DESIGN OF A HYPERMEDIA TUTORIAL PROGRAM FOR UNIVERSITY BIOLOGY STUDENTS

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Abstract

Students enrolled in biology programs often encounter problems and concepts that require an understanding of fundamental physical components and systems. Specifically students studying electrophysiology on a cellular or an animal level require a solid foundation in the physics of basic electricity. Although many students have studied some electricity, for most it was in high school and may have been several years prior to their electrophysiology course. Several commercial software packages were reviewed and found inadequate before embarking on the design of a needs centered tutorial program. This project presents the results of an interactive 'hypertutorial' system that was designed to meet the needs of the students in undergraduate cell and animal physiology courses. General characteristics of the tutorial system include the following:

- It is designed to be used as a stand alone tutorial without connection to any specific textbook.
- It is always accessed from four 'root' cards that allow students to directly go to the material that they wish.
- Its learning path allows sequential access with gradual exposure to more complex information and concepts.
- Quizzes allow students to assess their mastery of the material in each module.

As part of the formative evaluation process, a group of nine students in third year pharmacology worked through the tutorial

and provided feedback on several aspects of the program, and their attitudes toward computer assisted learning. This feedback indicated that the students enjoyed the format of the tutorial system, and they view it as a useful and valuable tool to enhance their learning of electrophysiology.

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Introduction

When properly employed the computer can be an in depth resource, far more flexible than any book, video, or other programmed based instructional material (Dori et al, 1990). Glass (1978) defined a process for statistically integrating the findings of a set of studies and labeled it meta analysis (analysis of analyses). A meta-analysis of 54 studies of computer aided instruction (CAI) versus traditional teaching in post secondary classrooms revealed higher student examination scores by approximately 3% favoring CAI and with effect sizes that are small but statistically significant (Kulik et al. 1980; Kulik et al.,1986).

Before undertaking the design of this project several commercial software offerings were reviewed including "Omegaware" and the tutorial series produced by Intellimation. For the most part these products were designed to teach students isolated topics in electrophysiology. The main shortcomings of these products included the following:

- Very little student interaction was required, most were simply electronic textbooks with little or no interactive feedback or testing facilities.
- They could not be expanded upon or easily linked to other tutorial programs.

- They provided very little or no instructional management tools.

Merrill et al.(1990) has categorized this type of software as 'First Generation Instructional Design". This type of courseware focuses on knowledge and skill components in isolation and not on the integrated wholes that are necessary for the understanding of complex dynamic phenomena. First generation CAI software often fails to address important issues in cognitive psychology that impact how useful a program is for learning. These issues include spaced practice, capacity of short term memory and representation forms of information in memory (Salisbury, 1990). With these issues in mind an interactive CAI system was designed.

Leonard (1989) reported significantly more positive experiences from university biology students using an interactive CAI system over conventional laboratory exercises on several measures. These measures included;

1. efficiency of time spent on activity
2. level of attention to lesson
3. effect in understanding results of the experiment
4. general satisfaction with what was learned

Soloman and Gardner (1986) recommend that research on instructional technology concentrate on holistic comparative studies that generate specific hypotheses rather than be

subjected to rigorous experimental design. They suggest that attention as to how the technology is actually used by learners is more important than what the technology can initiate the learner to do (Soloman, 1986). By using the tutorial students can attain a comprehensive and cohesive review of electrophysiology. One of the goals of this project was to construct a useful program that students would view as a useful tool to supplement lecture and lab material.

Rivers et al. (1987) state that an advantage of the simulated lab over a traditional lab is that students can manipulate data in a controlled setting. Inquiry lab experiments often produce data tainted with uncontrolled variables or measurement errors. This makes it very difficult for students to establish clear relationships or testable hypotheses. A simulated lab experience for some topics can serve as a useful adjunct to real lab work. Students can also manipulate data they themselves create. This may make students more active and effective in solving a particular problem, as compared with textbook data that then asks the students for an explanation (Rivers et al. 1987).

The instructional intent of this project was not to supplant any 'hands on' laboratory activity, but to provide a complement wherever possible. In attempting to complement student learning, computer aided instruction is more explicit than other forms of teaching with respect to sharing the teaching objectives

with the student. Its target is 100% mastery (Godfrey et al. 1982). Multimedia technologies have great potential to empower learners' mastery of higher order thinking skills (Dede,1992). Merrill (1990) outlines how first generation instructional design is moving to a second generation where more attention is given to structure in addition to performance and content. Jaspers (1991) sees the learner becoming "...more and more emancipated from the control of the school, the teacher, or the instructional designer". This leaves the student to interact independently with the instructional material.

Merrill et al. (1990) describe interactive instruction as a series of 'transactions' between the student and the instructional system. They characterize a transaction as dynamic, mutual real time exchange of information between the instructional system and the student.

Brand (1987) quoting Lippman at M.I.T. gives five characteristics for interactivity: interruptibility, graceful degradation, limited look ahead, no default, and impression of infinite database. This is probably an ultimate goal of any interactive system, that is to mimic a real time dialogue with a subject matter expert. Jaspers (1991) identifies three levels of interaction capacity relating to media:

- Linear media in which an ongoing flow of information reaches the learner; her activity is covert.

- Feedback media in which in addition to expository information, questions and assignments reach the student; the medium also responds to the learner's reactions with feedback.
- Adaptive media is dependent on the reactions and performance of the student, the medium determines the objective, the route, and the difficulty level.

Okey (1985) believes that CAI should be interactive, should promote student involvement in the science learning process, and should be built around specific examples, and should include both practice and feedback. Content is all too often treated as isolated facts and discrete skills to be learned rather than as knowledge, skills and attitudes to be used (Reeves,1992). Coyle (1988) indicates that a shift is needed from a model of drill and practice to a variety of other models that emphasize information processing, model building, and problem solving. This is true for students of electrophysiology where broad conceptual knowledge must be used in conjunction with skills in numerical and graphical analysis. It also involves integrating knowledge from physical chemistry, biochemistry, and fundamental physics. The inclusion of numeric examples with realistic numerical values was paramount in the design of exercises and simulations.
This computer-assisted learning project attempts to incorporate the aforementioned concepts to create a truly interactive tutorial session. Relevant findings from cognitive science were used to guide all aspects of the design process.

Chapter 2 Hypermedia

2.1 HyperText, and Hypermedia

In order to clarify three relatively new terms in computer education, we will define hypertext, hypermedia, and hypercard. Hypertext is non-linear or dynamic text that allows the user to immediately access to any portion of the knowledge base (Nelson,1978). Hypermedia connotes a hypertext document that interconnects graphics, digitized speech, music or video segments, linked together in an associative nonlinear way (Boone et al. 1991). The mixture of different media creates a "fluid" environment requiring learners to constantly make decisions and evaluate progress, thus forcing students to apply higher order thinking skills (Marchionini,1988).

The superlatives abound in the literature, Bevilacqua (1989) compares hypermedia to the invention of alphabetical order or Plato's dialectical argument as an organizing principle of knowledge combining text, graphics and sound. McCarthy (1989) suggests that the most important characteristic of hypermedia is its ability to encourage students to be proactive learners and that it is "a tool that ....immediately gratifies intellectual curiosity". This may be true for an ideal system, but practical hypermedia that lives up to the hyperbole is not widely available. Slatin (1991:56) offers the most comprehensive definition "A hypertext

(or hyperdocument) is an assemblage of texts, images and sounds - nodes connected by electronic links so as to form a system whose existence is contingent upon the computer".

From the perspective of learning theory, hypertext should improve learning because it focuses attention on the relationships between ideas rather than isolated facts (Kearsley,1988). It seems reasonable to assume that a high degree of interactivity in a well designed hypertext system will be absorbing in much the same way that a computer game is engaging. One of the challenges in designing the structure of the database is to attempt to match the myriad of ways that a user might want to access the material.

The user can select from a hypertext based on any of the several criteria outlined by Jonassen (1988). These are;

- personal relevance to the reader
- interest level of the reader
- curiosity fulfillment of the information
- experience level of the reader
- the information needs of the user
- task demands causing the reader to access the text.

Of these criteria, the task demands of the material were anticipated to be the most frequent reason for using hypertext. The tutorial material was constructed using the appropriate technical vocabulary. Students can access the concepts behind

the 'jargon' as frequently as they require by clicking on **boldface** words. This concept is illustrated in figure 1.

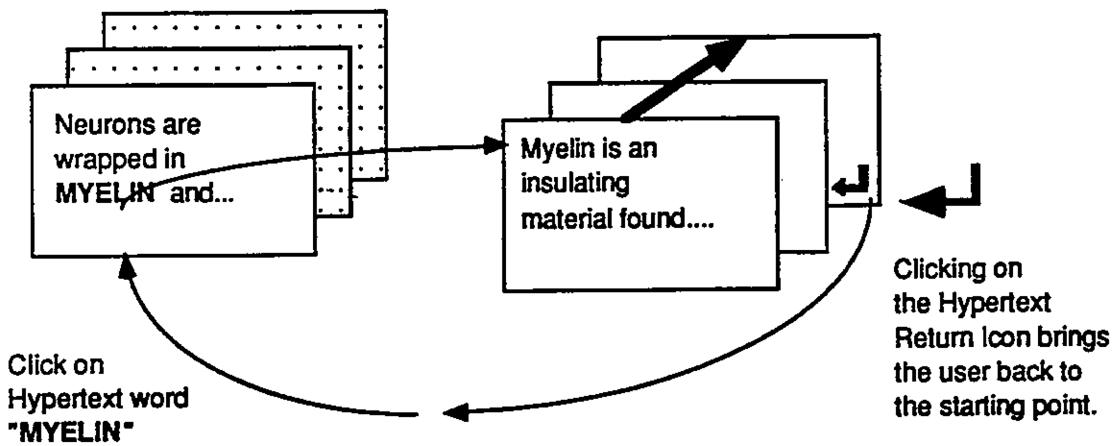

FIG.1 Hypertext Concept

Hypercard is a software product developed by Apple Computer, it is an operating system and authoring system for hypermedia (Atkinson,1987). It has been termed a "software erector set" and contains: (a) a development language called Hypertalk; (b) a set of tools for editing graphics and text; and (c) the means for creating and saving stand alone programs. In a Hypercard environment, a program is called a 'stack'. The card is the basic unit of organization in a stack, and is analogous to a single screen's worth of information (Bowers, et al.,1990).

In Hypercard every hyperdocument creates a stack, a linear pile of cards with the first card on top and the last card on the bottom. The Hypertalk language is unlike conventional programming languages such as Pascal or Basic, as it is not based on the principle of strict linear execution of the lines in a program but instead is more 'object' oriented. It operates on the concept of objects such as fields, buttons, cards, stacks, and backgrounds passing messages between themselves. In this application the user is totally unaware that the document shown on the screen is made up of many interlinked structures. As a result a student can clearly visualize an entire concept without being required to bring together disjointed pieces of information. This holistic aspect helps facilitate the learning process.

2.2 Development Platform

The reasons for choosing Apple's Hypercard system were dictated primarily by the availability of Macintosh computers within the biology department. Hypercard is not specifically designed to be a CAI authoring system, but it does possess the attributes necessary to be used as such. The features that make Hypercard amenable to CAI applications include the following:

1. It is relatively easy to specify linkage mechanisms between 'cards' of information and 'stacks' of information.

2. It is very easy to switch between author and user modes in order to test new ideas.
3. Capability to import existing text and graphic files.
4. A wide range of editing features are available. These include copying, moving, deletion and insertion commands.
5. A wide variety of graphic tools are available. These tools can be used for painting, and drawing purposes.
6. A wide variety of logical operators can be used to pass messages between buttons, cards, fields and stacks.

Several commercial CAI authoring packages exist, but the limited degree of flexibility and variety precluded their use in this particular project. Programs such as "Super Socrates" allow the author to select from several screen display 'templates' as well as from a limited pool of feedback responses to present to the student. These programs are best suited to drill and practice testing of material that has limited scope and complexity. They represent a group of rather primitive CAI products that under utilize the power of the computer by using it as a simple set of electronic flashcards. The one benefit they do offer however is a very short design and production cycle.

Chapter 3 Pedagogical Rationale for Using Computer-Assisted Instruction

3.1 Learning with Hypermedia

Hypermedia, being nonlinear and associative, mirrors the structure of human long term memory, lessening a learner's need to map from how computers represent data to how people store information (Dede,1992). Hypermedia simulates the human mind by organizing information by association (Phillipo,1991). The associative nature of hypermedia facilitates capturing and communicating knowledge, as opposed to fragmented data, allowing users to view their own mental models as visual webs of nodes and links (Dede,1992). Devlin et al.(1991) suggest that hypermedia materials offer an intuitive approach to learning in which the ability to link associated text and graphics matches the brain's natural tendency to think associatively. This idea of organization by association is emphasized by organizing closely related topics in the same pictorial or global map of the contents of the project. Dede et al.(1991) state that the capability of hypermedia to reveal and conceal the complexity of its content lessens the cognitive load of learners, and thereby enhances their ability to manipulate and assimilate ideas. A hypermedia

system besides helping the learner to 'dig' information out of a database, should help refine and create knowledge. As well it should have the qualities of coach, tutor and colleague, encouraging the learner to question, conjecture, create and experiment (Weyer,1988). Learners should not have to worry about 'where' they are in a hypermedia system, navigating around should be intuitive and easy.

In 'linear' media, reading, listening and viewing can be passive, whereas web hypermedia structures demand the learner make frequent choices regarding material and navigation. Hypermedia has the potential to develop more learner metacognition than linear media, since the learners must continually assess their current state of knowledge and ask themselves 'what do I need to find out about in order to understand concept x ?'.

The hypertext users are not totally constrained by the subject matter structure, nor by the author's organizational structure (Jonassen 1988). The premise is that an individual's knowledge structure is unique, being based upon that individual's own set of experiences and abilities. It then follows that the ways that an individual prefers to access and interrelate information is also distinct (Jonassen, 1988). Hypertext attempts to accommodate the material to the user instead of the other way around. A well designed hypertext system will encourage users to explore information, and organize it in ways that make sense to the

individual. A 'guided tour' of the material can also be set up in which the material is presented in a sequence that the hypertext author feels is the best approach to make the information meaningful. One of several 'guided tours' can be recommended to the learners based on a broad category of knowledge which they may want to explore. The effectiveness of hypertext rests on it being a node link system based on semantic structures and the fact that it can map directly the structure of knowledge it is presenting (Jonassen, 1988). Thus the students can navigate with ease through the program stopping to study concepts which they wish to focus on. In this way the learners have an active role in choosing material pertinent to their needs.

Most contemporary learning theories describe the learner as an active agent of knowledge acquisition (Paul,1992; Bandura,1977,Zimmerman,1989). Exploratory or discovery learning is an instructional approach that falls within this definition. This process encourages learners to acquire and formulate their skills in scientific discovery, problem solving, inductive and deductive reasoning in an active way. The benefits of exploratory learning are twofold: firstly it can encourage meaningful incorporation of the material into the learner's cognitive structure, and secondly, the exploratory process itself is seen as an important skill (Njoo et al., 1993). Computer simulations are appropriate for exploratory learning because they can hide a physical model that has to be uncovered or 'discovered' by the

learner (Woerner et al. 1988). The technique of progressive disclosure can be helpful in learning what is relevant because it produces a greater degree of control over the effective stimulus (Johnson et al.,1993). This concept of progressive disclosure was used in several simulations to gradually increase the model's complexity as students progressed through the material.

Learners may use a tutorial system to achieve several different but overlapping goals (Weyer,1988). These goals are outlined below as they apply to this project:

Learner's Goal	System's Interpretation
Tell me......	Give me the facts, no embellishments. The learner can go directly to the answer for a specific question, or directly to a topic they want.
Inform me..........	Give me the facts plus optional background and other points of view. This involves the learner surveying the overview of a module to gain more context.

Amuse me...........	Find me interesting connections or perspectives. This can involve simply browsing the hyperlinks between documents.
Challenge me.....	Make me find or create creative connections. Posing comparative questions such as "How does Ohm's Law help explain membrane conductance?" forces the learner to examine their understanding of both topics and to draw the requisite interconnections.
Guide me...	Let me browse, but give me over the shoulder advice.
Teach me..	Give me more step by step guidance, fewer irrelevant links. This would involve a

sequential prescribed tour through the material. Any hyperlinks would always return the learner to the sequential presentation.

A learner's goals are often fluid, changing in the context of the material they find themselves. The structure of this project accommodates all six goals of learners. Interactive multimedia can be designed as a focal event or problem situation that serves as an 'anchor' or focus for learners' efforts to retrieve and construct knowledge (Reeves,1992).

This type of learning has been called 'situated learning' and 'anchored instruction' because the process of constructing new knowledge relationships is situated in meaningful and relevant contexts (Collins et al., 1989). McLellan,(1991) terms it a highly realistic or "virtual" surrogate for the actual work environment.

Learning is heavily dependent on what students already know and Resnick(1989) suggests that interactive multimedia should be designed to provide 'cognitive bootstrapping' for the construction of knowledge and the development of intellectual skills. Some of these 'bootstrapping' activities have been incorporated into this project, these include providing students with multiple perspectives of a phenomena, allowing students to

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construct [illegible]

This [illegible] as [illegible]

[illegible] situated [illegible]

[illegible] 1960 [illegible]

[illegible]

Know [illegible] 1961 [illegible]

should be [illegible]

[illegible] and in their [illegible]

[illegible]

into [illegible]

were [illegible] a place [illegible]

resolve discrepant events and providing help with perceptual discrimination of complex processes.

Morariu (1988) points out that basically designers have to know 'how' students think in order to set up links which favour flexible and intuitive navigation within the hypercourse environment. This has been accomplished by breaking down complex feedback loops into frame by frame expositories and allowing students to control the pace of presentation and repeat them as often as they desire. The goal of many of the fundamental tutorials is to assist students in resolving discrepancies and to help them construct new knowledge on the re-configured foundation of what they presumed they already 'knew'. Examples of this 're-engineering' of fundamental concepts include tutorials that engage students in examining the meaning of voltage, current, and conductance. These are followed by simulations that get students to apply these ideas in a specific electrophysiology context. Brown (1985) and Anderson (1983) endorse the principle that the manner in which knowledge, skills, and attitudes are initially internalized plays a very important role in the degree that these skills can be used in other contexts. The context within which most of the electrical concepts are learned in high school and introductory university physics courses are not biological in nature. Biophysics or the relationships between physics and biology has often not been made explicit to students. An understanding of the specific conceptual areas that students encounter difficulties in and an

understanding of analogies to material that bridge those gaps is essential to good instructional design.

Bransford et al.(1990) has shown that students who are adept at 'regurgitating' memorized information rarely retrieve that same information when confronted with novel conditions that warrant its application. For example Ohms Law, a basic physical law that is taught to all advanced level high school students can also be used to analyze the conductance characteristics of biological membranes. Yet a student who has merely memorized the physical equation without understanding the relationships between current, resistance and voltage that underlie the law will in all likelihood not be able to apply it to membrane physics. "Interactive multimedia can employ a case based approach wherein learners are first presented with realistic problems to be solved; and then conceptual knowledge, skills, and even attitudes are introduced as required by individual cases. This enables learners to link newly acquired knowledge in the form of active responses to simulated problems" (Reeves, 1992:50).

3.2 Cognitive Psychology and Hypermedia

Cognitive psychology approaches learning as a reorganization of knowledge structures. These knowledge structures refer to the organization of ideas in semantic memory (Jonassen,1988). Human knowledge structures are modeled as

semantic networks in which each concept/idea constitutes a node and is connected to the other concepts/ideas by means of relationships of various natures (Norman et al.,1976). Hypercourses should induce cognitive internalization since learners must deliberately select links, and follow relationships in assimilating knowledge. The organization of information and the accessibility of it to learners then becomes a prime concern to the instructional designer.

A set of entity and link types is called a 'schema' (Garzotto, 1991). The schema of an object, or idea, is in turn comprised of a set of attributes, the attributes essentially being the associations that a person forms around an idea. The schema that an individual constructs represents a miniature framework within which to interrelate the elements or attributes of information about a topic into a single conceptual unit (Norman et al. 1976). The arrangement of all the interrelated concepts in a network constitute a 'semantic network' (Jonassen, 1988). Lanza (1991) suggests that since the netlike structure of hyperknowledge resembles human knowledge, a hypercourse approach in instruction is optimal in mapping a knowledge domain into the cognitive structures of learners. It is the semantic network which represents our overall knowledge structure. The interconnections of the schemata in our semantic network enable learners to combine ideas, infer, extrapolate and otherwise reason from them (Jonassen,1988).

Njoo et al.(1993) offers a couple of reasons for the limited success of computer simulations including the idea that exploratory learning techniques are too difficult for learners and as a result they make mistakes and show inefficient and ineffective behavior. The second reason is that students although in possession of exploratory skills often do not use them. This helps to focus on the dilemma of how to encourage students to perform exploratory actions and simultaneously support them to prevent them from floundering. Njoo et al. (1992) consider learner control to be of paramount importance in exploratory learning and suggest that supportive measures should be designed to leave as much freedom to the learner as possible. Klahr and Dunbar (1988) assume that scientific reasoning requires search in a hypothesis space which is a space that represents all the possible hypotheses open to the learner. This idea of a 'completely free' learner must be tempered in the context of the instructional situation. A question of balance between complete freedom and measurable instructional outcomes is necessary. The design of simulations for this project allows students to explore relationships between variables up to the point of where a violation of fundamental physical laws is implied. This is essentially the 'experiment space' that represents the range of possible experiments that can be practically conducted with the variables. The results of the simulations are

reflected back to the student when comparisons are made with actual physiological measurements.

Pulos (1993) uses the term 'processing capacity' to describe any cognitive bottleneck that limits the amount of information a person can simultaneously coordinate during problem solving. This processing capacity includes concepts such as working memory capacity and short term storage space among others. Simulations that contain an inordinate number of variables can complicate the learning process to the point of frustrating the student. An attempt was made to limit the complexity of the simulations in this project to include just the relationships that made the simulation reasonably accurate. Learners have access to several types of 'tools' in the simulations to lessen this cognitive load on them. These tools include the ability to review the theory underlying the simulated model, as well as the ability to access a review section of fundamental formulas.

3.3 The Role of Interactivity

Since learning is an active process, we can state with some certainty that the more mentally active learners are as they process information from a CAI system, the more likely they will be to comprehend the material. Bork (1984) suggests that the quality of the interaction in a program can be assessed in terms [illegible] refected [illegible]

[illegible] same [illegible]

[illegible] any [illegible]

[illegible] person [illegible]

[illegible] the pro [illegible]

[illegible] memory [illegible]

[illegible] Mind [illegible]

[illegible] sum [illegible]

[illegible] same [illegible]

[illegible] made [illegible]

[illegible] several types [illegible] the similarities [illegible]

3.3 Th [illegible]

[illegible] active [illegible]

[illegible] certain [illegible]

[illegible] process [illegible]

[illegible] how to [illegible]

[illegible] quality [illegible]

of the type of input required of the learner during the interaction, the method of analyzing the response, and the action taken by the program after the response. Keeping the learner engaged as much as possible has been a key design principle in this project. The types of interactivity include the following;

- asking learners if they want to review key concepts
- asking learners to 'click' on terms in mathematical formulas in order to obtain definitions and explanations.
- asking learners to calculate numerical parameters to satisfy a particular criterion.
- asking them to use proportional and analogic reasoning skills in answering multiple choice and true/false questions.
- asking learners if they would like to run or repeat animations of concepts.

3.4 Learner Control

A fundamental premise of this hypertutorial systems is to relinquish most of the control regarding sequencing and pacing of the instructional lesson to the learner. As mentioned earlier this approach does not accommodate a passive learner. In this system the learner controls the rate of presentation in most areas of the system except the animation sequences, by simply paging

through by clicking on the forward or reverse arrows. Learner control has been identified as a motivating factor as well as an anxiety reducing feature by several researchers (Steinburg, 1984; Hazen,1985). Identifying exactly what the optimal degree of learner control is, is a difficult task. Hazen (1985) reasons that the degree of learner control is determined by the characteristics of the learner, the nature of the content, and the complexity of the learning task.

The same information in the tutorial system can be accessed by two main approaches or 'hypertrails'. The first is via hierarchical cognitive maps, a type of index whereby free browsing and fast random access referencing is possible. In this mode the user simply goes to the question box list or to the section overview and clicks on a question or a 'hot' word to directly access a particular chunk of information.

The second access technique is the 'lesson' mode whereby the material is pedagogically organized to satisfy the objectives in the course curriculum of cell physiology. To access this mode the user simply clicks on the stack situated in the top left hand corner of the screen and proceeds linearly through the stacks indicated on that particular index page. This is essentially a default path for learners who seek more structure. The active learner can move forward or backward, branch to any section or review and practice any weaknesses. When given a choice, students prefer learner controlled instructional materials (Kinzie

et al.,1990). The ability to control the learning environment has also been shown to facilitate several affective outcomes, including increased levels of engagement, more positive attitudes and decreased anxiety (Hanson,1974). Incorporating learner control also encourages self-regulated learning and enhances motivation (Kinzie et al.,1990). These are both cornerstones for effective self directed learning environments.

Active engagement, not passivity is vital for success in a CAI project. People learn best when they are actively engaged, not merely flipping through static cards of text or pictures. User activities in manipulating a CAI system should generally be simple at any moment, although they may be complex when taken together or in conjunction with previous actions.

3.5 VISUAL LEARNING

The extensive use of visual models along with text allows the student to immediately connect the verbal and visual information during the formation of his or her own personal representation of the concept (Kumar,1990). When translation between the visual and verbal occurs, a conceptual or categorized concept level rather than only an identification level may have been reached (Jackendorff,1987). Graphic presentation of key concepts such as charging and discharging membrane capacitances are designed to further this goal of transferring categorized

concepts. Visuals also assist in the 'chunking' of information so that categorization and quick future recognition of the concept as a whole rather than as separate pieces of information (Rumelhart et al., 1984). McNamara (1986) suggests that the combination of visual and textual information along with chunking strategies assist with the orderly storage in long term memory of representations of the concept. This storage occurs both in a hierarchical (top down) form and in an associative or lateral sense. Hypertext structure certainly supports this learning context in that representation of concepts can be moved from identification to meaning-based storage in memory (Anderson,1985). Visual information is certainly a primary route to comprehension for most people.

Chapter 4 INSTRUCTIONAL DEVELOPMENT

Morariu (1988) outlines the fundamental conceptual components that must be considered in designing a hypermedia learning environment, they are:

1. Awareness of learner characteristics, including previous knowledge, learning styles and motivation.

2. Statement of goals and objectives in behavioral terms. This includes a full breakdown of the context and the measurable outcomes for the instructional environment.

3. A pedagogical model for teaching the content.

4. Navigational ease for the learner. The user interface to the material should allow for easy navigation through the system.

5. A knowledge of the overall structural organization of the information.

It is important to apply a systematic model of instructional design to CAI courseware development to make the end product usable and effective (Suzuki,1987).

4.1 Design and Formative Evaluation

Instructional development is the process of assessing needs, learners, and learning tasks; identifying the goal; establishing performance objectives; planning sequential learning steps; choosing instructional strategies and media format; using appropriate teaching and design principles; and evaluating instructional effectiveness (Smith and Boyce,1984; Billings, 1985). Formative evaluation is the systematic collection of information for the purpose of informing decisions to design and improve the product. (Flagg,1990; Dick et al.,1985).

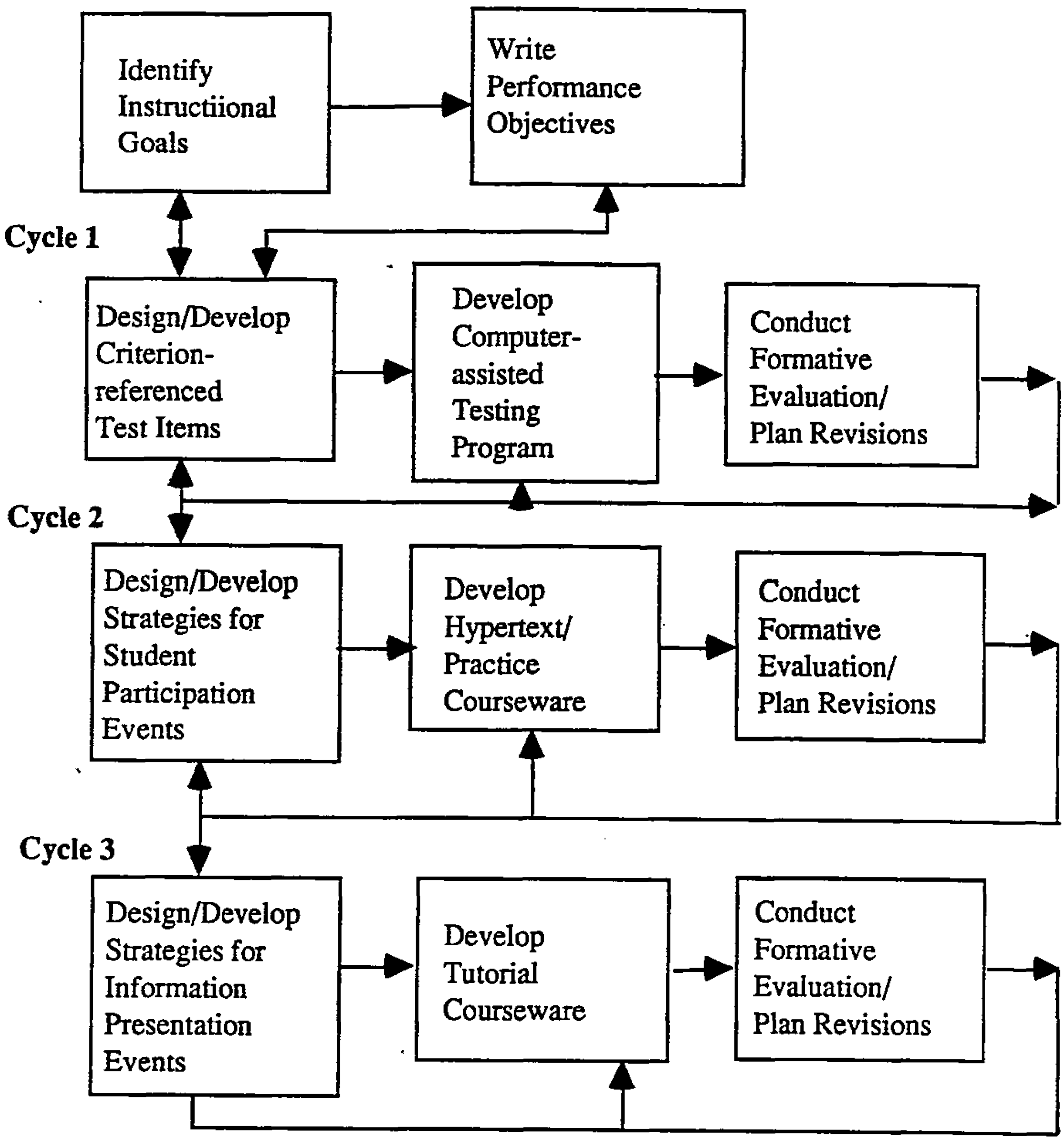
The advantages to using an instructional development approach as outlined by Patterson and Bloch (1987) and Dick et al. (1985) include;

1. Learning effectiveness is increased when instruction is planned, outcomes are derived from the learner's knowledge base, and learning is intentional.
2. Instruction is planned on curriculum needs versus those of the author or publisher.

3. Promotes the inclusion of relevant teaching-learning strategies.

One useful approach to CAI development is the short cycle approach described by Suzuki (1987). This model outlined in figure 4.1 was selected for this project since it provides a large degree of flexibility and is better suited for small scale (single person) development than the more formal models described by Bork (1984) and Barker (1991). Most commercial or institutional courseware design involves teams of content, instructional technology, and graphic design specialists. This project required flexibility and constant reflection and revision to pretest concepts and graphics with small groups of professors and students.

Fig 4.1 Short Cycle Approach to CAI Courseware Development (adapted from Suzuki, 1987)



Before beginning cycle one of figure 4.1 instructional goals and performance objectives were established. These were

developed using several strategies. Meetings were held with the professors involved in the course where specific problems students had with the course material were identified. This list served as a preliminary blueprint to focus on where remedial attention was required. Also identified at this time were several associated topics that the professors thought the students should cover but simply didn't have the class time and or the support materials to do so. Student assignments and quizzes served as an additional resource in order to gauge the depth and breadth of the material the professors wanted to cover. Part of this process involved designing an assessment form that asked students to rate using a Likert scale, the concepts that they encountered the most difficulty with. Using these tools a list of performance objectives was then constructed to delineate the breadth of this project. A completed list of performance objectives for the electrical principles section is shown below:

PERFORMANCE OBJECTIVES FOR MODULE 1 ELECTRICAL PRINCIPLES

Upon completion of this unit the learner should be able to:

1. Explain the relationship between charge, voltage and work.
2. Define the units of current, voltage, and resistance measurement.
3. Explain Ohm's Law and be able to solve for any of the variables.

4. Identify the schematic symbols for resistors, capacitors, and voltage sources.
5. Given a simple series or parallel circuit, solve for any unknown.
6. State the relationship between charge in coulombs and the number of electrons.
7. Given a current-voltage graph interpret it to determine conductance
8. Calculate the total conductance of a membrane patch, given the number and conductance of the individual channels.
9. State the relationship between the Faraday and the Coulomb.
10. State the purpose of electrical ground and identify its schematic symbol.
11. State the difference between a conductor a semiconductor and an insulator.
12. Describe the relationship between the cross-sectional area of a conductor and its resistance.
13. Explain the reason for the difference in input conductance between a large and a small cell.
14. Given the resistivity of a material, explain what parameters affect total resistance.
15. Explain qualitatively the relationship between current and electric shock.
16. Explain the current and voltage relationships for a charging and a discharging capacitor.

17. Define the term 'Time Constant' as it applies to membranes.
18. Explain why a membrane may be considered to have capacitance.
19. Explain the relationship between area, separation of plates, dielectric constant, and capacitance.
20. Explain the purpose of a dielectric.
21. State the nominal value for membrane capacitance.
22. State the relationship between stored energy, charge and voltage on a capacitor.
23. Explain the relationship between cell diameter and total cell capacitance.
24. State the significance of electric fields and channels.

The next major step in the first cycle of figure 4.1 involves developing criterion referenced test items and a computer assisted testing program. Test questions were developed from the performance objectives, and put into a format that permitted them to be used in Hypercard. A step that is not included in the short cycle approach but deemed essential for hypermedia design is the construction of schema or concept maps for the major topics in neurophysiology. By illustrating the conceptual links between the various topics these maps serve as a guide to lay out the hypertext architecture.The hypertrails in figure 4.2 allow the learner to interconnect material from the major instructional blocks. It is important to establish clearly defined inter-

relationships. Each card should be linked to other cards in meaningful sequences. Hypertext should only be used where appropriate to clarify technical terminology or interrelationships between concepts. Overuse of hypertext can lead to cognitive 'entropy' or a decay into a morass of disjointed facts.

An example of a schema map for the topic of capacitance is shown in figure 4.2 :

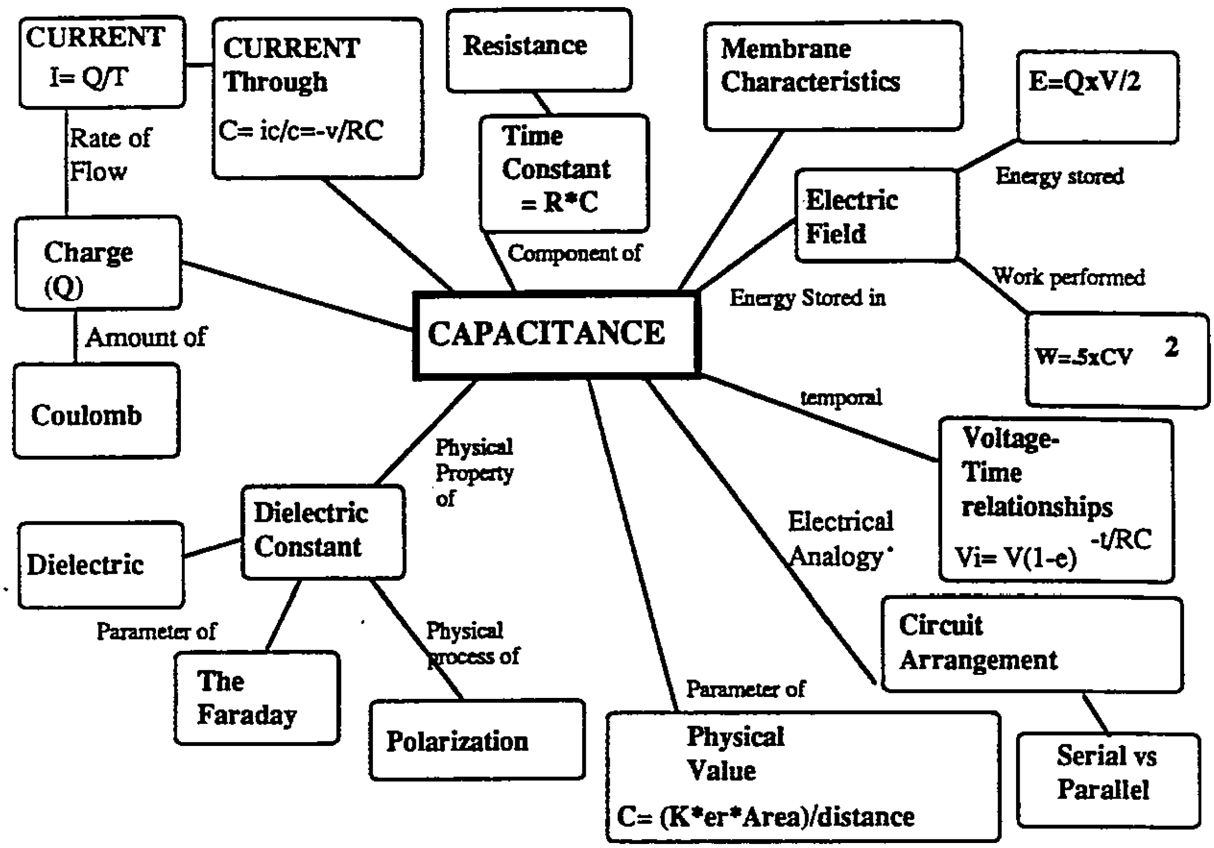


Figure 4.2 Schema Concept Map for Capacitance

The formative evaluation process in cycles one and two involved using two different evaluation checklists. The 'Educational Software Evaluation System' developed by Chang et al.(1987) and the checklist developed by Caffarella (1987). Both provided opportunities for ongoing reflection and re-evaluation of the process and content. On going meetings with the professors

involved helped refine ideas. Duby (1987) introduces the concept of "Self Formative Evaluation" as the formative evaluation of instructional materials during the process of their development, said evaluation being conducted by the users and/or developers. The advantages of this type of evaluation include: involvement and participation in the process of decision making, thus ensuring maximum suitability of the materials to fulfill their intended functions; the feedback can immediately be put into use, without the need of a mediator to communicate the information. (In 'traditional formative evaluation' the evaluator plays the mediator role). Since formative evaluation is integrated into developmental procedures from the very early phases of the program, it serves as an instant tool for improvement (Duby,1987). Patterson et al.(1987) describe formative evaluation as the process of collecting empirical data during the development of instructional materials to determine any needed revisions. It is during this phase that the hypothesis that the instructional material is an efficient and effective teaching tool, is tested (Golas,1983). Pilot testing is performed to obtain measures of validity, reliability, and instructional effectiveness (Patterson et al.,1987). Billings (1984) suggests the use of posttests to determine the instructional effectiveness, that is if the user does not obtain for example 80 percent mastery, the CAI developer should review objectives, content, test questions, and revise as necessary.

The rigid use of posttests was not used in evaluating this project since it was not designed to replace a cohesive unit of work in any one course. Since it is tutorial in nature it helps students instead focus on problem areas and helps fill in missing background material. The quiz modules however were designed to keep track of the number of correct and incorrect answers on a question by question basis.

Several evaluation tools were used in the formative evaluation of this project. They will be discussed in forthcoming chapters.

4.2 Tutorial Structure

The design of this hypertutorial system is based on components of both the 'Global' structure suggested by Cortinovis (1992) and the Hypermedia Design Model (Garzotto,1991). In both of these models the subject matter is organized as a series of instructional events or entities associated to specific course objectives. An entity can be considered to consist of a set of components that describe an object or a concept. These major instructional events are further sub divided into a set of 'micro-instructional events' that consist of a variety of instructional tools including expository text, simulations, animations, problem sets, and structured tests. The mixture of these tools in any given micro instructional event is based on the nature of the material

and the degree of difficulty students were thought to have encountered in that area. These micro events were designed to allow learners to achieve the performance objectives that were established. The micro-instructional events were designed of varying degrees of difficulty, and size, ensuring a frequent alternation between the different teaching and learning strategies. This is a sound strategy for any type of instructional design, in order to maintain learner interest and motivation. The general structure for this system is illustrated in figure 4.3 .

An effective concept attainment model for designing instruction has been suggested by Tennyson et al.(1980) and adapted for use in this program. It consists of structuring concept presentation in the following sequence: (1) A definition of the concept in terms of the concept's essential or critical attributes; (2) An expository presentation consisting of groups of divergent examples that span from easy to difficult; (3) An interrogatory practice presentation consisting of newly encountered examples.

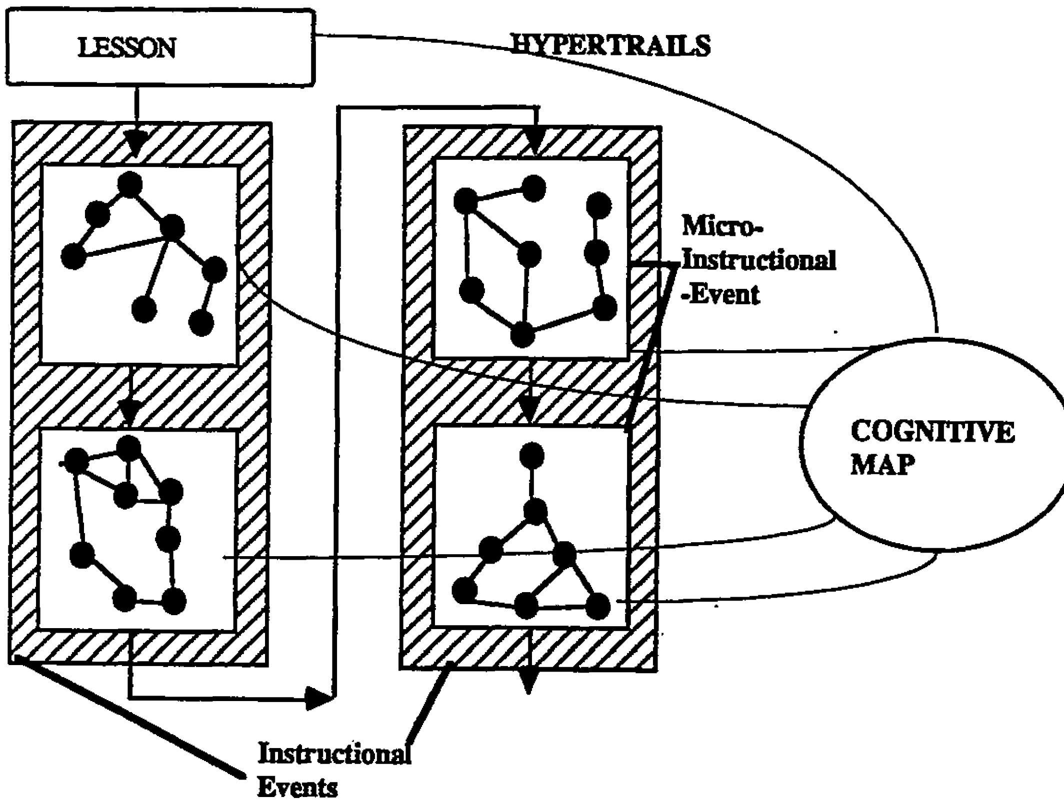


Figure 4.3 Global course structure adapted from Cortinovis (1992)

The four major instructional events that were identified are 'Fundamental Electrical Concepts', 'Membrane Channels and Signaling', 'Ionic Basis of the Action Potential', and 'The Neuron as a Conductor of Electricity'. They are illustrated in figure 4.4 . Garzotto et al.(1991) suggest that the basic appearance of similar

entities or events, as well as the structural links between the components that make up the entity, should be consistent. This should be done in order to minimize organizational confusion for the learner.

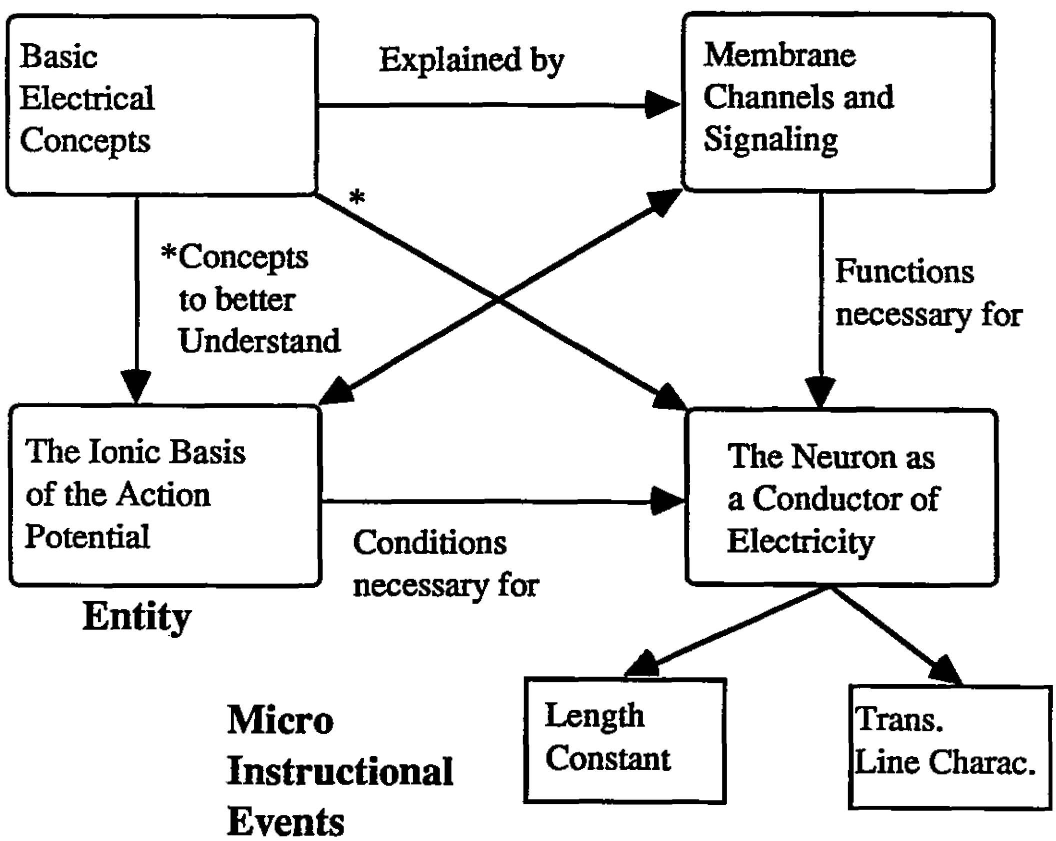


Figure 4.4 Schema of Major Instructional Events and Application Links

The 'Application Links' (Garzotto et al.,1991) in figure 4.4 reflect semantic relationships between disjoint subjects in the hyperdocument, and are used by the hypermedia author to give

learners access to information whose relevance depends on insight into the topic area, rather than the structure of the entity. Complementing the main instructional blocks are ancillary sections that provide help and performance evaluation.

The manner in which individual cards are linked to one another and to other discrete stacks form an important part of the program's internal structure. Designing the internal stack structure involved deciding whether to keep all the cards in one heterogeneous stack with several backgrounds fields, divide the project up into several homogeneous stacks, or some combination of both approaches. It was decided to design the project as multiple-linked stacks of information. This has several advantages over a single heterogeneous stack. Each stack can be dedicated to a single finite topic. This allows for easy revision and expansion and keeps the system modular in nature. It also allows the user to maintain a concept of space within the entire system (Goodman,1988). Each major concept has its own stack and this visual metaphor allows users to maintain a concept of 'space' within the system. Goodman (1988) cites this as a beneficial scheme to keep learners oriented as to where they are and where they may like to go. As well, record keeping and timing functions for instructional management are more easily implemented. The disadvantages of multiple linked stacks are: the debugging of linking structures is more complex, and the access time to information stored on any one card is longer than if the

information is contained in a single stack. This could lead to unacceptable delays in system operation. A practical reason for limiting stack size to less than 1.3 Megabytes(Mb) of information is that this is the maximum amount of disc storage for a high density drive. The total project occupies approximately 8 Mb.

Dori (1990) has identified four types of learning patterns used by students in computer tutorials:

1. Structured/systematic exploration, which involves a thorough, logical 'walk' along a sequence of cards, covering topics at a rate of 15-25 seconds per card.
2. Saw tooth exploration, involves repeating the same series of consecutive cards several times in a row.
3. Foraging, involves viewing cards in an unstructured manner; visiting many cards from various stacks at a rate of 10 seconds per card or less.

Dori (1990) also found that high achievers tend to use the first strategy, while weaker students use the second and third.

In an effort to discourage students' foraging' among different topics without real engagement, challenge questions were inserted within the learning paths to force students to engage themselves in the material before 'jumping' to a new topic. The difficulty level of the early challenge questions are lower than those found further on in a given topic area so as not to intimidate the learner. Wherever possible, critical cues are

used to focus learner attention on key aspects of the material. These clues include flashing arrows, icons, and large bold text.

4.3 Feedback Considerations

Keegan (1993) identifies the four "Kingdoms" of instructional methods that can be incorporated into a CAI system as ; Didactic, Socratic, Inquiry, and Discovery. A mixture of these four methods are interspersed throughout the project.

Of these four, the discovery and inquiry methods were selected as the dominant themes behind the design of the numerous simulations. In this method the learner generates the stimulus and the response, as in an interactive laboratory environment (Keegan,1993). Godfrey et al.(1982) list the three building blocks of Computer aided learning as: rule, example, question. A rule is any single testable element of the objective, an example is a single expression of any rule, and a question can be defined as any single query or test situation posed by the computer to the learner, which depends on the learner's mastery of a rule or set of rules in order to provide a correct answer.

A drill teaching strategy consists of any combination of rule, example and question (Godfrey et al., 1982). The learner's response is identified as either right or wrong using audio or video message feedback, but no complicated interactive diagnosis is made of the source of the learner's error. The feedback may

offer remediation like asking the learner if she wants to review a prerequisite concept. This should not be confused with active reinforcement, which could use phrases like "well done" or "great work". Overuse of reinforcement can result in it taking on a 'hollow ring', and consequently having less impact when it is truly merited.

Drills are good for helping learners memorize simple facts, but the limited amount of feedback can lead to frustration if they keep getting certain questions wrong (Godfrey et al.1982). Drills are not the best choice of strategy if the goal is to get the learner to think in imaginative ways. This strategy was used sparingly in this project.

An example of some of the feedback types used in drills is shown in figure 4.5 below;

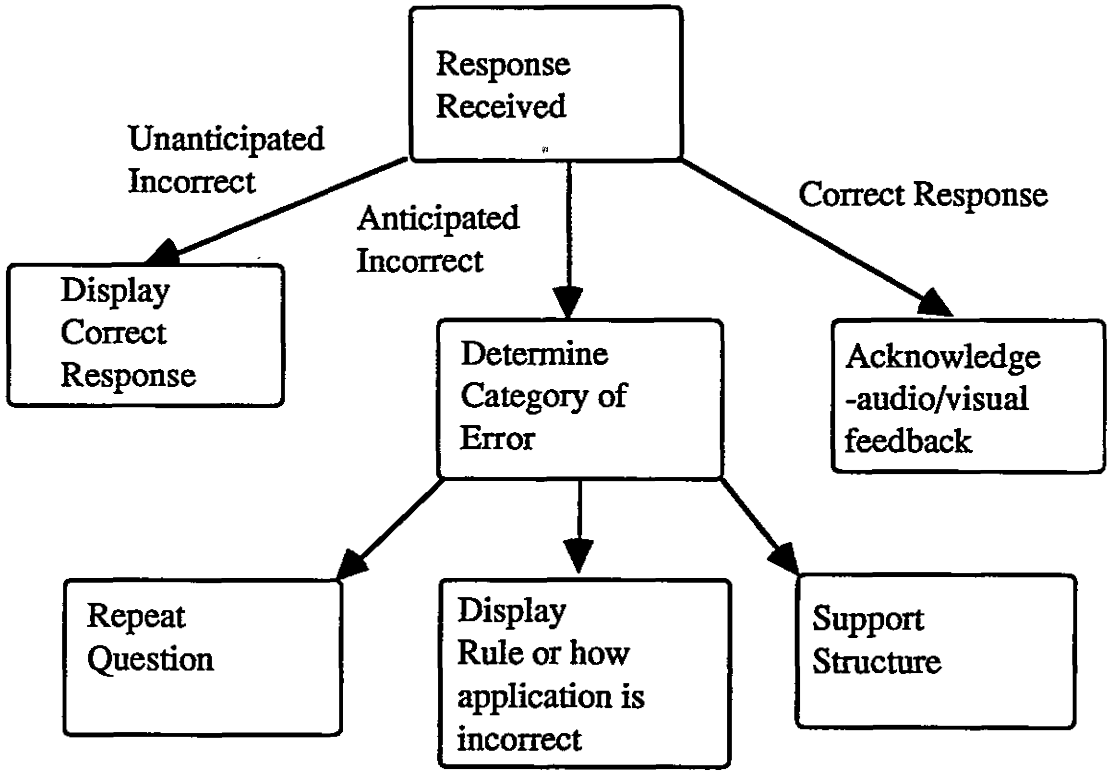


Figure 4.5 Feedback Response Variations

An example of a support structure is given below in figure 4.6, in which the student has selected the wrong answer and in the response is guided toward the correct answer.

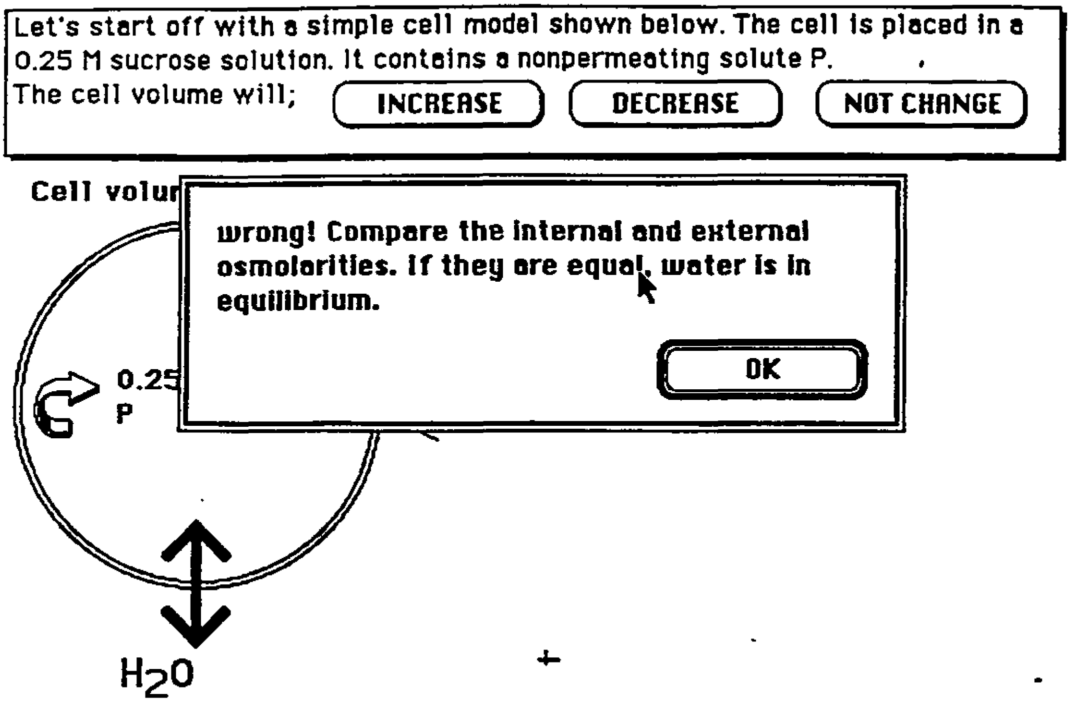


FIGURE 4.6

The question is the only building block used in the test strategy, but the difference between this and the drill strategy is that no attempt is made to give assistance or emphasis to areas of weakness (Godfrey et al.1982). This strategy is implemented with True or False, as well as Multiple Choice questions in this project. To incorporate true/false questions into a useful test strategy, rather than a simple guessing game involves using them in conjunction with other types of questions (Godfrey et al., 1982). Tests can be used to diagnose sources of consistent or continuing

errors with students. In using multiple choice questions it is important to incorporate 'distracters' or incorrect answers that are factually and grammatically possible (Godfrey et al., 1982). This tends to be the most time consuming aspect of test design.

The nature and extent of practice and feedback impact more on the quality of learning than any other factors. Jonassen(1987) states that the form of information processing performed by the learner during instruction will determine, more than anything else, the level of learning which occurs in most instructional settings. Yeany (1983) in a meta-analysis of the effects of diagnostic and remedial instruction on science learning among college and high school students found science students are capable, in the absence of prescribed remedial activities, to attend to their own remediation when provided with feedback from the diagnosis of achievement deficits. Providing only diagnostic feedback to the science student is far simpler and less demanding than following with complex remediation schedules and cycles (Yeany,1983). Even though remediation in a computer-aided instruction system is indeed possible, the time required to implement it in this particular project made it impractical.

Providing insufficient practice is a common courseware deficiency (Johnson, 1993). Practice items such as multiple choice, and fill in the blank exercises can invite mastery learning. Numerous practice questions of various types were provided to meet this end.

The literature displays little on the use of audio in courseware design. Audio can draw and hold attention, complement the visual information on the screen, minimize the amount of information that is necessary to present on the screen, and motivate the student (Aarntzen,1991).

A general conclusion of several meta-analytic studies on the use of feedback is that explanatory feedback that informs students why an answer is right or wrong is better than a simple knowledge of results (Grant et al.,1982).

4.4 Navigation in the Stack

An important factor in the usefulness of an information base is its complexity, which is directly related to the number of entities the user has to keep straight (Parunak,1991). Gay (1986) cites that completely nonsequential hypermedia are disorderly and lead to "idiosyncratic and exceptional forms of connection". Littleford (1991) describes a symptom he refers to as 'Lost in Hyperspace' that occurs when a reader of a document has been following a long chain of hypertext links and suddenly finds that he has lost his chain of thought or position in the document. This problem becomes more crucial as the size of the relational database grows, i.e. the more links and/or nodes the more probable that users will get lost. This problem also has implications with respect to integrating new information.

Jonassen (1988) warns that "The less structured the hypertext is, the less likely users are to integrate what they learned". This potential for getting 'lost' is a necessary tradeoff to provide the learner with the other advantages that a non- linear hyperdocument offers.

This also implies the need for an explicit external framework that still allows users to access information via hypertext.

This framework is illustrated in figure 4.7.

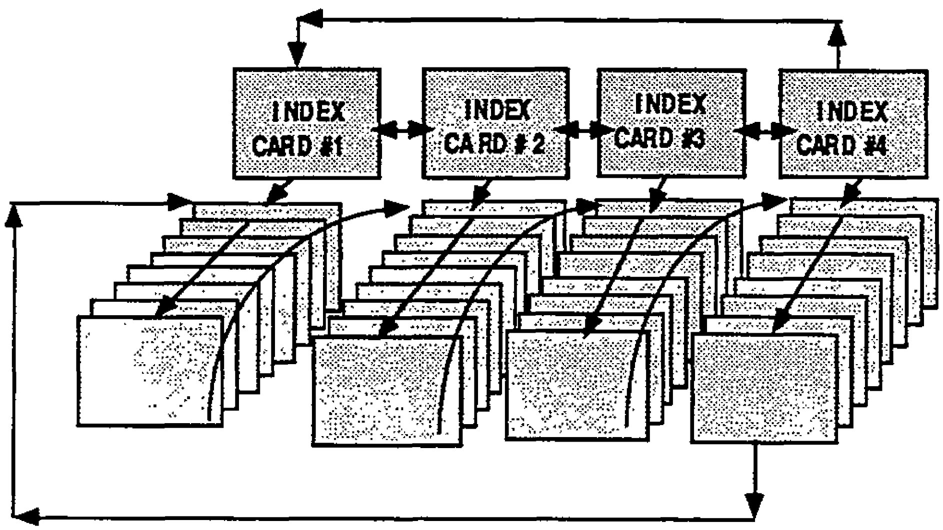


Figure 4.7 Overall Linking Structure of the HyperTutorial

Figure 4.7 illustrates the sequence through the tutorial that a learner who doesn't access hypertext would follow. Ideally the technology and the user interface should be invisible to the user. That is the learner should be able to determine what information

is contained in the hypermedia environment and use this 'cognitive map' to efficiently navigate through the material (Schneiderman,1987). Morariu (1988) suggests that in order to successfully use a hypermedia application, learners must be provided with appropriate and clear navigational tools in order to explore even the best designed systems. In order to minimize the navigation problem, several strategies have been used. Icons are visual symbols for entities (e.g. files, programs) or actions (e.g. go forward/backward, quit) (Kearsley,1988). They provide a useful visual metaphor for moving around in hypermedia. Upon using hypertext in this project the learner can simply click on the hypertext return icon until the initial starting point is reached. In the event that this bypasses the point of origination, the learner can also click on the compass icon to access the index or 'Global Map' as defined by Meyrowitz (1985). In hypermedia making the structure of the hyperbase explicit is a powerful aid in navigation (Parunak,1991). This approach allows a consistent anchor point for navigating through the stack and a 'rescue' structure for learners who become disoriented. Forward and backward arrow icons move learners through the tutorials card by card and are placed in the lower right hand corner of each card. In order to ensure the maximum internalization of the material in the tutorials, a 'notes' page icon is included on all the index cards. This allows students to record in their own words an

important concept or point. This page can be printed out as hard copy.

The 'root' document of a hypertext based system serves as an index point and a starting location for accessing the database. Kearsley (1988) and Godfrey et al.(1982) suggest several strategies for designing the root document:

1. Make the root document an overview that contains links to all major concepts in the database. (Glossary approach)

2. Adopt a hierarchical approach in which the links in the root document are major categories. (Top down approach)

3. Organize the root article as a list or table of contents of the major concepts in the database. (Menu approach)

4. Make the root document into a tour of the database. (Tutorial approach)

From a learner directed perspective, the root node establishes the principle whereby the most appropriate time for introducing a new topic is when it is needed or becomes important (Lanza,1991).

The root documents developed for this project make use of a combination of these strategies. Four index screens allow access to the entire database. the material is arranged hierarchically

with the stack icons representing the linkage points to specific topics. An example of an index screen is illustrated in figure 4.8 .

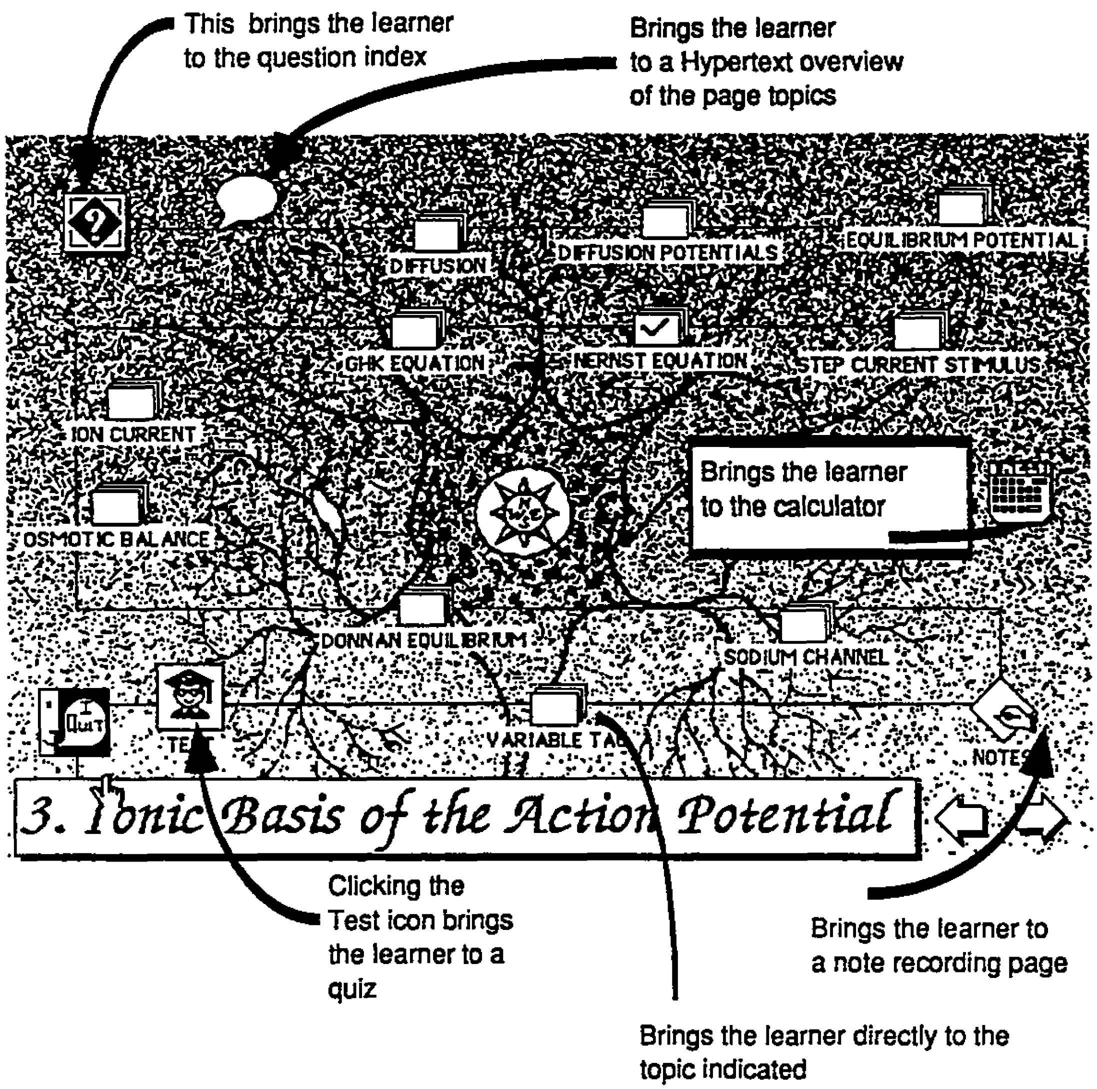


Figure 4.8 Index Card Three

Clicking on the sodium channel stack icon will take the learner on an exploration of the various attributes of the sodium channel and its associated functions .

Gay et al.(1991) suggests that if hypermedia databases are associative and contextual, the navigation should likewise be associative and contextual; interfaces should be appropriate to the database design. In order to make this tutorial as associative as possible, it incorporates a thematic cross reference system that allows the learner to roam the knowledge base in several modes. One mode involves clicking on the ? icon which brings them to a question list organized by one of the four main categories. Learners simply click on the question they want answered and they are transported to the section within which they will find their answer (figure 4.9).

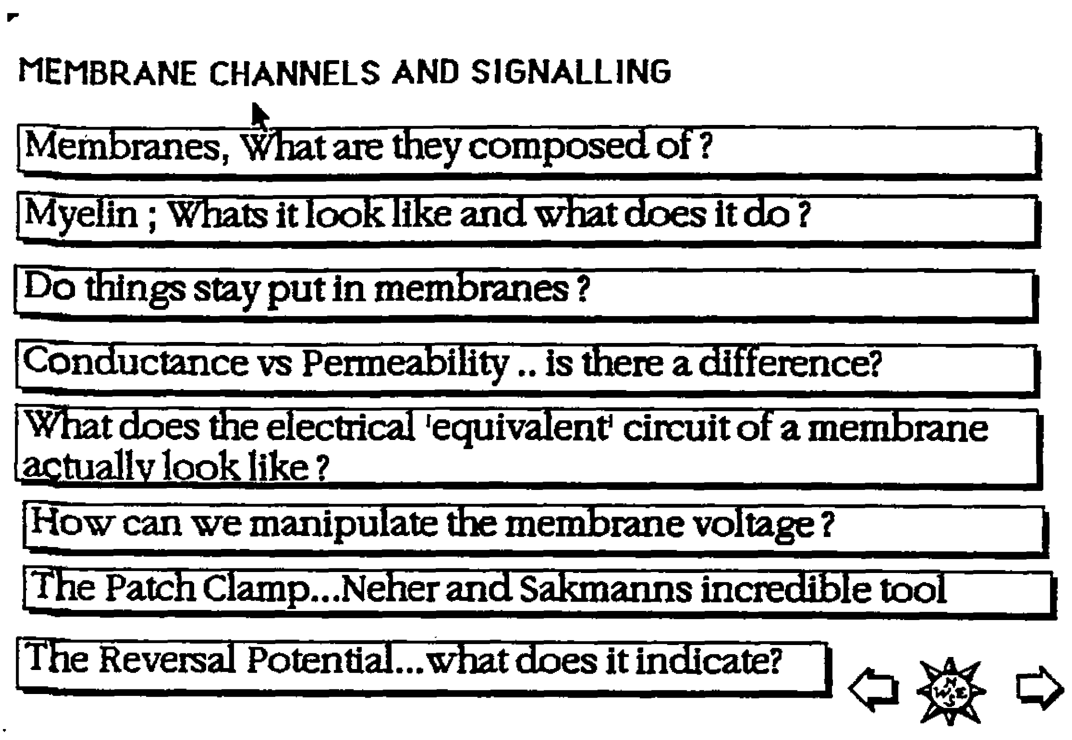


Figure 4.9 Question Mode Access

4.5 SIMULATIONS

Brant et al.(1991) identify two of the most promising roles of simulations in instruction as: 1) To establish a cognitive framework or structure to accommodate further learning in a related subject area, and 2) To provide an opportunity for reinforcing, integrating and extending previously learned material.

The benefits of simulations in improving science process skills have been documented by many researchers. They help in the following ways:

1. They activate learning (Hinze,1984).
2. Furnish situations and techniques that are dangerous, are too expensive, are otherwise unavailable, require too much or too little time to measure manually, or are frustrating due to complicated technique (Disinger et al.,1984).
3. Provide opportunities for risk assessment and encourage strategy development (Bowker et al.,1986).
4. Stimulate awareness of action and consequence (Disinger et al.,1984).
5. Teach problem solving skills (Rivers et al., 1987).
6. Integrate, analyze, and compare data and concepts over time (Okey,1984).

Simulations provide a viable option for actual experimentation in certain contexts. Rivers et al.(1987) found that students using computerized biology simulations were developing generalizable skills which transferred to novel settings. He also found that the impact of the simulation with respect to the inference and interpretation subtests of the Watson Glaser test depended on the content of the simulations and the nature of the thinking processes being measured. Simulations were most effective at enhancing the students' ability on both of

these subtests. Simulations allow for a wide flexibility in approaching discovery based learning situations. The benefits of discovery based instruction have been documented in the literature. Discovery instruction capitalizes on sensory and multisensory (or dual coding) effects, and provides a larger number of retrieval pathways for the learned material (Paivio,1971). It also involves a high degree of interactivity and exploits the Generation Effect (Piaget,1970). A person often learns more when she generates, induces, or deduces a portion of the material to be learned herself. In a general model for instructional computer simulations Reigeluth et al.(1989) outlines the major processes involved. These are acquisition of the content, application of the content, and assessment of learning. This model has been used to guide simulation design for this project.

The five simulation features that act as 'vehicles for achieving acquisition, application, and assessment' are: generality, example, practice, feedback, and help (Reigeluth et al.,1989). Research has indicated that students using a biology simulation as a framework for understanding *prior* to formal classroom instruction scored significantly higher on an applications posttest than did students using the simulation as an integrating activity *following* formal instruction (Brant et al.,1991). When the subject matter is inherently complex and the

instructional goal is application oriented, the simulation is most effective as an introductory activity (Brant et al.,1991).

Three major aspects of a computer simulation determine its instructional effectiveness: the scenario, the underlying model, and the instructional overlay (Reigeluth et al.,1989). The scenario attempts to recreate the real-life situation. An example of a scenario is the membrane conductance simulation. In this simulation the students 'place' ionic channels of a conductance value of their choosing in a membrane and observe the corresponding change in membrane conductance and current as they vary the membrane voltage. The underlying model is the mathematical relationship between voltage and individual channel conductance (g) as well as the total membrane conductance (G). Ohm's law and the reciprocal law for adding resistance form the basis of the model. The instructional overlay involves the support dialog that accompanies the simulation, to optimize learning and motivation. In designing the simulations for this project a compromise between maximum scenario fidelity and instructional clarity was decided on.

Alessi et al.(1985) identified four factors that should be considered in all decisions about fidelity of the scenario and the model:

1. **Overload** is the degree to which the complexities of the real life situation provide too many stimuli for the

learner to be able to acquire the desired content material.

2. **Transfer** is the ability to use what has been learned in real life situations.
3. **Affect** is the motivational appeal of the simulation.
4. **Cost** involves the design, development, and production expenses for creating the simulation.

Process simulations teach naturally occurring phenomenon composed of a specific sequence of events (Reigeluth et al., 1989). An example of this type involves the molecular steps involved in the opening and closing of the sodium channel during the action potential. Causal simulations teaches the cause and effect relationship between two or more changes in a system. An example of this type is the Goldman equation simulation (figure 4.10), in which students change concentration, permeability, and temperature variables and then observe the corresponding change in equilibrium and membrane potentials.

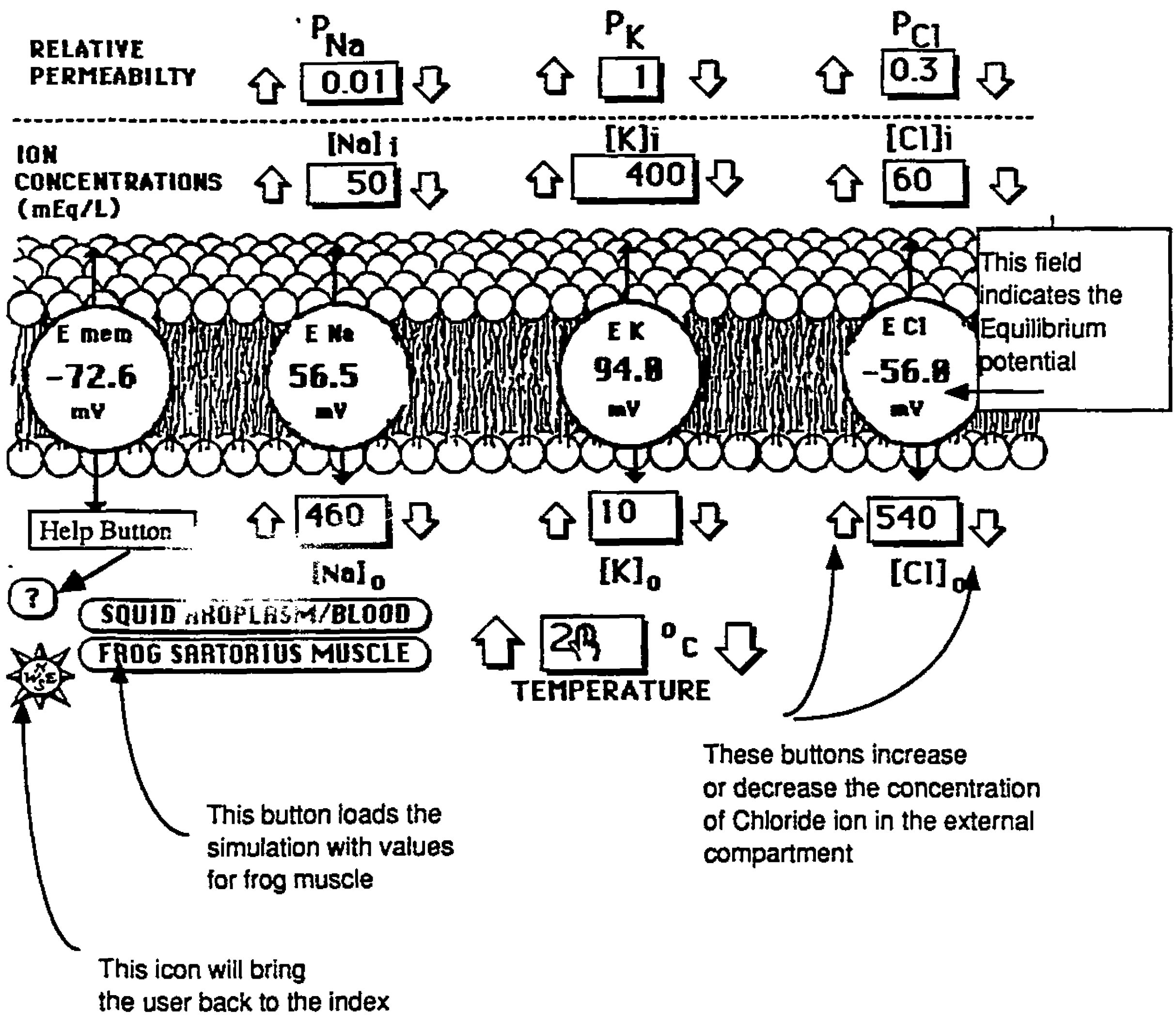


Figure 4.10 The Goldman Equation Simulation

Hooper (1988) points out that a critical aspect of understanding time based phenomena is the ability to control these phenomena directly. This feature has been incorporated into several time based simulations such as the sodium gate simulation in which conformational changes occur in response to a depolarizing potential. Students can step through the simulation and relate the conformational change to the corresponding change in membrane potential. The direct manipulation of complex events allows for more meaningful learning.

Alessi et al.(1985) describe two forms of feedback for computer simulations: natural and artificial. Natural feedback is the 'real life' consequence of a student response. An example of this is the change in membrane potential that accompanies a change in concentration. Artificial feedback is a contrived consequence that would not occur in the real situation. Limiting the allowable range of concentrations and providing 'pop up' messages if critical parameters are exceeded are examples of this type of feedback that is used in other simulations. A Help feature in the simulation can provide the learner with direction and assistance during the presentation of the generality, examples, practice and feedback (Reigeluth et al.,1989). Pressing the ? icon while in a simulation sets the scenario, by introducing the goals, parameters and rules that should be followed. Another form of help is by directing student attention using arrows, bold labeling,

flashing message fields, etc. to emphasize the most important aspects of the simulation. Providing information in the form of a commentary that relates the practice question or numerical example to the generality is another form of help. The questions that form part of the instructional overlay serve to focus the learner on the effects of changing specific variables. A third type of help involves providing an alternative representation of the material, with an explanation relating both representations. Providing alternative representations facilitates encoding and tends to increase the depth of processing and enhance understanding as well as retention (Paivio,1979). Alternate representations were used frequently in describing membrane conductance characteristics and the corresponding voltage vs. current graphs. The effectiveness of simulations in overcoming student's erroneous preconceptions about electric circuits has been reported by Carlson et al.(1992).

A preinstructional simulation presents students with a desired goal to be reached. Students assume their ideas are correct if the goal is reached. If the goal is not achieved students are led to question their preconceptions and to search for better ones. An example of this strategy is incorporated into the membrane conductance section where the learner is asked to figure out how many channels of a given conductance are required to attain a given membrane resistance. The learner is forced to 'confront' the inverse proportional relationship between the variables by

dragging channels in or out of the membrane with the mouse until the desired objective is reached. Conceptual change theorists such as Posner et al.(1982) argue that to overcome preconceptions, instruction should lead students to become dissatisfied with their preconceptions and must provide an alternative model that students perceive as understandable, plausible, and generalizable.

Doran (1978) has identified prediction as a science process skill, that includes mental activities like observation and pattern recognition, inferring rules and evaluating data. Prediction questions are used to support simulations, where students are asked to predict the outcome of changing specific variables in the simulation before actually doing it. The rationale for this has been outlined by several researchers including Good et al.(1986), who points out that prediction is an essential part of scientific inquiry and problem solving, and has become the terminal objective for science education research. Good and Lavoie (1986) suggest that prediction occupies a central role in the learning cycle (Fig 4.11). The advantages identified include:

1. Students will be encouraged to organize existing knowledge.
2. There will be greater commitment by students to follow up on their efforts.
3. Teachers can use students' predictions to aid in their assessment of their understanding.

4. Predictions can be used as a type of pretest by which to judge initial understanding and progress.

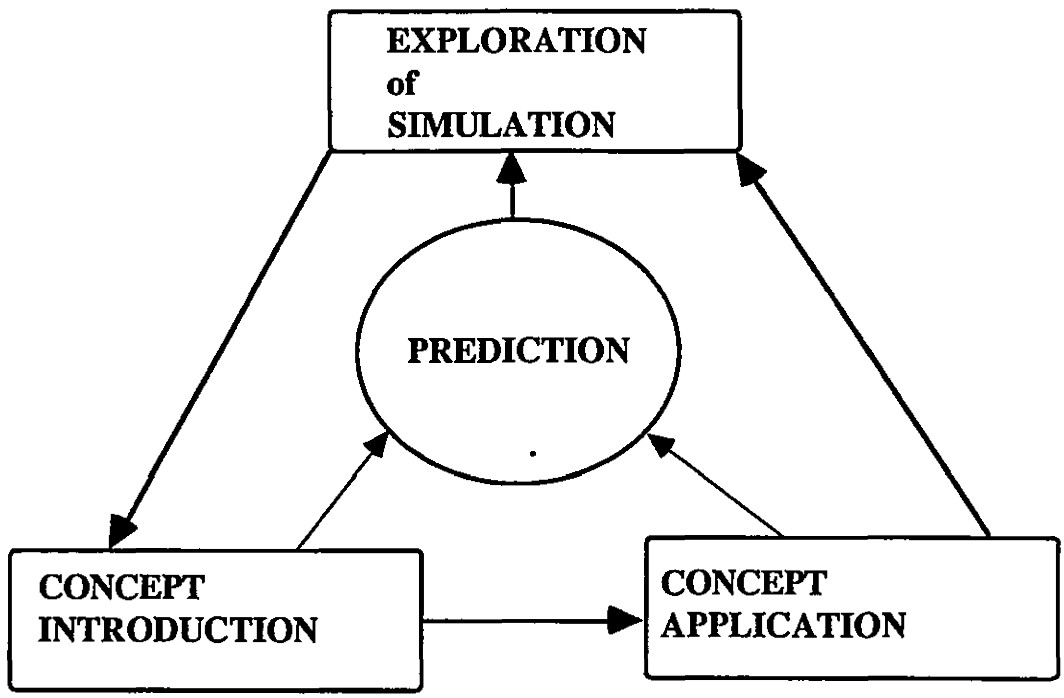


Figure 4.11 A Flexible Science Learning Cycle (adapted from Good et al.,1986)

Well designed simulations can be a very good tool for teaching complex relationships and for 'visualizing' mathematical relationships. As computer graphics continues to become more and more sophisticated, the easier it will be to incorporate dynamic simulation and animation techniques in science instruction.

4.6 Animation

The graphic animation sequences that were produced for this project are rudimentary frame by frame constructions. Animation is achieved by fast card sequencing. A commercial animation product "ADDMOTION" was reviewed but found to be too slow to load and run from the courseware. This problem could be rectified by using a faster machine. Research on the effectiveness of using animations to teach adults is mixed (Collins et al.,1978; Rieber et al.,1990). As Rieber (1990:79) notes, "It is very difficult to distinguish animations role when used as part of an interactive dynamic, as the experience is largely context specific." Visuals, whether animated or static, facilitate learning only when their attributes are applied in congruence with the specific learning requirements of the task (Park et al.,1991; Rieber,1990).

Five specific instructional conditions have been identified by Park et.al(1991) in which visual motion can be used effectively;

(refers to specific applications within this project)

1. demonstrating procedural actions *(Patch Clamping)*
2. simulating system behaviors *(Voltage Clamping procedure)*
3. explicitly representing invisible movements or phenomenon*(Sodium channel animation)*

4. illustrating structural, functional, and procedural relationships among objects and events *(Steps involved in the Hodgkin Cycle)*
5. focusing the learners attention on important topics *(Calcium Current's role in cell function)*

4.7 SCREEN DESIGN

Designing comprehensible and meaningful screen layouts implies taking into consideration the limited capabilities of human information processing (Franzwa,1973). The location of information serves as a mediator and complements recall by providing a natural diagrammatic presentation for organizing memory search (Aspillaga, 1991). Goodman (1988) cites several essential guidelines in designing effective visuals for hypermedia projects:

1. Keep screens as simple as possible. This entails keeping supplemental information off the screen, but available by means of nested pop up menus.
2. Let the information that you wish to project be the focal point. Keep ancillary buttons and functions on the periphery of the main ideas.
3. Make the graphics appropriate to the subject. Don't let the graphics overpower the instructional message.

4. Be consistent. Keep navigation and control buttons in the same place from screen to screen wherever possible.
5. Remind the learner where she is in the stack. Title appropriate introduction cards, and make transitions into new topics explicit.

The principal function of an 'organizer' according to Ausubel et al.(1978) is to manipulate the cognitive structure in such a way as to facilitate meaningful learning. There are two basic types of advance organizers, expository and comparative. An expository advance organizer is used when the material to be learned is completely unfamiliar and the learner lacks even generally related concepts (Healy,1989). When the material to be learned is familiar to the learner a comparative advance organizer is used to point out the relation between the concepts that are present in the learner's cognitive structure and the information that will be learned (Healy,1989). The advance organizers used in this project also have the added benefit of hypertext access to review previously learned concepts. The results of incorporating advance organizers in CAI materials have been inconclusive (Carnes et al.,1987). The effectiveness of the advance organizers in this project will be studied at a later date.

Lynch (1990) suggests that the role of graphic design in multimedia programs is crucial and inseparable from the

operation of the software, requiring even more sensitivity to the needs of the user than traditional print media. Faiola et al.(1988) suggest that the quality of screen design is an encouragement to improved performance, when it maintains the interest of the learner while also lowering the chances of confusion, eye strain, and fatigue caused by poorly designed information. Well organized information serves as a graphic organizer, helping in learning the information and guiding the acquisition of unfamiliar material by providing an external 'map like' organizer (Dean et al.,1981). Aspillaga (1991) suggests that this 'map' links incoming information to preexisting knowledge at a deeper level of encoding resulting in associative learning. Organized content also serves as an index for future tracing, directing the student attention and increasing the efficiency of the search (Christie et al.,1976).

Authoring hypertext documents entails additional considerations beyond the usual concerns of the science writer. One of the most important considerations is 'Chunking' size. The information should be organized into small "chunks" that deal with one topic, theme or idea. Chunks in this project include single concepts or definitions (Kearsley,1988). 'Chunking' large portions of course materials into smaller units has been shown to improve visual clarity and result in improved retention of information in a complexly structured instructional framework (Faiola,1988). Wainright (1989) cites that an inability to learn

chemical concepts effectively using a commercial chemistry CAI package was due to 'excessive information load demand' in working memory. Asking students to maintain too many cognitive connections in hypermedia without adequate opportunity for practice and rehearsal could lead to the overloads cited.

Kearsley (1988) cautions that the spacing of lines and the amount of information included on a single display is a major concern because of the small size of some computer screens and the fact reading computer text can be up to 30 percent slower than printed text. Text should appear on the screen as a paragraph rather than as a sentence or line because readers inspect and re inspect portions of a text while selecting and integrating the content. If text is shown one sentence at a time or unparagraphed, readers tend not to reread or skim previously read material in order to synthesize it (Gillingham,1988). Framing text in consistent looking fields and providing proper paragraphing is important for efficient comprehension of technical prose (Birkmire,1984). Other considerations for ease of readability include: making text double spaced, using consistent patterns of justification, and using a structure for natural eye movement, top to bottom and left to right. Text instructions for the various simulations have been separated from the main text body by the use of pop up windows that disappear after the learner presses an 'OK' button. Another concern is the

fragmentation of important concepts due to the limited size of the screen display. Where at all possible this was avoided.

4.8 Instructional Management Considerations

Gibbons et al.(1993) discuss the dearth of information about how instructional management becomes integrated with tutorial software. They cites reasons including the underestimation of the benefits of improved management of instruction, a trivialized conception of management as a clerical rather than instructional function and a stunted conception of instruction itself which provides few practical alternative instructional decisions to be made. The so called "lexical loop" as described by Bunderson et al. (1981) of a typical tutorial consisting of a period of 'telling' from system to student followed by a period of 'telling ' from student back to the system has been the prevailing instructional metaphor. It is primarily a verbally oriented system in which students receive information, attempt to convert it into some form of knowledge, and then rehearse it back to the system in order to demonstrate mastery (Gibbons et al.,1993).

"During instruction, rather than being 'told', students should be asked to perform. This will blur the distinction between practice and testing events, making them essentially the same" (Gibbons et al.,1993:8). This theme was incorporated into the hypertutorial system. Although end of section testing was

retained, periodic questioning is integrated wherever possible inside the tutorial. Each of the four main tutorial sections has an accompanying test module. Students can access the test for each instructional unit by clicking on the 'scholar' icon. They then register by inputting their name, class, and student number. This information can be used for tracking progress if the tutorials are used for evaluation. The length of these test modules vary from section to section, but they contain on average 30 to 50 multiple choice and true/false questions. The test would normally be taken at the completion of the section tutorials, but it can also serve as an inventory test if students want to assess their knowledge before starting the tutorials. The teacher may enter a password to access several instructor features. These include the options of indicating the correct answers to students if they get the test question wrong , turning audio feedback on or off, and accessing learner statistics. A typical statistics page is shown in figure 4.12. As well as recording the score for each student, the class average, and highest score on the test, the program also keeps track of the number of correct and incorrect answers for each question. This is a useful feature to allow the teacher to focus in on course material that students have particular problems with. It can also indicate portions of the tutorial that may require further work or clarification.

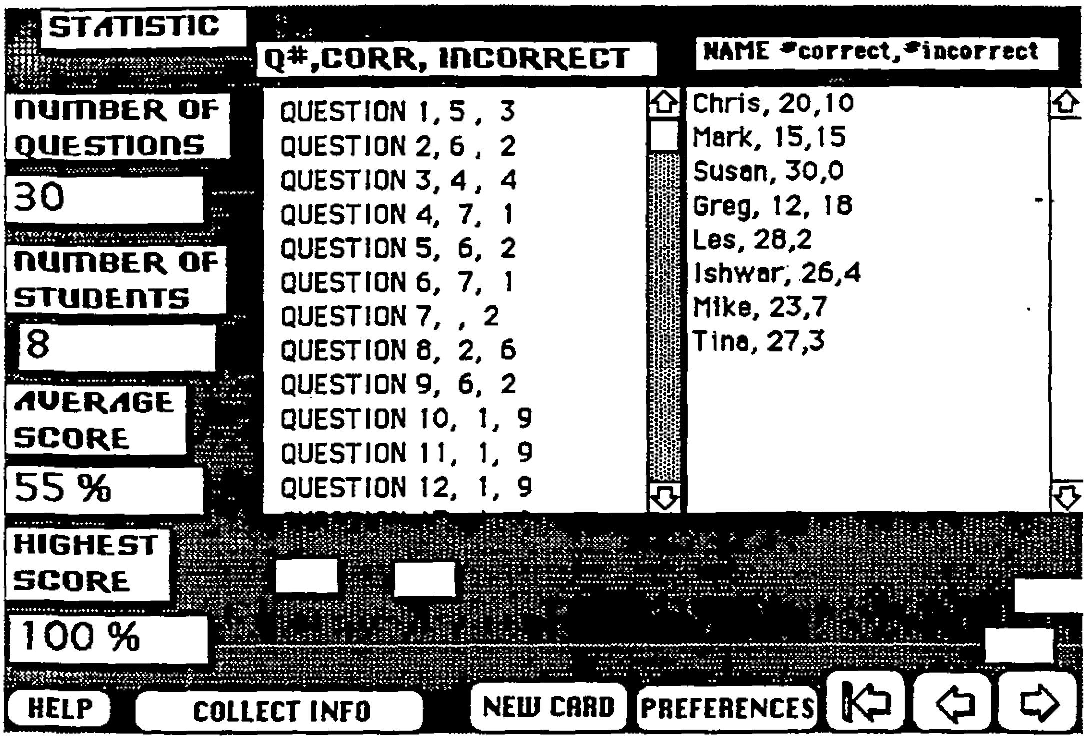


Figure 4.12 Statistics Report

Chapter 5 Project Implementation

5.1 Group Work Strategies

Several researchers have documented that students working in groups of three and four on CAI tutorials had significantly better rates of learning and achievement scores than students working alone (Carnes et al.,1987; Kulik et al.,1983: Stephenson, 1992). This tutorial system can be displayed on a large monitor enabling several students to participate cooperatively. Carnes also suggests that the interaction of students in groups of three or four provides a reduction in learning time, which in itself is a motivational factor for most students. Encouraging students to use this tutorial in pairs may be a good strategy to encourage this synergistic learning.

With relatively few exceptions, the literature indicates that students have positive attitudes toward learning with CAI. Skinner (1988); Kulik (1980); Guthrie et al. (1992) attribute this attitude to several factors: students enjoy the interactive nature of CAI; CAI creates a safe and comfortable learning environment for students; less time is required to reach competency; students tend to perform well on quizzes and tests as a function of CAI.

CAI works if students use the programs (Canelos et al.,1986). This is not a minor point, since students refuse to use CAI programs, in the same manner that they refuse to attend lectures

or read books. Interactive systems hold the promise of being more engaging to students than conventional CAI, and this will translate hopefully into longer and more active engagement time. The question of whether students using CAI learn better than those using conventional methods is a qualified yes from the literature. It depends on the program: improvements are documented by Canelos and Carney (1986); Turner(1988) and studies indicating no improvement also by Turner (1988).

At any rate the use of humorous graphics and sound is probably a useful adjunct to well designed CAI material toward the goal of keeping learners relaxed, motivated and positive in outlook.

5.2 Feedback from Student Opinion Survey

Before students could quit the program they were requested to answer an opinion survey. The questions surveyed their attitudes toward CAI in general as well specifics about the tutorial system itself. A seven point Likert scale, was used. The results are tabulated below:

Stack Opinion Survey

Strongly Agree — Strongly Disagree

1	2	3	4	5	6	7	

Question	Mean
1. The introductory module made using this program easier.	3.0
2. Computer-Based learning suits my personal learning style	3.25
3. I would like more tutorials of this type	2.25
4. These stacks encouraged me to improve my basic skills	2.25
5. I generally tried to finish the stacks before I had mastered the material in them.	3.75
6. I found the level of presentation right for me	4.0
7. The directions for navigating through the material were straightforward and easily understood.	3.5
8. I thought that the degree of audio feedback was distracting.	5.0
9. The simulations were difficult to understand.	3.5
10. The graphics were aesthetically pleasing.	2.75
11. The quizzes were useful for reinforcing basic concepts.	2.0

12. I found the ability to review important concepts and definitions by simply clicking on key words, a useful feature.	2.75
13. I found the ability to select a question I wanted answered and then to go directly to the tutorial material, a very useful feature.	2.25
14. The variety of presentation formats for the materials was adequate.	2.5
15. The 'HELP' features found in the tutorials were useful and informative.	3.0
16. Reinforcement of key concepts was adequate.	2.5
17. The tutorials were the right length.	4.75
18. The level of interactivity in the tutorial was too low,	6.0
19. The navigation icons made it easy to move around the tutorial.	4.25
20. I would recommend this tutorial system to anyone starting to study electrophysiology.	2.5
21. I am primarily a visual learner.	4.0

A sample of the written Feedback is shown below:

On CAI;

"Overall, I learned a lot. I am a person who learns well by diagrams and illustrations and therefore I enjoy a program like this."

"...the interactive learning style is the best way I learn. The questions helped to clarify some misconceptions that I had."

"....since my background in physics was poor, the use of computer illustrations combined with working at your own pace helps the user understand concepts."

" Overall it was helpful, the concepts were explained in ways that were different from textbooks."

On the General Structure of the Tutorial;

"The listing of different kinds of channels was very helpful. I knew there were more than one type of K+ channel, but I didn't know how to classify them until now."

"It's good to force users to answer the questions before moving on."

" In general the large print and bold words with the questions helped immensely in my understanding of this topic...keeps the interest, the humor is also very effective!."

" Capacitance; very in depth coverage and the questions interspersed really brought everything together."

On Animations and Simulations;

.."It was amazing how much better you understand a concept when you see it 'working' before your eyes instead of trying to create a picture in your head as you read from a textbook."

" Voltage clamping...excellent demos of channel activation and inactivation."

" I did not previously fully understand the step current stimulus...I do now much better."

" GHK equation and the action potential simulation showing the Na and K gates with plot of Em was very helpful. It was great to see everything interacting on one screen as it actually happens!!"

" The demonstrations are particularly effective in allowing one to grasp abstract concepts that cannot be easily visualized from a text description."

" The pictures showing the patch clamp technique were excellent, great stuff!"

" Membrane tour; visuals were excellent! Clicking on components of the membrane was good too."

" The diagrams used to illustrate the role of myelin were excellent. It reinforces a simple concept."

Issues for Revision and Improvement;

"I Don't like reading text in Capital Letters"

"If you could get the fade ins/outs to go faster or smoother it would be easier to look at and remain focused"

"The screen changes too fast for me in the capacitor subsection, to comprehend fully the subject matter"

"I didn't completely understand the axon tau unit, I think this section requires some clarification"

"Add more compass buttons!, I would like to be able to go back to the index more frequently"

"The 'Acme Axon Analyzer' was a bit confusing, there were so many variables all over the screen."

" Improve the axon tau help screen, I couldn't figure it out!"

Students were also very helpful in identifying program 'bugs' regarding buttons that did not function the way they should, and navigational linking problems in Hypertext mode.

Chapter 6 Summary

Hypercourses are able to stimulate and amplify the cognitive skills of learners. They can be regarded as tools for achieving two essential educational goals: realizing more effective learning and helping students to enhance and acquire metacognitive abilities (Lanza,1991). Future revisions of this program will include instructional management facilities to track the paths of learners through the hypermedia as well as a time monitoring feature to determine the amount of time spent on each card. The fact that hypermedia systems can be accessed in a non linear or exploratory fashion, allows them to accomodate a wide variety of learning styles. An extension of this project could track learners through the hypermedia knowledge base to find what information they have or have not interacted with. Card numbers as well as time spent on each card could be recorded. This information could be used to gain more insight into how students actually use hypermedia. This would allow instructional designers to better modify instructional strategies and to design enhancements to meet the needs of the learners. Wainright (1989) cautions against the general assumption that CAI is more successful than traditional methods. Citing that in the vast

majority of cases where CAI was favored, subjects were volunteers rather than randomly assigned, and they often used CAI as remedial or supplemental instruction, beyond that which the control group received. He suggests that these approaches may be optimum applications for CAI, rather than controlled whole group instruction.

Gibbons (1993:9) envisions the disappearance of traditional expository courseware with it being replaced by "...knowledge and instructional objects capable of being reused in a variety of instructional contexts". This concept can be extended to the 'information stack' metaphor that is used to organize this project. The ability to use any number of these stacks in other computer assisted tutorials is possible. In fact by building a database of interactive modules, students can be provided with an extremely flexible system of dynamically assembled lessons.

The hypertutorial system described in this paper was designed for maximum flexibility and ease of future expansion. It is hoped that an entire neurophysiology tutorial system can be constructed within the framework presented here. To add more subject modules simply requires the addition of more index cards and the subsequent hyperties to the existing material. This would further enhance the 'information environment' for students using this tutorial. This open ended approach extends to the quiz and testing capabilities of this program as well. New questions

can be appended to the existing database, or entirely new quizzes can be created very easily.

Jonassen (1985:163) has proposed that "rather than creating problems to which we can apply our most popular interactive technology, we need to develop design processes which identify the required components of interactive adaptive instruction". Instructional designers must clarify their instructional goals before considering the organization and technological delivery system they wish to use. This project has identified useful and attainable instructional goals for an electrophysiology tutorial system.

Perhaps Ambrose (1991:54) sums it up best in stating that "Hypermedia is still a work in progress, changing with each new technological innovation, each new application". Hypermedia appears to be the next great technological wave to hit education. Its impact in terms of acceptance, and usefulness will depend on how well some of the issues identified here have been addressed.

This project has confirmed that students perceive hypermedia materials to be useful and worthwhile tools to help them master course material.

Bibliography

Aarntzen, A., "Audio in Courseware: Design Knowledge Issues"., Educational Technology and Training International, 30,4, 1991, pp. 354-365.

Alessi, S.M., Trollip,S.R. Computer Based Instruction Methods and Development, NJ: Prentice Hall,1985.

Ambrose,D.W., The effects of Hypermedia on Learning", Educational Technology, December 1991, pp 51-55.

Anderson, J.R., The Architecture of Cognition. Cambridge, MA:Harvard University Press, 1983.

Anderson, J.R., Cognitive Psychology and It's Implications, 2nd ed. NewYork: W.H. Freeman, 1985.

Aspillaga, M., "Screen Design: Location of Information and Its Effects on Learning", Journal of Computer-Based Instruction, 18(3), 1991, pp 89-92.

Atkinson, B., Hypercard [Computer Program]. Cupertino: Apple Computer,Inc., 1987.

Ausubel, D.P., Educational Psychology, a Cognitive View. New York:Holt Rinehart and Winston, 1978.

Bandura, A., A Social Learning Theory. Englewood Cliffs, NJ: Prentice Hall,1977.

Barker, P. "Designing Interactive Learning Systems", Educational Technology and Training International, 27(2), 1991, pp 125-145.

Bevilacqua, A.F., "Hypertext: Behind the Hype", American Libraries, February 1989, 20, pp158-162.

Billings, D.M., "A Model for Evaluating Computer-Assisted Instruction", Nursing Outlook, 32, 1984, pp 50-53.

Billings, D.M., "An Instructional Design Approach to Developing CAI Courseware", Computers in Nursing, 3, 1985, pp 217-223.

Birkmire, D.P., "Text Processing: The Influence of Text structure,background knowledge, and purpose. Reading Research Quarterly, 20,1984, pp 314-326.

Boone, R., Higgins, K.," Hypertext/Hypermedia Information Presentation: Developing a Hypercard Template", Educational Technology, February 1991, pp 21-30.

Bork, A. "Production Systems for Computer-Based Learning" Instructional Software: Principles and Perspectives for Design and Use, Walker,D., Hess, R. (Eds.); Wadsworth Inc.,Belmont, California,1984, pp 96-115.

Bowers, D.,Tsai, C. "Hypercard in Educational Research: An Introduction and Case Study", Educational Technology, February 1990, pp 19-24.

Bowker, L., Bowker, R., "Using Computers to increase course efficiency: an example in a general ecology laboratory", Collegiate Microcomputer, 4(1), 1986, pp 1-6.

Brand, S., The Media Lab. New York: Viking, 1987.

Bransford,J.D., Sherwood, R.D., Hasselbring, T.S., Kinzer, C.K., Williams, S.M., "Anchored Instruction: Why We Need It and How Technology Can Help", Cognition, Education, and Multimedia: Exploring Ideas in High Technology, Nix, D., Spiro, R.(Eds.) Hillsdale, NJ:Lawrence Erlbaum, 1990, pp 115-141.

Brant, G., Hooper, E.,Sugrue, B. "Which Comes First The Simulation Or The Lecture? "Journal of Educational Research, 7(4), 1991, pp 469-481.

Brown, J.S., "Process Versus Product: A Perspective on Tools for Communal and Informal Electronic Learning", Journal of Educational Computing Research, 1985, 1, pp 179-201.

Brown, A.L., Palinscar, A.S., "Guided , cooperative learning and individual knowledge acquisition", Knowing, Learning, and Instruction: Essays in honor of Robert Glasser. Resnick,L. (Ed.). Hillsdale, NJ: Lawrence Erlbaum Associates, 1989, pp 394-452.

Bunderson, C.V., Gibbons, A.S., Olsen, J.B., Kearsley, G.P., "Work Models: Beyond Instructional Objectives", Instructional Science, 10,1981, pp 205-215.

Caffarella, E.P., "Evaluating the New Generation of Computer-Based Instructional Software", Educational Technology, April 1987, pp19-24.

Canelos, J., Carney, B.W., "How computer-based instruction affects learning," Engineering Education., 298 , Feb.1986 pp 341-48.

Carlsen, D., Andre, T., "Use of a Microcomputer Simulation and Conceptual Change Text To Overcome Student Preconceptions about Electric Circuits", Journal of Computer-Based Instruction, 19(4), 1992, pp 105-109.

Carnes, E., Lindbeck, J., Griffin, C.F., "Effects of Group Size and Advance Organizers on Learning Parameters when Using Microcomputer Tutorials in Kinematics", Journal of Research in Science Teaching, 24(9), 1987, pp 781-789.

Chang, L., Osguthorpe,R.T., "An Evaluation System for Educational Software: A Self-Instructional Approach", Educational Technology, June 1987, pp 15-19.

Christie, J., Just, M.A., "Remembering the location and content of sentences in a prose passage", Journal of Educational Psychology, 68, 1976, pp 702-710.

Collins, A., Adams, M., Pew, R., "Effectiveness of an Interactive Map Display in Tutoring Geography", Journal of Educational Psychology, 70(1), 1978, pp 1-7.

Collins, A., Brown, J.S., Newman, S.E., "Cognitive Apprenticeship: Teaching the Crafts of Reading, Writing, and Mathematics", Knowing, Learning, and Instruction: Essays in Honor of Robert Glaser, Hillsdale, NJ: Lawrence Erlbaum, 1989, pp 453-494.

Cortinovis, R., "Hypermedia for Training: A Software and Instructional Engineering Model", Educational Technology, July 1992, pp 47- 51.

Coyle, K., Thompson, A.D., Jarchow, E.M., "Computers in Education: A call for exemplary software", Journal of Research on Computing in Education, 1988, pp 245-257.

Dick,W., Carey,L., The Systematic Design of Instruction (2nd Ed.) Glenview Ill: Scott, Foresman, and Company,1985.

Disinger, J., Fortner, R., "Using computers for Environmental Education (Information bulletin No.3)". Washington, DC:National Institute of Education, Department of Education.(ERIC Document Reproduction Service No. ED 260 907).

Dede, C., Palumbo, D., "Implications of Hypermedia for Cognition and Communication", Impact Assessment Bulletin 9, 1-2, 1991, pp 15-28.

Dede, C.J. "The Future of Multimedia: Bridging to Virtual Worlds" Educational Technology , May 1992, pp 54-60.

Dempsey, J.,Sales,G.,(Eds.) Interactive Instruction and Feedback. Engelwood Cliffs,NJ: Educational Technology Publications,1993.

Dervin, B. "Information as a user construct: The relevance of perceived information needs to synthesis and interpretation." Knowledge Structure and Use: Implications

for Synthesis and Interpretation., Ward,S.A.,Reed,L.J., Eds. Philadelphia: Temple University Press,1983, pp153-183.

Devlin, J., Berk,E. "Why Hypertext?" The Hypertext/Hypermedia Handbook. Ed. Emily Berk and Joseph Devlin, New York: McGraw Hill, 1991.

Doran,R.L., "Measuring the 'Processes of Science', Objectives", Science Education, 62(1), 1978, pp 19-30.

Dori, Y., Yochim,J.M., "Learning Patterns of College Students Using Intelligent Computer-aided Instruction, Journal of College Science Teaching, November 1990, pp 99-103.

Duby, A., "Self-Formative Evaluation of Instructional Materials", Educational Technology, February, 1987, pp 48-50.

Faiola, T., DeBloois, M.L., "Designing a Visual Factors-Based Screen Display Interface: The New Role of the Graphic Technologist", Educational Technology, August 1988, pp 12-21.

Flagg, B.N., Formative Evaluation for Educational Technologies, Hillsdale, NJ: Lawrence Erlbaum,1990.

Franzwa, D., Influence of Meaningfulness, Picture Detail, and Presentation Mode on Visual Retention", Audio Visual Communication Review, 21, 1973, pp 207-223.

Garzotto, F., Paolini, P., Schwabe, D., Bernstein, M., "Tools for Developers", The Hypertext/Hypermedia Handbook. Eds. Emily Berk and Joseph Devlin, New York: McGraw Hill, 1991.

Gay, G. "Interaction of Learner Control and Prior Understanding in Computer-Assisted Video Instruction", Journal of Educational Psychology, 78(3), 1986, pp 225-227.

Gay, G., Trumbell, D., Mazur, J., "Designing and Testing Navigational Strategies and Guidance Tools for a Hypermedia Program", Journal of Educational Computing Research, 7(2), 1991, pp 189-200.

Gibbons, A.S., Fairweather, P.G., O'Neal, A.F., "The Future of Computer-Managed Instruction (CMI)", Educational Technology, May 1993, pp 7- 11.

Gillingham, M.G., "Text In Computer-Based Instruction: What the Research Says" Journal of Computer-Based Instruction, 15(1), 1988, pp 1-6.

Glass, G.V., "Integrating Findings: The meta-analysis of Research", Review of Research in Education, Shylman, L.(Ed.), Itasca Illinois: Peacock Publishing, 1978.

Godfrey, D., Sterling, S., The Elements of CAL. Victoria BC:Press Porcepic, 1985.

Golas, K.C., "The Formative Evaluation of Computer-Assisted Instruction", Educational Technology, 23, 1983, pp 26-28.

Good, R., Kromhout, R., Bandler, W., "Human and Machine Diagnosis of Scientific Problem Solving Abilities", Journal of Research in Science Teaching, 23, 1986, pp 263-275.

Goodman, D., Danny Goodman's Hypercard Developer's Guide., Bantam Books, Toronto, 1988.

Grant, L.,McAvoy,R.,Keenan, J.B., "Prompting and Feedback Variables in Concept Programming", Teaching of Psychology, 9, 1982, pp 173-177.

Guthrie, B.M., McPherson, M., "The Efficacy of a Customized Approach to Computer Assisted Instruction", Journal of Computer-Based Instruction, 19(3), 1992, pp 100-104.

Hansen,J. B.,"Effects of Feedback,Learner Control,and Cognitive Abilities on State Anxiety and Performance in a Computer Assisted Instruction Task. " Journal of Educational Technology, 1974, 66, pp 247-254.

Hazen, M. "Instructional Software Design Principles", Educational Technology, 25(11), November 1985, pp 18-23.

Healy, V.C., "The Effects of Advance Organizer and Prerequisite Knowledge Passages on the Learning and Retention of Science Concepts", Journal of Research in Science Teaching, 26(7), 1989, pp 627-642.

Hinze, K., "Using a population- ecology simulation in college courses", Collegiate Microcomputers, 2(1), 1984, pp 61-63.

Hooper, K. "Hypercard: A Key to Educational Computing", Learning with Interactive Multimedia, Eds. Ambron, S., Hooper,K.,Redmond Wa.; Microsoft Press, 1988, pp 7-25.

Jackendorff, R., "On Beyond Zebra: the relation of linguistic and visual information", Cognition, 26, 1987, pp 89-114.

Jaspers, F., "Interactivity or Instruction? A Reaction to Merrill", Educational Technology, March 1991, pp 21-24.

Johnson, C.W., Grover, P.A. "Hypertutor Therapy for Interactive Instruction". Educational Technology, Jan. 1993, pp 5-16.

Jonassen, D.H., "Hypertext Principles for Text and Courseware Design", Educational Psychologist, 21(4), 1986, pp 269-292.

Jonassen, D.H., Hannum,W.H., "Research-Based Principles for Designing Computer Software", Educational Technology, December 1987, pp 7-14.

Jonassen, D.H., "Designing Structured Hypertext and Structuring Access to Hypertext", Educational Technology, November 1988, pp13-16.

Kearsley, G., "Authoring Considerations for Hypertext", Educational Technology, November 1988, pp 21-24.

Keegan, M., "Design and Effects of Scenario Educational Software", Educational Technology, June 1993, pp 19-25.

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[illegible] and Effects of [illegible]
[illegible] Germany [illegible]

Kinzie, M.B., "Requirements and Benefits of Effective Interactive Instruction: Learner Control, Self Regulation, and Continuing Motivation". Educational Technology Research and Development, 1990,38(1), 5-21.

Klahr, D., Dunbar, K., "Dual space search during scientific reasoning", Cognitive Science, 12, 1988, pp 1-48.

Kulik, J.A., Kulik, C.L., Cohen, P.A., "Effectiveness of computer based college teaching: A meta-analysis", Review of Educational Research, 50, 1980, pp 525-544.

Kulik, J.A., Bangert, R.L., Williams, G.W., "Effects of computer-based learning on secondary school students", Journal of Educational Psychology, 75, 1983, pp 19-26.

Kulik, C.C., Kulik, J., Shwalb, B., "The Effectiveness of Computer-Based Adult Education: A Meta-Analysis", Computer-Based Adult Education, 75, 1986, pp 235-253.

Kumar, L. " Does Learning Improve With Videodisc Tutorials?", Journal of College Science Teaching, November 1990, pp 85-89.

Lanza, A., "Some Guidelines for the Design of Effective Hypercourses" Educational Technology, Oct. 1991, pp 18-22.

Leonard, W.H., "A Comparison of Student Reactions to Biology Instruction by Interactive Videodisc or Conventional Laboratory", Journal of Reasearch in Science Teaching, 26(2), 1989, pp 95-104.

Littleford, A. "Artificial Intelligence and Hypermedia". The Hypertext/Hypermedia Handbook. Ed. Emily Berk and Joseph Devlin, New York: McGraw Hill, 1991.

Lynch, P. "Graphic Design and Multimedia", Syllabus #13, Cupertino:Apple, Sept/Oct.1990, pp 18-21.

Marchionini, G., "Hypermedia and Learning: Freedom and Chaos", Educational Technology, November 1988, 28(11), pp 8-12.

McCarthy, R., "Multimedia: What the Excitement's All About". Electronic Learning, 8, June 1989, pp 26-31.

McLellan,H., "Virtual Environments and situated learning", Multimedia Review, 2(3), 1991, pp 30-37.

McLellan, H., "Evaluation in a Situated Environment", Educational Technology, March 1993, pp 39- 44.

Merrill, D.M, Li, Z., Jones, M.K., "Limitations of First Generation Instructional Design", Educational Technology, 30(1), pp 7-12.

Merrill, D.M, Li, Z., Jones, M.K. "The Second Generation Instructional Design Research Program" Educational Technology, March 1990, pp.26-31.

Meyrowitz, N., "Networks of scholars' workstations: end-user computing in a university community", IRIS Technical report, Brown University, IRIS, Providence RI., 1985.

Morariu, J.,"Hypermedia in Instruction and Training: The Power and the Promise" Educational Technology, 28(11),1988, pp 17-20.

Nelson, T.H., "Electronic Publishing and Electronic Literature", Information Technology in Health Science Education, Deland, E.C.(Ed.).New York: Plenum,1978.

Njoo, M., De Jong, T., "Exploratory Learning with a Computer Simulation for Control Theory: Learning Processes and Instructional Support", Journal of Research in Science Teaching, 30 (8),1993, pp 821-844.

Norman, D. A., Gentner, S., Stevens, S., "Comments on Learning Schemata and Memory Representation." Cognition and Instruction, D Klahr(Ed.) Hillsdale,NJ: Lawrence Erlbaum Associates,1976.

Okey, J.R.," Integrating Computing into Science Instruction", Journal of Computers in Mathematics in Science Teaching, 4(2), 1984, pp 14-18.

Park, O., "Hypermedia: Features and Research Issues", Educational Technology, August 1991, pp 24-30.

Park, O.,Gittelman,S.S., "Selective Use of Animation and Feedback in Computer-Based Instruction", Educational Technology Research and Development, 40(4), 1992, pp 27-38.

Paivio, A.,Imagery and Verbal Processes Hillsdale ,NJ; Lawrence Erlbaum Associates, 1971.

Parunak, H.V.D., "Ordering the Information Graph"., The Hypertext/Hypermedia Handbook. Ed. Emily Berk and Joseph Devlin, New York: McGraw Hill, 1991.

Patterson, A.C., Bloch,B., "Formative Evaluation: A process Required in Computer-Assisted Instruction", Educational Technology, November 1987, pp 26-30.

Paul, R., Critical Thinking. Santa Rosa: Foundation for Critical Thinking Press, 1992.

Phillipo, J., "Videodisc Technology and Hypercard: A Combination That Can't Be Beat.", Educational Technology, December 1991, pp 51-55.

Piaget, J., Science of Education and the Psychology of the Child. New York: Viking Press,1970.

Posner, G.J., Strike, K.A., Hewson, P.W., Gertzog, W.A. "Toward a theory of conceptual change" Science Education, 66,1982, pp 211-227.

Pulos, S., "Processing Capacity, Science Education, and Rival Hypotheses", Journal of Research in Science Teaching, 30 (2), 1993, pp 213-214.

Reeves, T.C., "Evaluating Interactive Multimedia", Educational Technology, May 1992, pp 47-52.

Reiber, L.P., "Animation in computer based instruction" Educational Technology Research and Development, 38(1),1990, pp 77-86.

Reigeluth,C.M., Schwartz, E. "An Instructional Theory for the Design of Computer Based Simulations" , Journal of Computer Based Instruction,16(1),1989, pp 1-10.

Resnick, L.B., Knowing, Learning, and Instruction: Essays in Honor of Robert Glaser. Hillsdale, NJ: Lawrence Erlbaum,1989.

Rivers, R., Vockell, E., "Computer Simulations to stimulate scientific problem-solving", Journal of Research in Science Teaching, 25, 1987, pp 403-416.

Rumelhart, D.E., Norman, D.A., "Representation in Memory", Handbook of Experimental Psychology, ed. Atkinson,R.C.,Herrnstein, Lindsay, R.J., Luce,R.D., New York: Wiley, 1984.

Salisbury, D.F., "Cognitive Psychology and Its Implications For Designing Drill and Practice Programs For Computers", Journal of Computer Based Instruction,17, 1990, pp 23-30.

Schneiderman, B., Designing the User Interface: Strategies for Effective Human Computer Interaction. Reading, MA:Addison-Wesley, 1987.

Skinner, M.E., "Attitudes of College Students Toward Computer-Assisted Instruction: An Essential Variable for Successful Implementation.", Educational Technology, February,1988, pp 7-15.

Slatin, J.H., "Composing Hypertext: A Discussion for Writing Teachers",The Hypertext/Hypermedia Handbook. Ed. Emily Berk and Joseph Devlin, New York: McGraw Hill, 1991.

Smith, P.L., Boyce, B.A., "Instructional Design Considerations in the Development of Computer Assisted Instruction", Journal of Educational Technology, 24,1985, pp 5-11.

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ment of Computer
Technology

Soloman, G., Gardner, H., "The computer as educator: Lessons from television research", Educational Researcher,15, 1986, pp 13-19.

Steinberg, E.R., Teaching Computers to Teach. Hillsdale, NJ: Erlbaum, 1984.

Stephenson, S.D., "The Effects of Student-Instructor Interaction and Paired/Individual Study on Achievement in Computer-Based Training (CBT)", Journal of Computer-Based Instruction, 19(1),1992, pp 22-26.

Suzuki, K., "A Short-Cycle Approach to CAI Development: Three-Stage Authoring for Practitioners", Educational Technology, July 1987, pp 19- 24.

Tennyson, R.D., "The Teaching of Concepts: A Review of Instructional Design Research Literature", Review of Educational Research, 50(1),1980, pp 55-70.

Trollip, S.R. "Wrestling with instructional computing," Acad. Comput., 2(26) , Dec.1987/Jan.1988, pp 24-30.

Turner, J.A.,"Books vs computers:the message, not the medium, is said to be important for the student," Chronicle Higher Educ., A22 Oct. 5,1988 pp 3-12.

Wainwright, C.L., "The Effectiveness of a Computer-Assisted Instruction Package In High School Chemistry", Journal of Research in Science Teaching, 26(4), 1989, pp 275-290.

Weyer, S. A., "As We May Learn" Interactive Multimedia , Eds. Ambron, S., Hooper, K., Redmond Wa.: Microsoft Press,1988.

Woerner, J.J., Stonehouse, H.B., "The Use of the Neuro-Linguistic Programming Model for Learning Success", School Science and Mathematics 88, 1988, pp 516-524.

Yeany, R.H., Miller, P.A., "Effects of Diagnostic/Remedial Instruction on Science Learning: A Meta-Analysis", Journal of Research in Science Teaching, 20(1), 1983, pp 19-26.

Zimmerman, B.J.,"A Social Cognitive View of Self Regulated Academic Learning". Journal of Educational Psychology, 81,1989, pp 329-339.

Appendix 1

Student Feedback on difficult concepts in electrophysiology

Perceived Difficulty of Electrophysiology Concepts

Very Easy — Very Difficult

1	2	3	4	5	6	7

	MEAN
1. Maintenance of cell volume, osmotic balance and tonicity	2.7
2. Ionic Equilibrium and Membrane Potential	
How diffusion potentials originate	3.3
The Nernst Equation....what it tells us	3.2
The principle of Electrical Neutrality	2.0
The cell membrane as a capacitor.	4.0
Donnan Equilibrium	3.3
The pump leak model of a real cell	3.3
The role of the sodium pump	2.7
The Goldman Equation	3.2
3. Basic Electrical- Physical concepts	
How coulombs are related to electron quantity	3.5

How coulombs are related to the Faraday	4.2
How coulombs are related to Amperes	4.2
How voltage,work and charge are related	3.8
The difference between AC and DC	3.5
How resistance is related to conductance	3.7
How the resistance of a conductor is related to cross sectional area	4
The relationship between conductivity and resistivity	4.2
Ohm's Law	2.6
Physical relationships that determine the quantity of capacitance in a capacitor	4.8
How charge, voltage and capacitance are related	4.2
The electric field and voltage 'sensors'	3.5

Current and voltage relationships in a charging and discharging capacitor	4.7
The membrane time constant	3.0
Parallel and Series Resistance circuits	2.7
Parallel and Series Capacitor circuits	2.5
4. Membrane Channels and Signalling	
Electrical Equivalent circuit of a membrane	3.6
The voltage clamp technique	3.8
The patch clamp technique	4.2
The role of probability in channel gating	3.2
TEA, TTX and the role of other pharmacological agents	2.4
How the ACh receptor operates	3.2
The difference between capacitive and gating current	4.4
Delayed rectifier channels	4.7
The role of Calcium channels	2.2
Activation and inactivation in channels	2.5

The Stokes-Einstein relationship	1.0
Diffusion Coefficients and molecular radii	3.5
The difference between pores and carrier molecules	2.0
Electrical and Chemical Driving Forces	2.0
5. The Action Potential and its Propagation	
Characteristics of the Action Potential	2.3
Initiation and Propagation of the Action Potential	2.7
Changes in relative permeability during the action potential	2.7
How Repolarization is achieved	2.9
What the refractory period represents	2.9
Role of the specific resistances Rm, and Rl	3.3
The Length Constant	4.7
Local currents and the spread of the action potential	4.2
The electrical role of Myelin	2.3
Have you taken the 3P03 course ? (circle one) YES / NO ?	

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