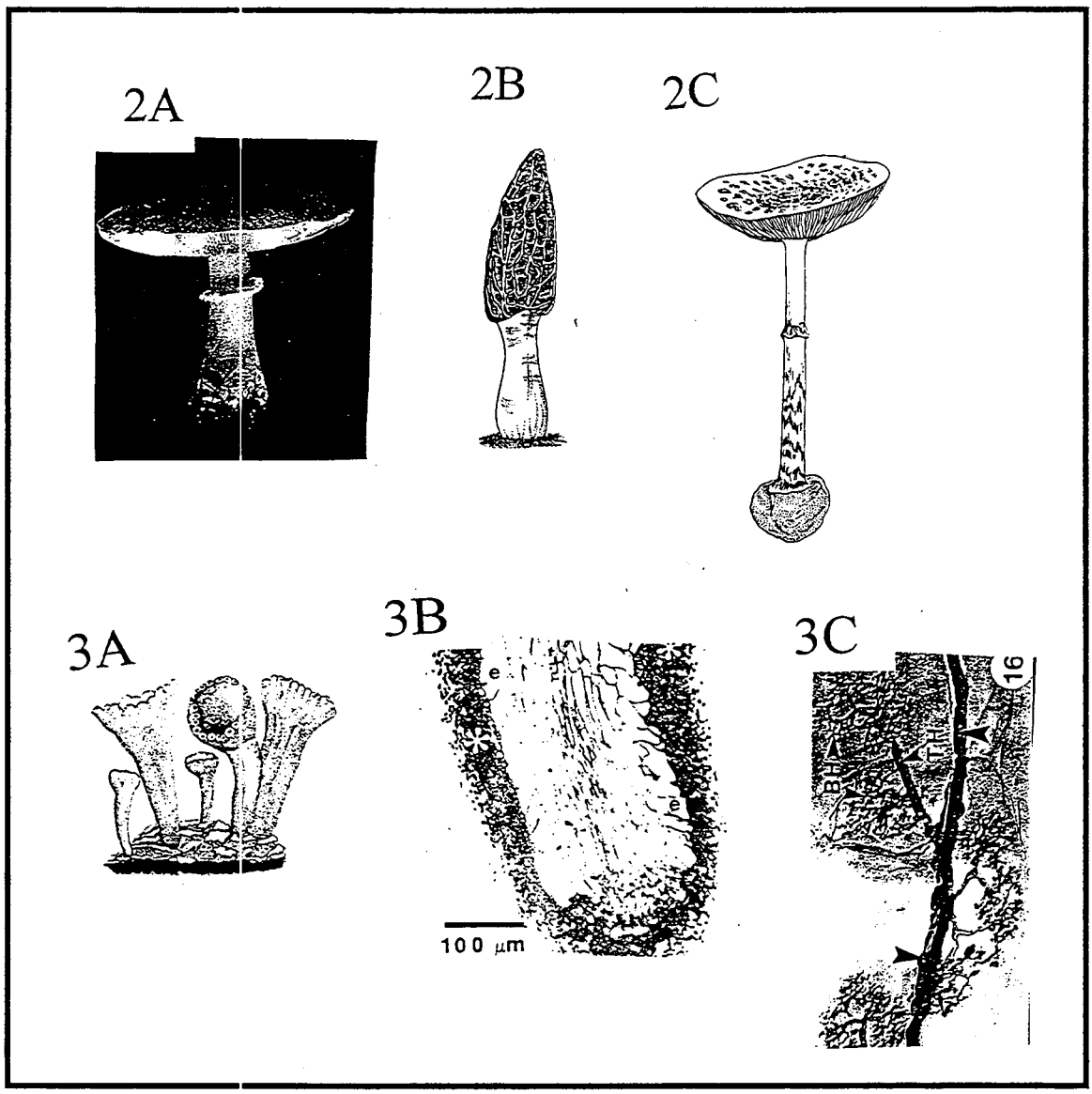


2. You have been out collecting mushrooms and have collected specimens similar to images A, B & C. Which are safe to eat and which are poisonous? Indicate what feature of each tells you that it is safe to eat or poisonous. Also indicate what phylum or group each image is from. (9 marks)

3. Which type of fungal symbiotic relationship is represented in images A, B, C? In each case, name the other partner in the symbiotic relationship? (6 marks)

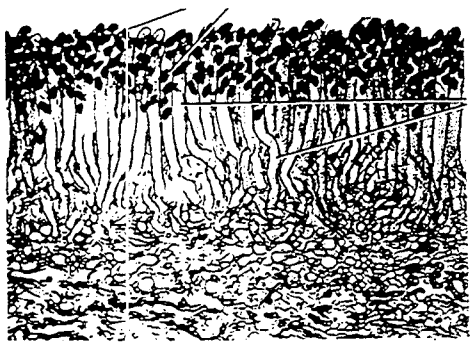
4. For each image, indicate whether the image depicts sexual or asexual reproduction. Name the type of spores being produced in each image. (6 marks)

Images for questions 2 and 3:



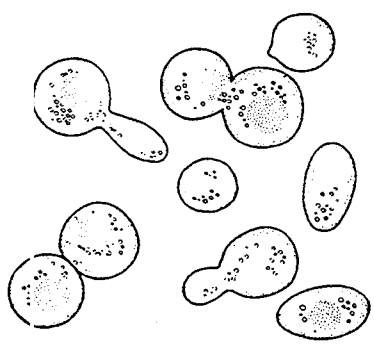
Images for question 4:

4A



4B

4C



Appendix D

Student Survey, March 1999

A. Covering Letter:

Dear 2D03 student

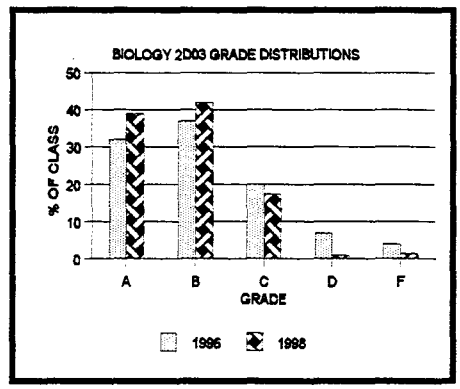
Last fall, several innovations were made in the 2D03 curriculum. We would like to get additional student feedback regarding these changes. While the course evaluations you completed are helpful, they were filled out before the lab exam and final exam were written and do not give us a complete picture of student feedback. We would appreciate it if you could take a few minutes to respond to this questionnaire. Your comments will help us to make future improvements in 2D03. The identity of respondents will be kept confidential but comments regarding the curriculum may be used in writing reports and educational articles. You may respond to this survey either by e-mail or you may slip your completed survey under the door of Mrs. Leech's office (LS 332). Please remember to remain anonymous and do not put your name or ID number on the questionnaire. Any responses made by e-mail will have the identity of the sender removed before the response is put into the 2D03 files and the e-mail message will be deleted.

Background information to this survey:

Prior to 1998, the 2D03 term mark was based on weekly quizzes (16%), slides & dissections (4%), and two lab exams (45%). Common comments made by students were:

a. Weekly quizzes required too much memorization and were worth very little
b. Lab exams were too stressful and should be worth less of the final grade.

In response to these comments, in 1998 the weekly quizzes and one lab exam were replaced by the mini lab practicals (which comprised 35% of the final grade). One lab exam (worth 20%) at the end of the term was retained to ensure motivation of students to attend labs throughout the term. Generally, the grades on the mini lab practicals was high (average 77%) and as a consequence, term and final marks under the new system were higher than under the old. The graph to the right compares mark distribution between the 1996 and 1998 assessment systems. While there is some variation in grade distributions from year to year, 1996 (the last year Dr. Lott taught 2D03) was typical for 2D03 so it is the year used for comparison to 1998.



Now that you know the course statistics and have experienced a lab exam and the final exam, we would like your comments regarding assessment in 2D03.

Thank you for your cooperation and comments,
T. Leech & J.N.A. Lott

B. **2D03 Student Survey Questions:**

Testing procedures used in 2D03:

1. Which type of test do you think best tested your knowledge in 2D03?
    a. Mini lab practicals
    b. Lab exam
    c. Final exam
    d. All types of tests combined
    e. None of the above

2. Do you think that the testing procedures used in 2D03 relied solely on rote memorization or did you have to think about what you know and apply it to the questions asked in the test? Please comment on each type of test:
    a. Mini lab practicals
    b. Lab exam
    c. Final exam

3. Course statistics show a direct correlation exists between the lab and final exam grades. Do you think that the mini lab practicals helped to prepare you for other types of tests used in 2D03 (circle all that apply):
    a. Lab exam
    b. Final exam
    c. Both types of tests
    d. None

4. Do you have any other comment regarding the type of tests used in 2D03?
    a. Mini lab practicals:
    b. Lab Exam:
    c. Final Exam:
5. Do you have any comments regarding the testing procedures used in 2D03 with other types of assessment used in any other university courses you have taken?

7. Would you recommend that in Biology 2D03 we:
    a. Keep the testing procedure used in 1998?
    b. Go back to the old system with two major lab exams worth 45%
    c. Find another method of assessment for 2D03 (suggestions)?

Other innovations in 2D03

1. Tapes of classical music with natural sounds were played during the 2D03 labs in order to set a relaxing, natural atmosphere. Did you like the use of music with nature sounds in the labs? Should we continue with playing music during the labs? Any comments about the use of music in lab classes:

2. Essay on the personal importance of plants. Marks for the essays were uniformly high (90%).
    A. Did the essay make the 2D03 curriculum seem more relevant to you?
    B. Weighting of the essay. The essay was worth 5% of the final grade. Circle the appropriate response:
        a. 5% is about right
        b. It should be worth more (suggest a number)
        c. It should be worth less (suggest a number)
        d. It should be eliminated.
    C. Any comments or suggestions regarding the essay:

A short report on the findings of this survey will be made available for participants in this survey. If you would like a copy of this report please add your name and e-mail or surface mail address here and it will be sent out to you when available (probably this April):

C. Ethical Approval of Survey:

McMaster University
Hamilton, Ontario, Canada

President's Committee on Ethical
Considerations in Human Experimentation

To: J. N. A. Lott + T. G. Leech

Re:

Title: Using multiple intelligence theory to revise laboratory curriculum and to develop more authentic assessment procedures.

The above named applicant has submitted an application to the Committee on Ethics of Research on Human Subjects.

The Committee has reviewed this request and finds that it meets our criteria of acceptability on ethical grounds. The review has been conducted with a view toward insuring that the rights and privacy of the research participant have been adequately protected; that the risks of the investigation do not outweigh the anticipated gain; and, that informed consent will be appropriately obtained.

We concur in all necessary endorsements of the application.

Cindy Riach
Cindy Riach (Chair)

Date: March 25, 1999

For the President's Committee on Ethical Considerations in Human Experimentation:

C. Riach, Associate Professor, Kinesiology (Chair)
C.K. Bart, Associate Professor, Business
E. Boetzkes, Assistant Professor, Philosophy
R. Brown, Associate Professor, Social Work
M. Cooper, Professor, Anthropology
P.T. Kroeker, Associate Professor, Religious Studies
C. Lafreniere, Legal Consultant, Martin & Martin, Hamilton
C. Rosenthal, Professor, Gerontology/Sociology
J. Synge, Associate Professor, Sociology
M. Tamopolsky, Assistant Professor, Kinesiology
C. Wood, Ecumenical Chaplain
L. York, Professor, English