THE CELL MEMBRANE SCIENCE SUITCASE: AN EDUCATIONAL MODULE FOR HIGH SCHOOL BIOLOGY STUDENTS

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DEDICATION

I would like to thank my thesis committee for their guidance and help through this process. I'd also like to thank my parents and friends for their support.

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by

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This thesis documents the production and testing of an educational module, the Cell Membrane Science Suitcase, for high school introductory biology students. The module is part of the Science Teacher Access to Resources at Southwestern series of educational Science Suitcases, made available to teachers within the Dallas Independent School District and neighboring communities. The series is funded by the Howard Hughes Medical Institute, and produced by the Biomedical Communications graduate program at the University of Texas Southwestern, and the Dallas Museum of Nature and Science. The Cell Membrane Science Suitcase is intended to supplement the current curriculum with a comprehensive, three-dimensional animation, models, and student activities related to biological membranes. The goal is to not only provide a useful resource for teachers, but to engage and appeal to students through a variety of media and tools not often found in the science classroom.

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LIST OF DEFINITIONS

Texas Essential Knowledge and Skills (TEKS) – Established by the Texas Board of Education to represent the skills and knowledge students need to succeed throughout, and after, K-12.

Texas Assessment of Knowledge and Skills (TAKS) – A Texas Board of Education standardized test to assess student attainment of TEKS-required skills in writing, reading, math, science, and social studies.

CHAPTER ONE
Introduction

The Cell Membrane Science Briefcase is a multi-component educational module including 1) an animation; 2) tactile model; 3) classroom activities. The modules are intended to be a multimedia resource for high school introductory biology students in the Dallas-Ft. Worth area. The module, entitled *The Cell Membrane: A Portable Science Suitcase for Introductory Biology Students*, is part of the Science Teacher Access to Resources at Southwestern (STARS) Science Suitcase series. It is contained within a portable suitcase and made available for use in area classrooms. Components will also be available on-line, and available for students and teachers, outside of the tangible suitcase.

Goals and Objectives

The Cell Membrane Science Suitcase aimed to develop successful activities and multimedia resources to supplement and enhance DISD high school biology teachers' current strategies in teaching the topic of cellular membranes. Research into areas where students struggle with related material, and where teachers lack teaching materials, was beneficial in targeting key areas of improvement. The developed materials comprise five days of classroom activity for a total of five hours, target a variety of learning styles, and are contained within an easily portable briefcase.

To maximize the performance gains from using the briefcase materials, learning objectives were defined. To do this, research was conducted of the Texas Essential Knowledge and Skills (TEKS), the current textbook for DISD ninth grade biology, and current available literature and visual resources for education of cellular membranes. Joel M. Goodman, Ph.D., Professor in the Department of Pharmacology at UTSW, provided insight, and acted as primary content expert. Kenneth Coulter, Assistant Professor of Animation in the Biomedical Communications Graduate

Program at UT Southwestern, served as the animation advisor and thesis chair. Following a thorough literature and media review, a preliminary and formative survey of the target audience, DISD biology teachers, was conducted. Brainstorming sessions to assess current curriculum, identify topics students struggle with, and a review of current teaching materials, were also beneficial in guiding the project's development. Lynn Tam, STARS program coordinator at UTSW, served as high school science advisor. Lynn provided critical information based on her experience teaching high school biology in the Richardson ISD, as well as guidance for labs and activities. Teaching strategies and learning styles were additionally researched to ensure that the largest audience was reached by incorporating various learning styles with similar material. Based on knowledge obtained throughout the research process, as well as teacher surveys, learning objectives were written for the various media components comprising the briefcase.

The learning objectives drove the development of the briefcase components. The first component is an animation containing structurally accurate 3D geometry of membrane structures and function using atom coordinates derived from the PDB (Protein Data Bank) data. The video is intended to be a comprehensive teaching and review tool. It is organized into twelve chapters, and was produced as a DVD for classroom use, as well as made available online.

In conjunction with the animation, a tactile model with correlating activities was developed to demonstrate the hydrophobic effect. Twenty large scale phospholipid models were built by the Dallas Museum of Nature and Science from 3D geometry created from the Protein Data Bank, and a corresponding activity was produced.

Additionally, a membrane puzzle was developed to reinforce key aspects of cellular membrane structure. The *Build-A-Membrane* activity aimed to create an updated and more visually appealing, version of a commonly used lab, *The Fluid Mosaic Membrane*.

A teacher manual incorporating instructions and worksheets for all portions of the module was created. The activities and animation were presented to DISD biology teachers and tested on a sample audience for evaluation through a formative survey.

Significance

The TEKS (Texas Essential Knowledge and Skills) were established to represent the skills and knowledge students need to succeed throughout, and after, K-12. Students in DISD have continuously scored poorly on the biology Texas Assessment of Knowledge and Skills (TAKS), within which cellular membranes is a reoccurring topic. Membrane structure and function are core concepts in the ninth grade biology curriculum. Osmosis, transport across the membrane, and the hydrophobic effect, are concepts students continuously struggle with, according to preliminary surveys of biology teachers.

The overuse of teaching strategies used in science classrooms, namely lecture based approaches, have produced a state of 'Instructional Selection', or "an environment … created where only a subset of learners can succeed".[1] The key to avoiding 'Instructional Selection' and retaining a broader range of students interested in science is differentiated instruction. It is a teaching style derived from multiple instructive approaches, not a singular approach. This teaching style is the predominant strategy behind *The Cell Membrane: A Portable Science Suitcase for Introductory*

[1] Tanner K, Allen D. Approaches to biology teaching and learning: learning styles and the problem of instructional selection--engaging all students in science courses. Cell Biol Educ. 2004 Winter;3(4):197-201

Biology Students. The objective is to create a multi-component teaching module that targets multiple learning styles of the VAK framework. The VAK theory states there are three major learning styles: visual, auditory and kinesthetic.[1] Visual learners learn best through seeing and observing, such as through pictures, diagrams, and film. Auditory learners learn best through the spoken word, from themselves or others. Kinesthetic learners learn best through hands on experience such as touching, holding, and feeling.

Presently, DISD ninth grade biology students are taught cellular membrane information through teacher directed lecture, with supplemental lab work. Such reliance on lecture may provide an inadequate platform to reach the full spectrum of students, according to Tanner and Allen's theory of instructional selection. This module will supplement current membrane teaching strategies to reach a more diverse audience of learners through activities and materials emphasizing auditory, kinesthetic and visual learning. The comprehensive 3D animation will appeal to visual learners, and the phospholipid models provides hands on activity for kinesthetic learners. These components, combine with interactive class discussion, activity, and lecture, will target the full spectrum of learning styles.

Background

Science Teacher Access to Resources at Southwestern (STARS) was developed to improve the quality of science education in North Central Texas. Since its inception, the STARS Program has grown to serve over 6,000 teachers and 35,000 students in 2,000 schools in the Dallas/Fort Worth area. One of the goals of the STARS Program is to assist science education by providing instructional aids.[2]

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[2] "Texas Essential Knowledge and Skills" Texas Education Agency. www.tea.state.tx.us.

The Science Suitcase series was conceived by the UTSW STARS program, and funded by a grant from the Howard Hughes Medical Institute. Through collaboration with UTSW (Biomedical Communications Graduate Program), The Dallas Museum of Nature & Science, and STARS, seven suitcases are to be produced over a span of five years. These are portable kits illustrating principles of specific high school biology subjects. Each suitcase contains demonstrations and activities that DISD teachers can check out from the STARS office at UTSW. Evaluative surveys are included with each suitcase and used to assess the effectiveness of the series. The suitcases cover topics such as evolution, enzymes, membranes, organelles, cell respiration, and photosynthesis. *The Cell Membrane: A Portable Science Suitcase for Introductory Biology Students* is the sixth suitcase in the series.

The suitcase series was developed to be a part of the STARS annual Science Triathlon, which is a fifteen-month program for DISD biology teachers and students. The three-event triathlon was developed to provide training for biology teachers, educational materials for high school students, and encourage enthusiasm for science within the community. Event one is a twelve-day workshop during the summer, at UTSW, for DISD biology teachers. They receive training in seven laboratory exercises that demonstrate basic principles of biology. Thirty students also participate in the workshop, and are exposed to the laboratories and demonstrations at the Dallas Museum of Nature and Science. Event two is a demonstration and implementation of the Science Suitcase series during the school year. Event three occurs in the following summer. Teachers are paired with investigators at the medical school to perform a research project. Throughout the three events, the seven basic principles of biology are reinforced. These seven principles are the Texas Education Agency (TEA) mandated core science topics, and correspond with the seven topics covered in the science suitcase series.

Limitations

This thesis project is limited to level-appropriate information on membranes and related concepts. The activities contained within the suitcase must provide five days of classroom activity (one week of instruction) and the materials included in the suitcase, and the suitcase itself, must remain under 50 pounds. Also, long term testing of effect on TAKS scores will be completed outside the time frame of this thesis project.

CHAPTER TWO
Review of the Literature

Review of Cellular Membrane Literature

An important objective of this project was a thorough review of current cellular membrane literature, including journal articles, textbooks, and the Texas Education Agency (TEA) education requirements.

Texas Essential Knowledge and Skills (TEKS) and Textbooks

Texas Essential Knowledge and Skills or TEKS is the official K-12 curriculum for the state of Texas and details the curriculum requirements for every course. A state-mandated standardized test, Texas Assessment of Knowledge and Skills (TAKS) measures attainment of specific knowledge and skills.[3] In order to determine the content of the *Membrane* project, the current TEKS requirements were reviewed. Section 112.34 of the Science TEKS covers the knowledge and skill objectives for introductory high school biology. Relevant objectives were Bio 4A; "identify the parts of prokaryotic and eukaryotic cells," and Bio 4B; "investigate and identify cellular processes including homeostasis, permeability, energy production, transportation of molecules, disposal of wastes, function of cellular parts, and synthesis of new molecules."[4] Reviewing the TEKS established how and where membrane information fits into the curriculum.

The TEKS objectives cover broad concepts. In order to determine the specific curriculum for the introductory biology course, several popular textbooks were reviewed. *Texas Biology* is the DISD standard textbook for introductory high school biology. This textbook covers Singer and

[3] "Texas Essential Knowledge and Skills" Texas Education Agency. www.tea.state.tx.us.
[4] Texas Administrative Code (TAC), Title 19, Part II, Chapter 112, Texas Essential Knowledge and Skills for Science; 112.34

Nicolson's fluid mosaic model, polarity of phospholipids, polarity's effect on lipid bilayer formation (hydrophobic effect), and selective permeability. Passive and active transport are covered; this includes diffusion, osmosis, crossing the membrane, movement against a concentration gradient, movement in vesicles and membrane receptor proteins. Some key themes in the chapters are the relation of structure and function, and the cellular basis of life. Supplementary resources included with the textbook offers two-dimensional (2D) animations related to some of the topics in the chapter.[5] In order to create a resource DISD teachers could easily incorporate into their current lesson plans, the initial outline of the module was based on concepts and information covered in the *Texas Biology* textbook.

Current Research

Biological membranes make up a broad field of research that is continually advancing. For that reason, a review of literature was conducted on current research and information beyond that found in introductory biology textbooks. Current journal articles were reviewed and content expert, Joel Goodman, offered insights and direction. The review uncovered inaccuracies in textbook information and new scientific discoveries that are not yet included in curriculum.

The lipid raft concept for sub-compartmentalization in cell membranes has evolved over the past thirty years. Recently, advances in microscopy and spectroscopy were able to reveal these nanoassemblies within living cells.[6] Lipid rafts are nonrandom lateral organizations within a cell membrane, enriched with cholesterol, sphingolipid, and GPI-anchored protein. This concept is relatively new, and not included in current introductory biology texts. However, the ability of the cell membrane to sub compartmentalize, for a functional purpose, is a significant structural and

[5] Johnson, George, and Raven, Peter. *Biology.* Texas : Holt, 2004.
[6] Lingwood D and Simons K. Lipid Rafts As a Membrane Organizing Principle. Science. 2010 Winter;327:46-50

functional idea. Singer and Nicolson's fluid mosaic model is widely accepted, but since it's establishment is 1972, certain aspects need revision. A main idea of the model is random organization of the bilayer, this and other ideas are refuted by new research, such as lipid raft organization.[7]

The discovery of aquaporins was a landmark study in membrane channels. Water diffuses through lipid bilayers, but until the discovery of aquaporins in 1991, a generally held misconception assumed that simple diffusion accounted for all water movement through biological membranes.[8] Specialized membrane water transporter, aquaporins, are found in tissues with high water permeability. These proteins freely permit movement of water across the cell membrane and allow for higher levels of permeability in certain cells. So far thirteen forms of aquaporins have been found in animals and another thirty-five in plants.[9]

Membrane fluidity is a concept covered in *Texas Biology*, but is not accurately illustrated in the text or animations.[10] According to teacher interviews and an initial teacher survey, the concept is hard for students to understand. Also, teachers do not have access to any media depicting fluidity with lateral movement of phospholipids. To measure lateral movement of membrane components, fluorescence recovery after photobleaching (FRAP) has been the main tool for the past few decades. Membrane components are marked with fluorescent markers, and a high intensity laser light photobleaches a section of the membrane, destroying the markers. The method can use the

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[7] Wiśniewska A, Draus J, Subczynski WK. Is a fluid-mosaic model of biological membranes fully relevant? Studies on lipid organization in model and biological membranes. Cell Mol Biol Lett. 2003;8(1):147-59.
[8] Borgnia M, Nielsen S, Engel A, Agre P. Cellular and molecular biology of the aquaporin water channels. Annu Rev Biochem. 1999;68:425-58.
[9] Carbrey JM, Agre P. Discovery of the aquaporins and development of the field. Handb Exp Pharmacol. 2009;(190):3-28.
[10] Johnson, George, and Raven, Peter. *Biology.* Texas : Holt, 2004.

diffusion of outlying fluorescent markers back into the radiated patch to measure the fraction of lipids and proteins that move, the rate of movement, and the fraction of proteins that do not move. According to this, the rate of phospholipid lateral movement is 2 um per second. Also, on average, twenty-five percent of the proteins drift laterally, while the remainder are stationary, connected to cellular matrix or cytoskelton.[11]

Teaching Strategies and Learning Styles

For all components of the module, Blooms taxonomy of cognitive domains, "a well-defined and broadly accepted tool for categorizing types of thinking into six different levels: knowledge, comprehension, application, analysis, synthesis, and evaluation," is implemented as a framework for learning objectives. Blooms taxonomy has been used in K-12 education since the 1960s.

Cooperative learning is a highly successful instructional model commonly used in classrooms and implemented in this project. The model utilizes small groups of students working together to promote positive interdependence, face-to-face promotive interaction, individual accountability, social skills development, and group processing.[12]

Analysis of Three-Dimensional (3D) Animation in Teaching

Reviewing the visual resources associated with the DISD curriculum revealed that none of the visual media currently includes three-dimensional (3D) animation and limited availability of two-

[11] Jacobson K, Sheets ED, Simson R. Revisiting the fluid mosaic model of membranes. Science. 1995 Jun 9;268(5216):1441-2

[12] Brandt, Ronald S. "20th Century Advances in Instruction." *Education in a New Era*. Alexandria, Va.: Association for Supervision and Curriculum Development, 2000.

dimensional (2D) animation. Since the development of 3D media, research has indicated a clear benefit in using it to teach and visualize science concepts, especially related to cell biology.[13]

Value of Animation

Animation in general is a valuable educational resource. The value of graphics is associated with the dual-coding theory, which suggests that "long-term memory retention is facilitated by a combination of verbal and visual cues." As such, "animations are valuable aids in supporting the visual aspects of long-term memory."[14] By combining animation and narration, dual-coding is further supported.

A study was conducted on effects of media in student understanding. Five different media were tested in groups; 1) a static graphic group, 2) a static graphic with full audio group, 3) an animation group, 4) an animation with cued audio group, and 5) an animation with full audio group. Research results found that either static graphics without audio narration, or animation with full audio can help students understand the abstract concepts better than either static graphics with full audio or animation alone groups. Animation with full audio has the best effect on long-term retention.[15]

The animations currently available to DISD students only cover a few concepts related to membranes and generally are optional for student use. Appealing to students, especially visual learners, and improving long-term retention would be more effective if animations were provided

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[13] McClean P, Johnson C, Rogers R, Daniels L, Reber J, Slator BM, Terpstra J, White A. Molecular and cellular biology animations: development and impact on student learning. Cell Biol Educ. 2005 Summer;4(2):169-79.
[14] Paivio A. Dual Coding Theory: Retrospect and Current Status. Can. J. Psychol. 45, 255-287.
[15] Lai S. Increasing Associative Learning of Abstract Concepts Through Audiovisual Redundancy. Journal of Educational Computing Research. 2000;23(3):275-289.

and implemented on a larger scale. These realizations lead to creation of a comprehensive narrated animation covering introductory cell membrane concepts.

2D vs. 3D

Most current biology textbooks, including the DISD standard text *Texas Biology*, contain additional online or CD resources with animations that are two-dimensional (2D) interpretations of processes. Because they are flat, important spatial relationships of the process are not shown. Dalgarno et al.'s paper on the contribution of 3D environments to conceptual learning, defines a few features that distinguish a 3D environment from other learning resources. One of these characteristics is fidelity, or realism, offered by 3D rendering. This can be seen in realism of the display (using perspective, lighting and occlusion), smooth display of object motion, and consistent modeling of object behavior.[16]

According to a study by Csikszentmihalyi, some 3D environments "can be so engaging that our mental focus is shifted away from our surroundings…allowing us to focus entirely on the task."[17] Thus suggests that student motivation is a potential learning benefit.

The exploration of 3D environments that cannot be visited, whether it be outer space or molecular structures, is the most discussed application of 3D in learning. Winn and Jackson suggest that virtual environments are "most useful when they embody concepts and principles that are not

[16] Dalgarno, B, Harper, B, Hedberg, J. Dalgarno, B., Hedberg, J. & Harper, B. The contribution of 3D environments to conceptual understanding. *Winds of change in the sea of learning: Charting the course of digital education* (2002)
[17] Csikszentmihalyi, M. (1990) *Flow: The Psychology of Optimal Experience*, New York: Harper Collins.

normally accessible to the senses".[18] Scientific visualization, in particular, provides a way of "observing natural phenomena that, perhaps due to their size, duration, or location, are difficult or impossible to observe directly".[19]

Design Principles

In order to ensure an animation is effective, there are various design principles to keep in mind during production. According to the spatial contiguity effect, important terms within the animation should be included as "written text or labels adjacent to the event or structure under consideration, and include narration of the labels as they appear…When the written words are presented near the corresponding pictures, the student is more likely to hold the information in their working memory at the same time."[20]

Another research-based principle is the personalization effect, in which students learn more deeply when words are presented in conversational rather than formal style.[20]

Implementation

Although research has clearly shown the benefit of animation to student learning,[21] this is "maximized by lesson plans that include lecture and other learning inputs."[22] According to dual-

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[18] Winn, W. and Jackson, R. (1999) Fourteen propositions about educational uses of virtual reality. *Educational Technology* 39, 5-14.
[19] Litvak, S, Mintz, R, Yair, Y. 3D Virtual Reality in Science Education: An Implication for Astronomy Teaching. *Jl. of Computers in Mathematics and Science Teaching* (2001) **20**(3), 293-305
[20] Mayer R. The promise of multimedia learning: using the same instructional design methods across different media. Learning and Instruction. 2003;13(2):125-139.
[21] McClean P., Johnson C., Rogers R., Daniels L., Reber J., Slator B.M., Terpstra J., White A. Molecular and cellular biology animations: development and impact on student learning. Cell Biol Educ. 2005 Summer;4(2):169-79.
[22] Rieber L. Using animation in science instruction with young children. J. Ed. Psychol. 1990;82:135-140.

coding theory, "learning is best achieved when an animation is coupled with lecture, because this combination provides a reference from which students can appreciate the knowledge presented in the animation."[23] An in-class research experiment at North Dakota State University demonstrated that student retention of content material was significantly higher when students received a lecture coupled with animations and subsequently used the animation as an individual study activity outside of class.[21] The Cell Membrane animation will be most effective if provided as a DVD for classroom use and also made available online for individual student use.

According to preliminary DISD HHMI teacher interviews, short two to three minute chapters would make the DVD easiest to incorporate into lectures and also provide time for questions, to keep students engaged. Therefore, the animation was broken down into twelve two to three minute chapters that could each be played individually or as a full twenty-minute video. Also, chapter questions were included in the teacher manual.

[23] Paivio A. Dual Coding Theory: Retrospect and Current Status. Can. J. Psychol. 45, 255-287.

CHAPTER THREE
Methodology

Concept Development

The goal of this thesis project was to create a learning module that would supplement and enhance DISD high school biology students' current biological membranes curriculum. Surveys of, and discussions with, current DISD teachers, research of journal articles, textbooks and educational media, and meetings with content experts and committee members resulted in the decision of what to include in the module. A 3D animation was developed, as a DVD and online flash video. This required production of a script, storyboard, animatic, and teacher and student evaluation. Activities were outlined, approved by committee, produced with the help of the Dallas Museum of Nature and Science, and tested on a sample audience. A teachers' manual was also produced, and all components were organized into a briefcase.

Target Audience

The target audience for this project is DISD ninth grade introductory biology students. The students will use the video, models, and activities in class, as well as the video as an individual study aid outside of class. The current DISD Introductory Biology textbook, section 112.34 of the Science TEKS, and teacher surveys were used to ensure all project content was considered level appropriate. The 3D animation imagery, voice narration style, and hands-on activities were all designed to appeal to the ninth grade age group.

Pre-Project Planning

Initial Meetings and Preliminary Survey

A committee of experts and UTSW Biomedical Communication faculty were assembled to discuss and facilitate the production of this project. The committee consisted of Kenneth Coulter, Associate Professor of Animation in the Biomedical Communications Graduate Program at UTSW, Joel M. Goodman, Ph.D., Professor in the Department of Pharmacology at UTSW, and Lewis Calver, Associate Professor in the Biomedical Communications Graduate Program at UTSW. Kenneth Coulter was the project advisor, and Joel Goodman acted as content expert. Lynn Tam, Program Coordinator for the STARS program, acted as an additional expert. Steve Hinkley, Education Coordinator at the Dallas Museum of Nature and Science, and Kyle Brewer, graduate student in the Department of Biomolecular Sciences at UTSW, provided further input.

During initial meetings of committee members, general goals of the STARS Science Suitcase series were discussed. It was important to include at least five days worth of classroom activity, to make sure the contents of the suitcase were not too heavy to transport, to talk with teachers for a better understanding of what works and what doesn't in high school science classrooms, and to incorporate new and current research ideas. A basic content outline was then created and reviewed by the committee. The outline was continually added to and changed throughout the initial stages of suitcase planning.

During this time, preliminary surveys of Dallas science teachers were conducted to evaluate current curriculum and teaching materials, available electronics/lab equipment, and what media and materials they would be most likely to use in their classrooms (see Appendix A). A joint survey was developed for the Membrane Science Suitcase and the Genetics Science Suitcase composed of yes/no, multiple-choice and open-ended questions. The survey was distributed to 100 Dallas science teachers by the STARS department, via e-mail. Five teachers responded. All

participants were high school teachers teaching science as their primary course. The results were collected and evaluated (Appendix A).

Evaluation of Survey Responses

The following are responses to some of the more relevant survey questions.

All participating teachers had access to a TV and DVD player in their classrooms, and their students had access to computers and internet in class (questions 7 and 8). Three out of the five participants believed their students all have access to computers and internet outside of class. The remaining two did not know (question 9). These results help in evaluating the type of media to use in the suitcase.

Overall participants taught similar topics, none reaching beyond the content outline established for the suitcase. Osmosis and membrane transport were found to be the most difficult subject for students of this sample group (question 11 and 12). The majority of participants also believed models were the most important form of media for teaching the cell membrane and that games were the least. Animation and visual aids was split evenly among the group (question 16).

While four out of five participants have used 3D animation when teaching a class, only two out of five have used animation to teach, specifically, cell membranes (questions 18 and 19). However, all participants would be willing to use animation to teach cell membranes (question 20). This indicates an interest in using animation to teach this topic, but perhaps a lack of availability. One teacher additionally commented that the textbook's online resource has some animation but that, "they aren't satisfactory and certainly aren't 3D."

Lastly, four out of five teachers believed a hands-on model demonstrating the hydrophobic effect would be useful, some showing strong enthusiasm for the idea, the fifth did not know (question 21). All participants would be willing to use a game to teach cell membranes and when given the choice, prefer a simple or moderate level game to anything complex (questions 23 and 24).

Secondary Meetings

A group of twelve HHMI DISD science teachers assembled for a meeting and brainstorming session. The initial model and activity ideas, and content outline were presented to the teachers. They provided direct feedback. The teachers explained what imagery and concepts they would like to see in the animation and brainstormed activity and model ideas. The teachers also provided handouts of membrane labs they used over the years. Most teachers in the group use the same few labs, *Elodea Leaf* (or version with an onion/potato), *Build-A-Membrane*, and *Osmosis in Action* (using dialysis tubing) when teaching membranes. Lynn Tam also provided five labs used within the DISD.

After subsequent meetings of the committee, and consideration of time and budget, it was decided that a video, a model with a corresponding activity, and one lab would be included in the suitcase. The video would be a comprehensive 3D animation on the structure and function of the cell membrane. The activity would include a model and teach the hydrophobic effect. The lab would be either an original lab developed by a UTSW graduate student or an enhanced version of a commonly used lab.

Learning Objectives

The next step was producing learning objectives for the entire module (see Appendix B). The suitcase was intended to cover main topics related to cell membrane structure and function.

Current introductory biology textbooks, current membrane research, learning research, and preliminary surveys were referenced to create the list of learning objectives. Each learning objective fit into one of the Bloom's taxonomy levels of learning: knowledge, understanding, application, analysis, synthesis, and evaluation.

Animation

In developing the animation, a script, storyboard, and animatic were produced and tested before the final animation was rendered and compiled. The final output of the animation was as a multi-chapter DVD, as well as flash video file for upload to the STARS website.

Script

Audio and animation were written out for each individual learning objective. Textbooks and journal articles were researched to produce content, and content expert Joel Goodman provided direction and editing. The audio sections were organized into a first draft of the script. Joel Goodman edited and made suggestions, and after some changes, approved the script (see Appendix C).

Storyboard

An animation storyboard was produced with the second draft of the script. The storyboard was comprised of scene sketches with accompanying audio, creative commentary, and notes on camera movement and action (see Appendix D). This was reviewed with project advisor, Kenneth Coulter, and revised.

Style

At this point, the overall style of the animation was also established. Current DISD textbook images of the cell membrane are simplistic and 2D (see Figure 3-1). Many spatial relationships are lost. The style for this animation was decided as a semi-realistic and aqueous cell membrane environment, to capture much of which basic models of the membrane fail to.

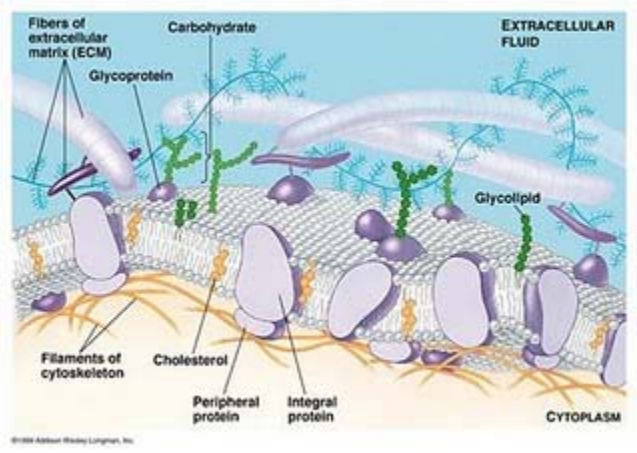

Figure 3-1. Image from *Biology* textbook of the cell membrane. Campbell, N, and Reece, J. *Biology*. Benjamin Cummings, 2004.

The cell membrane is 8 nm thick and covers an entire cell. One of the animation goals was to capture the vastness of the environment, as well as the aqueous quality. The cell membrane is microscopic, but correctly portraying size relations is important in any 3D environment. So images of vast deserts, as well as ocean floors, were used as inspiration. The aqueous, fluid quality of the cell membrane would be highlighted by a fluid underwater environment. Molecularmovies.com and other 3D molecular animations (*Inner Life of a Cell*) were referenced as style guides and examples, and the final look was established (see Figure 3-2).

Adjusted microscribe shaders were utilized to give the 3D models a slight electron micrograph appearance. The color scheme was based on the look of colorized electron micrographs, desaturated with pops of bold color. Bright, and highly saturated colors (teal, magenta, purple, lime, red-orange, yellow) were used to appeal to a high school audience.

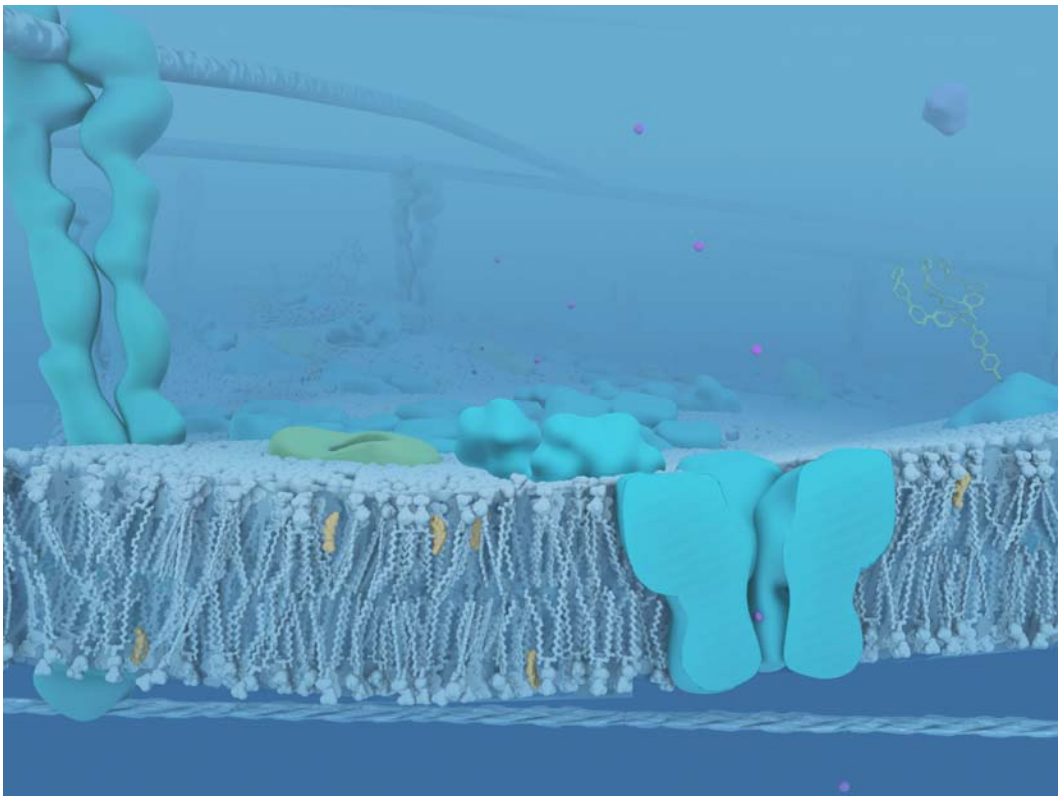

Figure 3-2. Still from *The Cell Membrane* final animation.

3D Modeling

Before producing the 3D models, an asset list was established, based on the storyboard. The list included all 3D models and special effects techniques needed to execute the animation. These

elements needed to be either produced or purchased. The assets were produced in Autodesk Maya® or purchased from www.Turbosquid.com.[24]

The Protein Data Bank[25] and other online molecular structure resources were utilized to gather files (.pdbs) containing atom coordinates of most of the membrane structures. The data was imported and visualized in Autodesk Maya® software using the pdbReader mel plug-in. The jPivToParticle mel plug-in was used to convert the coordinates to a particle system. At that point, the particle render type could be manipulated to create the desired level of molecular detail. This method was used to visualize phospholipids, channel protein, glucose carrier protein, glucose, sodium potassium pump, integrin, talin, receptor protein, aquaporin, cholesterol, and actin filaments of the cytoskeleton.

[24] *3D Models, 3D Modeling Textures and Plugins at TurboSquid*. Web. Summer 2010. <http://www.turbosquid.com/>.
[25] *RCSB Protein Data Bank*. RCSB. Web. Summer 2010. <http://www.pdb.org/>.

a **b**

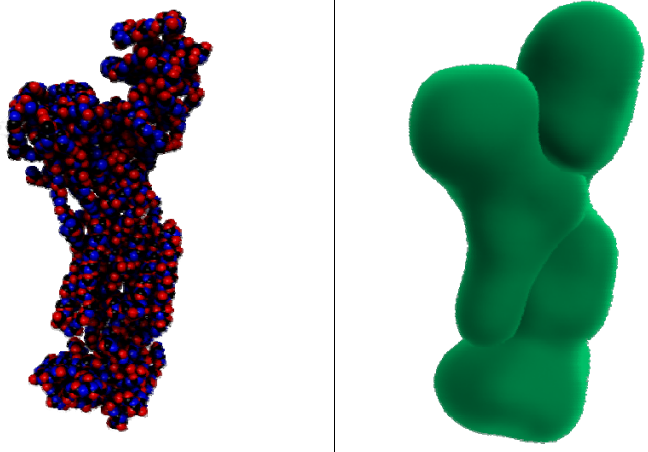

Figure 3-3 (a) Visualized pdb atom coordinates for sodium potassium pump, produced in Autodesk Maya® using the pdbReader mel plug-in and **(b)** converted to a particle system using jPivToParticle mel plug-in.

The original intent was to create a realistic underwater environment for all the action of the animation to take place. John Clark's *Maya Dynamics: Underwater Environments* was referenced while creating the 3D environment in Autodesk Maya®. An underwater environment can be created using a fog cube, animated caustic lighting and light rays, and particle sprites for particle debri. Through development it was established that the animated caustic lighting and light rays were too distracting during the animation, and were removed. However the underwater concept remained.

Animatic

A rough audio track of the script (second draft) was recorded with non-professional talent at the UTSW Biomedical Communications graduate program. The rough audio track was edited in Adobe Premiere® and incorporated into an animatic, an animated version of the storyboard. The

animatic was produced in Adobe Premiere® and consisted of playblasts exported from Autodesk Maya® (see Figure 3-3), still images, and 3D objects animated in 2D.

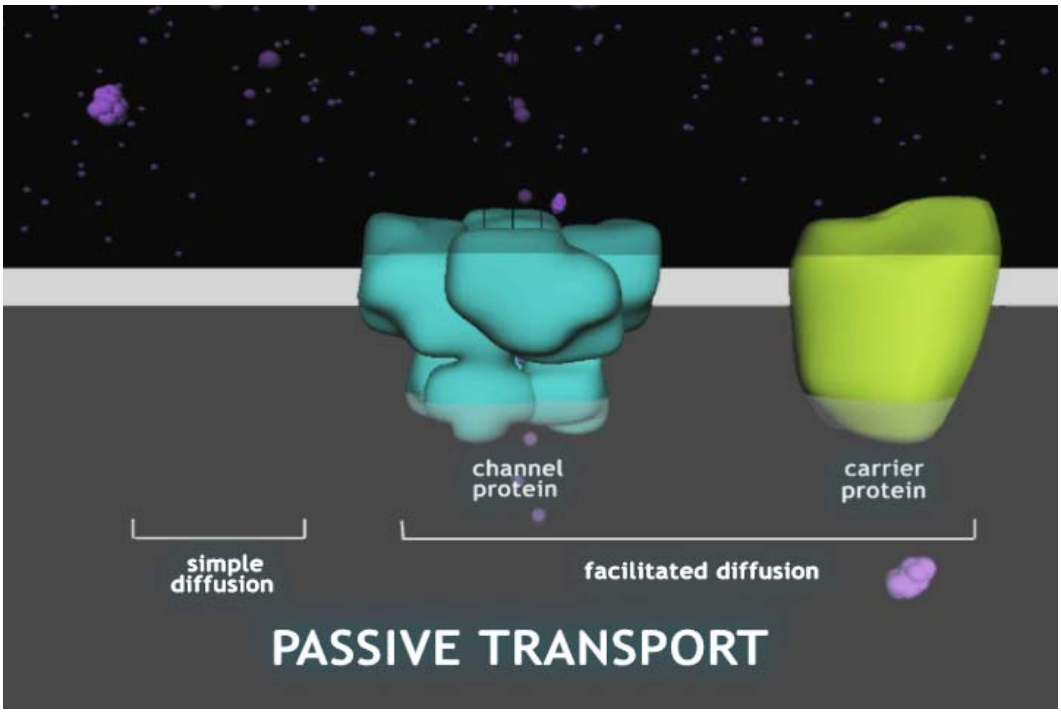

Figure 3-4. Playblast still from *The Cell Membrane* animatic.

Narration

Once the final draft of the script had been approved by my committee, and had been tested for timing with the animatic, it was time to record the final audio. Sound studio facilities at the UTSW Medical Television Center were rented, and voice talent, Dan Young, was hired to record the narration.

Animating

During the process of final animation, the storyboard and animatic were continuously referenced.

Focus was placed on lateral movement of phospholipids and some protein, as well as lipid raft movement, “like a raft on an ocean,” according to the content expert.

Final Production

Final rendering from Autodesk Maya® was done using both Mental Ray and Maya Software. Rendering passes included color, ambient occlusion and specular highlight layers. After Effects® was used to compile and edit the render layers. At this point, adjustments to brightness and contrast, color correction and any necessary masking was performed. Each sequence was exported as Quicktime .mov file using H.264 compression and imported into the animatic Premiere file. Here it was combine the newly recorded and edited audio.

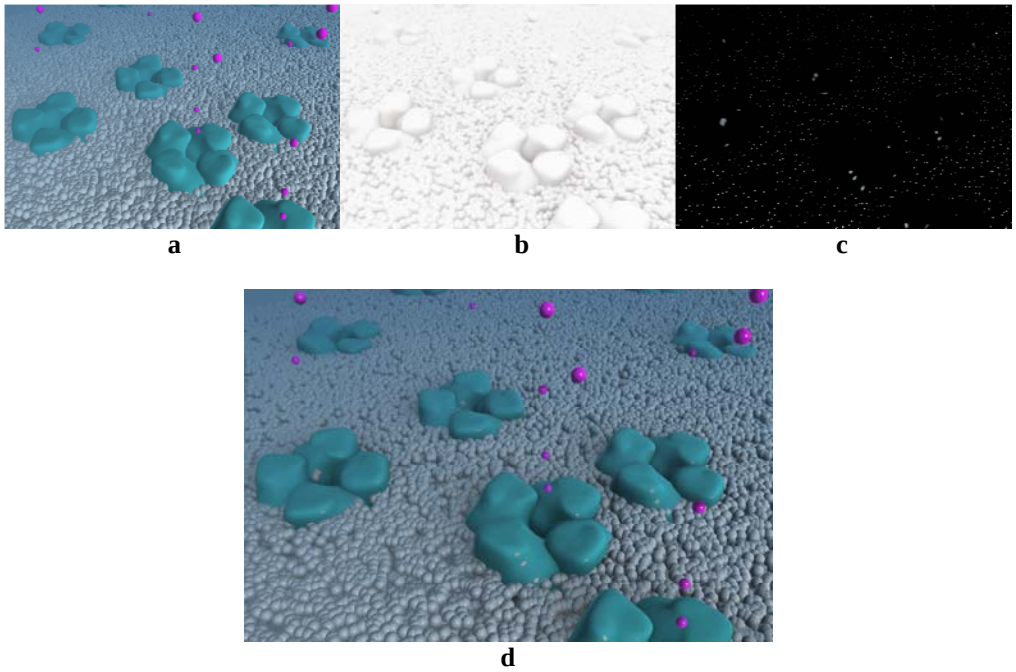

Figure 3-5 (a) Color render pass **(b)** Occlusion render pass **(c)** Specular highlight render pass **(d)** Composited render layers.

After the movie transitions and titles had been added, an .mov of just the animation was exported from Premiere® and imported into an After Effects® file. At this point a ripple effect adjustment layer was added to the entire video sequence, the video was exported again as an .mov, and imported into the same Premiere® file. Titles became revisable and the final .mov chapters were exported to Adobe Encore®.

The final output of the animation was as a multi-chapter DVD, as well as flash video file for upload to the STARS website. To produce the DVD, each chapter was exported from Adobe Premiere® as a Quicktime® .mov to Adobe Encore®. Chapters were added and the Encore® file was burned to DVD. A DVD cover was designed, and five DVDs were packaged.

To produce the flash video file for use on the web, the entire animation sequence was exported from Adobe Premiere® to Adobe Media Encoder® as a 10 minute video.

Hydrophobic Effect Activity

Based on feedback from the initial teacher meetings, the hydrophobic effect is difficult for students to understand and also lacks many available teaching models or games. Brainstorming began with teachers, as well as the thesis committee, and the Dallas Museum of Nature and Science production staff to come up with an original activity and model.

The initial idea for the hydrophobic activity was a collection of large scale phospholipid models depicting the polar phospholipid head's affinity for water, and the hydrocarbon tail repulsion, in a tank of water. When a model was added to the water it would float, tails up. Multiple models added would create a monolayer. A prototype was developed by the Dallas Museum of Nature

and Science. The model was sculpted and a mold created from a 3D model built in Autodesk Maya®. Models were poured and set in a floatable plastic material, holes drilled in the head, and weights added to achieve the correct floating level. Unfortunately, the prototype did not achieve desired results.

A hydrophobic activity was instead produced centered around individual phospholipid models (see Figure 3-5), sans floating tank. The new activity requires students to understand and build assemblies (bilayer and monolayer) with the model. The tangible model gives students a sense for the three dimensional structure of a phospholipid, and engages students in a hand-on project. Also, teachers currently do not have access to phospholipid models in the DISD classrooms. The worksheet accompanying the model takes students through polarity, the hydrophobic effect and polarity, and the hydrophobic effect and phospholipids (see Appendix E).

Figure 3-6. Tactile phospholipid model for Hydropphobic Effect Activity.

The activity was tested and evaluated by a sample audience to ensure usability.

Build-A-Membrane Activity

A common lab currently used by DISD introductory biology teachers for the membrane structure and membrane transport, is *The Fluid Mosaic Model* (Appendix F). The images included in this activity are simplistic, inaccurate, black and white line drawings. To teach structure of the membrane, accurate, appealing visual should be presented.

New images were created using 3D assets from the animation. The new version of lab (Appendix G) was then tested on a sample audience.

Teacher Manual and Briefcase

A Pelican briefcase was ordered through the Dallas Museum of Nature and Science to contain all items and supplies of module.

The manual was organized into six sections, including a suggested five day lesson plan (Appendix), DVD follow-along questions and answers (Appendix), Hydrophobic Effect Activity teacher guide and student worksheet, and Build-A-Membrane teacher guide and student worksheet. The manual pages were printed on durable paper and spiral bound with dividers.

CHAPTER FOUR
Evaluations

Survey Development

To ensure this project met its goal, evaluation was performed throughout the development process. Initially, preliminary surveys of Dallas science teachers were conducted to evaluate current curriculum and teaching materials, available electronics/lab equipment, and what media and materials they would be most likely to use in their classrooms (see Appendix A). Secondary assessment occurred with the presentation of initial ideas to a group of HHMI DISD science teachers. They provided direct feedback, insight and suggestion.

As a final evaluation of the video developed for the suitcase, an online link to the animation and survey was developed for Dallas high school science teachers. The animation presented was the animatic version so teacher input could help shape the final product. Teacher surveys were distributed, via e-mail, to the STARS contact list of Dallas science educators. The results provided key feedback for final development of the video.

The activities aimed to provide for a variety of student learning styles through hands-on interaction. The final evaluation was conducted on a sample audience of UTSW Biomedical Communications graduate students. The activities were tested via a survey for usability and appeal.

The teacher survey consisted of nine statements and four open ended questions. For each of the nine statements the participants were asked to indicate their level of agreement based on a five point Likert scale. An answer of five being “strongly agree”, one being “strongly disagree”. These statements and questions were intended to evaluate the effectiveness of the content,

imagery, and animation, as well as the overall video as a teaching tool. Under each statement was an area for the participants to write additional comments.

The activity survey was composed of five statements, also answered on a Likert scale, evaluating the effectiveness of the visuals, models, and overall usability of the activity.

Survey Distribution

The animatic was exported as an FlV (Flash Video) and a website was created for teachers to view it. The video link and survey was distributed to 40 teachers as an e-mail through the STARS program.

To test the activities, each was performed with a group of six participants (Biomedical Communications graduate students) in a mock classroom setting.

Evaluation of survey responses

Animation Survey

Of the 40 teachers surveyed, seven responded. Four filled out the full survey, the remaining three provided only open feedback. The seven participating teachers all taught Introductory and/or AP Biology, and five of them taught within the DISD. The following are the responses to the survey statements.

Statement 1. I think the video was easy to follow and the concepts are presented in a logical order.

2 Strongly Agreed, 2 Neutral

One neutral viewer commented that she wanted to see, "links in the video that allow those watching the video to open chapter in the order of their choosing." Due the format in which the survey/animation was distributed, she did not know that the final format of the animation is as a DVD that allows the user to choose and play individual chapters from the video. Other viewers commented that it was, "very easy to follow the sequence."

Statement 2. I think the chapters were effective in covering their topic

4 Agree

One viewer felt that, "this is a lot of material to cover in 10 minutes, so some of the topics were a bit short in coverage, others too long…This video appears to be of a review of concepts already covered in lecture (or as a side-by-side presentation). I wouldn't necessarily use it to introduce the topics." This comment was accurate. The video is supposed to be incorporated into lecture, not as a stand alone introduction. The idea was to create a comprehensive video to help students visualize the information as it is presented.

Statement 3. I think the level of information is appropriate for Introductory Biology students.

3 Agree

One viewer agreed, and also commented that, "I don't teach about lipid rafts at the introductory level." This response was expected. The nature of this video was to cover the topic of cell membranes a little beyond the necessary information, and provide accurate, up to date information. Many teachers do not teach lipid rafts at the introductory level, but it is an important aspect of cell membranes, and so was included in the video.

Statement 4. The concepts in this video fit into my curriculum.

2 *Strongly Agree, 1 Agree*

One of the viewers that responded to this statement commented that there was, “definitely complete coverage.”

Statement 5. I would use this video in my classroom and/or have my students view it online.

3 *Strongly Agree*

Similar to statement two, a viewer felt the video was more, “a review than a preview.” This is the intent of the video, to be a visual supplement to teacher lecture and to be used as a student review tool outside of class.

Statement 6. The imagery is clear and helpful.

1 Strongly Agree, 2 Agree

Though not all viewers provided a response to the statement, others provided feedback. One viewer wrote, “animation is great, but more labeling and closed captioning would be helpful.” The need for more labeling and close captioning comes up again in statement seven. Another viewer commented that, “I particularly like how the video impresses upon the viewer that the membrane is not static.” The overall response to the imagery was positive.

Statement 7. The 3D imagery/animation will appeal to students and keep them engaged.

1 Agree, 3 *Neutral*

Positive comments were made about the imagery and animation, but overall viewers were neutral about how well the video would keep students engaged. One viewer commented that, ”even the rough draft is beautiful. I am looking forward to seeing the final copy.” Others wrote, “the video was awesome, but long and I could envision students losing interest when there’s no engagement with the video. I would suggest having challenging questions from time to time so that students can take part in the video.” Also, “although the animation is good, the “storyline” is rather dry and packed with so much info I see attention spans wandering – mine did after the first 3 minutes – maybe some music or special effects to catch their attention (in an appropriate way) would help. Also each topic just blended into the next, so it would be nice to have something separating but segueing into each concept.”

The viewers seemed to think the animation and visuals were appealing, but had concerns about how engaging the video was for students. It seemed the 3D animation alone was not enough to keep students watching. To remedy this, questions were inserted between chapters. This both allows students to take part in the video, and catches their attention between sections. Based on the feedback, it seems the objective of creating a dynamic 3D environment to engage students was not effective for the span of 10 minutes. So other strategies were implemented to increase student engagement.

Statement 8. This video will enhance my current lesson plan for teaching the cell membrane.

3 *Agree*

Again, only a portion of the viewers provided their level of agreement with the statement. No additional comments were given.

Statement 9. The information presented will help students with TEKS and TAKS.

3 Strongly Agree

One teacher wrote, “definitely all topics covered are required by TEKS, should help with the TAKS.”

The following questions were open-ended.

Question 11. Are there are additional topics you would like to see in this video?

3 No

One viewer commented, “no, this covers a lot already.”

Question 12. Would you like any of the current chapters to go more in depth?

2 Yes, 1 No

One of the viewers who answered yes commented, “especially give examples of the molecules being transported; also aquaporins weren't mentioned for water molecule transport, polar and nonpolar wasn't explained (but again, this could be done a lecture).” Polar and nonpolar were not covered in depth in the video, however are explained extensively in one of the module activities (*The Hydrophobic Effect*). Aquaporins were mentioned for water molecule transport, so that statement was unclear.

Question 13. Would you like to see more labels and text boxes throughout the animation?

4 Yes

The majority of viewers mentioned this during the survey. One viewer also brought to attention the needs of ESL and hearing impaired students, she wrote, “absolutely needs more - like closed captioning and labeling of molecules, maybe a legend or key that pops up from time to time - I can see ESL and hearing impaired students having difficulty following this video.” After this

comment, the video was edited accordingly and twice as much close captioning and text was added throughout the animation.

The animation survey provided feedback on the animation content, appeal of 3D animation to students, and usefulness of the resource to current DISD teachers. Overall, feedback was very positive. The majority of participants agreed the content is appropriate for introductory students, would fit into their current curriculum and is relevant to TAKS. The response to the 3D imagery was extremely favorable by all viewers and the majority said they would use it in their classrooms. However, a majority of the viewers also agreed there was a need for more interactivity and close captioning. Based on responses, alterations were made to the final video.

Hydrophobic Effect Activity Survey

Statement 1: I enjoyed this activity

1 Strongly Agreed, 5 Agreed

Statement 2: The models helped me comprehend the material.

3 Strongly Agree, 3 Agree

Statement 3: The visuals were appealing.

2 Strongly Agree, 4 Agree

Statement 4: The hands on aspect of this activity was appealing.

3 Strongly Agree, 3 Agree

The majority of participants strongly agree that the hands on aspect of the activity was appealing. This was one of the main objectives of the phospholipid model activity, to appeal to students through hands on learning. This appeared to be successful with the sample audience.

Statement 5: After watching the animation, the corresponding model enhanced my understanding of phospholipids.

4 Strongly Agree, 2 No Response

All participants that answered this question strongly agreed. The participants that did not answer, did not leave comments, so it is undetermined what they felt about this statement.

Build-A-Membrane Activity Survey

Statement 1: I enjoyed this activity

4 Strongly Agreed, 2 Agreed

Statement 2: The visuals were appealing.

3 Strongly Agree, 1 Agree, 2 Neutral

Suggestion was made to make the images, "less toned and more graphic." One participant commented the visuals were, "so much better than the original."

Statement 3: The hands on aspect of this activity was appealing.

5 Strongly Agree, 1 Agree

While the majority found the hands on nature appealing, participants found the cutting portion of the activity time consuming and suggested, "deck of cards or puzzle may be more engaging for students." Due to cost and time constraints, the paper cut outs were the most practical option. The amount of cutting in the activity was decreased for the final version. However, these suggestions were beneficial for changes that could be made in the future.

Statement 4: The Build-A-Membrane activity is an improvement over the original.

4 Strongly Agree, 2 Agree

Viewers commented, "images are so much better, huge improvement," and, "more accurate resemblance of the structures. Old ones looked so crude and terrible."

Overall, the sample audience agreed the activities fulfilled the objectives set forth.

CHAPTER FIVE
Conclusions and Recommendations

Project Summary

This thesis documented the development, production and testing of a multi-component educational module for high school biology students. The module contains a 3D animation, a tactile model, and classroom activities. The module covered introductory topics related to biological membranes, such as the hydrophobic effect, the cell membrane structure and function, including compartmentalization, membrane transport, membrane fluidity, and organization.

The developed materials comprise five days of classroom activity, target a variety of learning styles, and are contained within an easily portable suitcase. Literature and media review, a preliminary survey of the target audience, DISD biology teachers, as well as brainstorming sessions helped guide the project's development. Teaching strategies and learning styles were additionally researched to ensure that the largest audience was reached by incorporating various learning styles with similar material.

The materials were produced and presented to DISD biology teachers and a sample audience of Biomedical Communication graduate students for evaluation through a formative survey.

Successes

The Cell Membrane Science Briefcase aimed to develop successful activities and multimedia resources to supplement and enhance DISD high school biology teachers' current strategies in teaching the topic of cellular membranes. Based on the results of evaluation throughout the

development process, the goals and objectives of this thesis project were successfully met. The final surveyed teachers perceived the video as a helpful learning and review tool. 3D animation and imagery in the video were thought to be clear and appealing for students. However, the video was not believed to be able to keep a student engaged for the 10 minutes. So, changes were made to increase student interaction and engagement with the video. The activities were perceived as enjoyable, with an appealing use of hands on models. Overall the responses were very positive, and helped in the final stages of development. Minor changes were made based on the feedback. All these factors lead to the belief the project will be a worthwhile resource for DISD introductory high school biology students.

Suggested Areas for Further Research

Long-term Testing

The STARS program will be conducting long term testing on the effectiveness of Science Suitcase Series. This will be completed outside the time frame of this thesis project, over the next two to three years. Teacher surveys will be included with the Cell Membrane Briefcase and filled out by each teacher that uses it.

Producing a Digital Suitcase

Interactive and computer based educational modules could be an interesting new direction for the Science Suitcase series. Implementing completely digital educational modules or 'suitcases' has the potential to reach more students. Multiple classrooms could simultaneously use one digital suitcase, while currently, only one teacher can check out a *The Cell Membrane Science Suitcase* at

a time. Further research into the educational value of interactive computer simulations, labs, and games would shed more light on this possibility.

APPENDIX A
Preliminary Survey Responses

Do you teach or practice within DISD?
1 Yes, 4 No

Do you teach Science as your primary lessons?
5 Yes

Do you have access to a TV and DVD player in class?
5 Yes

Do your students have access to computers and internet in class?
5 Yes

Do they have access to computers and/or internet outside of class?
4 Yes, 1 Don't Know

Do you have access to a centrifuge in your classroom/lab?
2 Yes, 3 No

What concepts about Cell Membranes do you teach? Circle or list additional concepts:

Compartmentalization of the Cell: *2 Yes*
Fluid Mosiac Model: 5 *Yes*
Lipid Rafts: *1 Yes*
Membrane Fluidity: *2 Yes*
Membrane Transport: *5 Yes*
Cell to Cell Communication: *3 Yes*

If any concepts, which seem to be difficult for the students to understand?
Transport: *1 Yes*
Osmosis: *2 Yes*
Structure: *1 Yes*

Do you have time to teach material about Genetics, Genetic Mutations or Cell Membranes that may go beyond the established guidelines found within the TEKS requirements?
2 Yes, 1 No, 2 Don't Know

Do you currently use any kind of visual aids, models, animations or games to teach Genetics, Genetic Mutations or Cell Membranes?
4 Yes, 1 Don't Know

Do you think that visual aids, models, animations or games are useful in teaching Genetics, Genetic Mutations or Cell Membranes?
4 Yes, 1 Don't Know

If "Yes", in what order, from most useful to least, would you place each item?

Please list the following: Visual Aids, Models, Animations and Games (from MOST important to LEAST)

Participant 1: Visuals, Models, Games, Animation
Participant 2: Models, Games, Animations, Visuals
Participant 3: Animations, Visuals, Models, Games
Participant 4: Models, Animations, Visuals

From these items of Visual Aids, Models, Animations and Games, are there any you have never used before?
1 Yes, 3 No, 1 Don't Know

Have you ever used interactive media animations, such as a comprehensive 3D animation, to teach a class?
4 Yes, 1 No

Have you ever used such animations to teach Genetic Mutations or Cell Membranes?
2 Yes, 3 No

Would you use, or be willing to use, an animation to teach Genetic Mutations or Cell Membranes?
5 Yes

Would you find a hands-on model demonstrating the Hydrophobic Effect useful?
4 Yes, 1 Don't Know

Have you ever used a game to teach Genetic Mutations or Cell Membranes?
2 Yes, 3 No

Would you be willing to use such to teach Genetic Mutations or Cell Membranes?
2 Yes, 1 No, 2 Don't Know

If you would use games, would you feel you have the time to read the instructions on how to use the games properly?
3 Yes, 1 No, 1 Don't Know

What level of complexity would you accept in a game for classroom use?

Simple: *2 Yes*
Moderate: *4 Yes*
Complex: *2 Yes*

What type of game would you prefer for teaching Genetic Mutations or Cell Membranes?

Interactive games: *5 Yes*
Board games: *3 Yes*
Card games: *4 Yes*
Communication games: *3 Yes*
(Shout-out games)
Word games: *4 Yes*
Memory games: *3 Yes*
Matching games: *1 Yes*
Physical models: *4 Yes*
Combination: *4 Yes*
(A game that is integrated into a usable model)

Would you prefer a game that can be played quickly in one day, or that can be played across several days?
5 One day

That has few pieces but simple, or more pieces but a more complex game?
4 Few pieces, 1 More pieces

That follows a standard well known game, like Chutes and Ladders, or is different from what most students have played?
5 Standard

.

APPENDIX B
Learning Objectives

Overall Goal: This animation will supplement current teaching strategies to help student understanding and retention of the core cell membrane concepts of the DISD introductory biology course and the biology TEKS.

Execution: By incorporating 3D animation as a major presence in teaching cell membranes, in conjunction with lecture and hands-on labs, the three major student learning styles are targeted. Thus instructional selection, the creation of an environment where only a subset of learners can achieve, is avoided (Tanner and Allen 2004). The use of animation to improve student retention is most effective when students receive a lecture coupled with the animations and then used the animation as an individual study activity (McClean et al, 2005). Therefore, this animation will be part of class activity as a DVD and also be made available online.

LO1

Educational Goal:
Students will construct a 2D cellular compartment diagram and define its common function. This will utilize Bloom's Cognitive Domains *Application* and *Knowledge*, respectively.

Execution:

Audio
"Organelles provide protection for the cell's interior and regulate its interaction with the extracellular environment. Membranes are found around the entire cell, mitochondria, the Golgi apparatus, lysosomes, and the nucleus. Here you can see a lysosome, an enzyme containing organelle, as it is digesting an old, worn out organelle. The membrane surrounding the digestive enzymes is necessary as a barrier between the digestive enzymes and the rest of the cell."

Visuals

1. animate camera zooming in close to a cell
2. top half fades out
3. highlighting of various compartmentalized cellular components occurs
4. camera zooms closer to focus on a lysosome
5. animate lysosome digesting expended organelle

highlight surrounding compartmentalized organelles that would otherwise be effected by the digestive enzymes if not for membranes

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LO2

Educational Goal:
Students will be able to visually identify each component of a typical phospholipid bilayer (based on the fluid mosaic model/lipid raft theory and utilizing the Protein Data Bank to visualize molecular structures) and describe each component's structure and function. This will utilize Bloom's Cognitive Domains *Comprehension* and *Knowledge*. Presenting a proper mental model for the students can give them a platform from which to visualize the material read in the textbook and presented in lecture (Brisbourne et al, 2002).

LO2a

Educational Goal:
Students will describe the functions of two types of cell-membrane proteins.

Execution:

Audio
"Cell membranes contain different types of proteins. Marker proteins attached to a carbohydrate on the cell's surface help cells recognize cells of their own type. Receptor proteins bind specific substances, such as signal molecules, outside the cell. Enzymes embedded in the cell membrane aid in biochemical reactions. Transport proteins aid in the movement of substances into and out of the cell."

Visuals

1. camera move to cut edge section (3/4 view)
2. membrane structures (except proteins) fade to transparent 'glass'
3. marker protein highlighted
4. animate cell entering and 'recognizing' the marker
5. receptor protein highlighted
6. signal molecule enters from off screen to bind to receptor
7. flash occurs at binding site, signal molecule exits
8. enzyme highlighted
9. animate the enzyme speeding up biochemical reaction
10. transport protein highlighted
11. camera move perpendicular to outer surface of protein and then quickly through the ion channel
12. molecules continue to move through channel
13. animate camera refocusing on membrane cut edge
14. fade out membrane, leaving transport protein visible

15. animate protein spinning 360 degrees

LO2b

Educational Goal:
Students will explain how the arrangement of phospholipids in the lipid bilayer makes the cell membrane selectively permeable.

Execution:

Audio
"Lipids form a barrier that separates the inside of a cell from the outside of a cell. The phospholipids are arranged in a double layer called a lipid bilayer. This barrier allows only certain substances in the cell's environment to pass through. The selective permeability of the cell membrane is caused mainly by the way phospholipids interact with water [continue to LO3]."

Visuals

1. camera focus on cut edge
2. highlight the entire bilayer
3. fade out all but two phospholipids from top and bottom layer
4. [visuals/audio from LO3 about hydrophobic effect]

LO2c

Educational Goal:
Students will describe the function of carbohydrates in the cell membrane.

Execution:

Audio
"The extracellular surface of the cell membrane is decorated with carbohydrate groups attached to lipids, glycolipids, or proteins, glycoproteins. These short carbohydrates, or oligosaccharides, are usually chains of 15 or fewer sugar molecules. Oligosaccharides give a cell identity (i.e., distinguishing self from non-self)"

Visuals

1. camera move along cell outer surface

2. focus on cut edge
3. highlight carbohydrates
4. fade out membrane, single carbohydrate remains
5. animate 360 spin of structure
6. membrane fades back in
7. animate another cell coming into the scene
8. show cell-cell recognition

LO2d

Educational Goal:
Students will describe the function of cholesterol in the cell membrane

Execution:

Audio
"Cholesterol is found between the phospholipids of the bilayer to maintain fluidity by preventing packing of the phospholipid fatty acid tails."

Visuals

1. Membrane fades to transparent 'glass'
2. cholesterol of membrane shown in full color (showing cholesterol wedged between phospholipid molecules)
3. camera zoom in on stucture

LO2e.

Educational Goal:
Students will explain the effect of lipid rafts on membrane organization.

Execution:

Audio
"Phospholipids and membrane proteins are not simply randomly distributed in cell membrane. Cell membrane are a complex mix of lipids and proteins designed to perform the functions cells require. To better coordinate these functions, the membrane is able to subcompartmentalize its' components. Lipid rafts are assemblies of sphingolipid, cholesterol, and proteins that can unite as one group, forming platforms that function in

membrane signaling and trafficking. Lipid rafts are more ordered and tightly packed than the surrounding bilayer, but float freely in the membrane bilayer."

Visuals

1. camera move to area of membrane surface with lipid raft
2. highlight and isolate a lipid raft area
3. camera zoom on a cut edge (3/4 view)
4. highlight unique components individually

LO3

Educational Goal:
Students will be able to explain the hydrophobic effect and it's effect on the structure of the membrane. This will utilize Bloom's Cognitive Domain *Comprehension*.

Execution:

Audio
"Each phospholipid is made up of a phosphate group and two fatty acid tails. The hydrocarbon tails are nonpolar, unable to bond with water and are hydrophobic (hydro=water, phobic=fear). The polar phospholipid head has an affinity for water, and thus is hydrophilic. This is similar to the opposite poles of a magnet. When opposite poles face each other they attract. When the similar poles face each other they will repel. When phospholipids are added to water, they self assemble into aggregates that shield their hydrophobic portions from water."

Visuals
1. one phospholipid isolated
2. phospholipid transforms into ball and stick or line model
3. hydrophobic vs hydrophilic ends labeled
4. cut to scene with a magnet (positive and negative ends labeled)
5. another magnet comes in, opposite ends facing each other and thus are attracted
6. another magnet comes in similarly, but same ends face each other and thus are repelled
7. magnets fade into a phospholipids with tail facing a water molecule and repelling
8. animate the phospholipid flipping and the hydrophilic head and water molecule attracting
9. fade in the entire phospholipid bilayer

zoom camera out and illustrate aqueous environments on inside and outside of cell, but not within the bilayer

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LO4

Educational Goal:
[Lipid droplet as example of hydrophobic effect on organization of phospholipids]

Execution:

Audio

Visuals

LO5

Educational Goal:
Students will be able to explain the concept of membrane fluidity, that many proteins are not static, and the benefits of a fluid system. This will utilize Bloom's Cognitive Domains *Comprehension* and *Knowledge*.

Execution:

(Method 1)

Audio
"Membranes are not static sheets of rigid material locked rigidly in place. A membrane is held together by primarily by hydrophobic interactions, which are much weaker than covalent bonds. Most of the lipids and some of the proteins can drift about laterally. The cell membrane must be a dynamic structure if the cell is to grow and respond to environmental changes. The lateral mobility of membrane proteins can be measured using the FRAP method..."

Visuals
1. focus on cut edge of membrane
2. camera moves perpendicular to the membrane on the outer edge
3. (the FRAP method is shown to confirm movement of proteins)

(Method 2)

Throughout the animation whenever the full membrane is shown it will remain constantly in motion, with the proteins and lipids appropriately drifting within the membrane (phospholipids lateral movement averages about 2um per second).

LO6

Educational Goal:
Students will be able to explain the various transport mechanisms and what differentiates passive from active transport.

LO6a

Educational Goal:
Students will be able to relate concentration gradients, diffusion and equilibrium.

Execution:

Audio
"Movement across the cell membrane that does not require energy from the cell is called passive transport. To understand how molecules diffuse across the membrane, take the example of a sugar cube dropped in water. Particles of a substance in a solution move around randomly. If there is a concentration gradient in the solution, the substance will move from an area of higher concentration to an area of lower concentration. This is called diffusion. Eventually the concentration of substance in solution will reach equilibrium, where the concentration of a substance is equal throughout the space. Many substances enter or leave cells by diffusing across the membrane. They move from an area of high concentration to and area of low concentration until equilibrium is reached.

Visuals

1. camera focus on cut edge of membrane
2. animate various molecules passively moving across the membrane (passive transport title)
3. cut to water filled beaker as a sugar cube is dropped in
4. zoom camera in to sugar cube to show the randomly moving molecules it and the water is made up of
5. animate sugar molecules dispersing
6. zoom camera out to the sugar mixed into the water evenly
7. cut to cut edge of membrane
8. animate molecule net movement from higher concentration to lower concentration through the membrane

---

LO6b

Educational Goal:
Students will be able to predict the direction of water movement into and out of cells.

Execution:

Audio
"Water molecules are small and can diffuse through the cell membrane. Diffusion of water through a selectively permeable membrane is called osmosis. Like other forms of diffusion, osmosis involves the net movement of a substance--water--down it's concentration gradient. The direction of water movement across the cell membrane depends on the relative concentration of free water molecules in the cytoplasm and in the fluid inside the cell. There are three possibilities for the direction of water movement: 1. Water moves out, thus the cell shrinks. A solution that causes this is called a hypertonic solution. 2. Water moves in, thus the cell swells. This solution is called hypotonic. 3. If no net water movement occurs the solution is isotonic. The fluid outside and inside the cell have the same concentration of free water molecules so water diffuses into and out of the cell at equal rates. No net movement."

Visuals

1. focus on cut edge of cell membrane with water molecules floating inside and outside the cell
2. animate camera to follow water molecule as it squeezes through the auquaporins
3. zoom camera out to focus on cut edge of an entire cell as water molecules (small molecules, high density of them) continue to move back and forth in equilibrium
4. solution surrounding the cell changes, decreasing the free water molecules
5. water molecules move out of the cell, the cell shrinks
6. solution surrounding the cell changes, increasing the free water molecules
7. water molecules move into the cell, the cell swells
8. solution surrounding the cell changes, matching the free water molecules concentration within the cell
9. water molecules move in and out but remains at equilibrium

---

LO6c

Educational Goal:
Students will be able to describe the role of aquaporins within the membrane.

Execution:

Audio
"Aquaporins are proteins embedded in the cell membrane that regulate the flow of water. They are "the plumbing system for cells."

Aquaporins are integral proteins that form pores in the membrane of cells through which only water molecules travel"

Visuals

1.

LO6d

Educational Goal:
Students will be able to describe the importance of ion channels in passive transport.

Execution:

Audio
"Most ions and polar molecules cannot pass across the cell membrane because they cannot pass through the nonpolar interior of the lipid bilayer. However, such molecules can cross the cell membrane when they are aided by transport protein. Transport protein called channels provide polar passageways through which ions and polar molecules can move across the cell membrane."

Visuals

1. camera focus on cut edge of membrane
2. animate ions or polar molecules, moving down the concentration gradient, unable to permeate through the lipid bilayer
3. animate the ions passing through specific protein channels

---

LO6e

Educational Goal:
Students will be able to identify the role of carrier proteins in facilitated diffusion.

Execution:

Audio
"Another transport protein used to transport specific substances, such as amino acids and sugars, are carrier proteins. This method of passive transport is called facilitated diffusion. The carrier protein binds to specific substances on one side of the cell, carries

the substance across the cell membrane and releases it, moving down the substance's concentration gradient and therefore not using the cell's energy."

Visuals

1. camera focus on cut edge of membrane
2. animate carrier protein binding molecule on one side of cell membrane
3. camera zoom on protein
4. carrier protein shape change exposes the molecule to the other side of the cell membrane
5. protein shields molecule from interior of lipid bilayer and releases it
6. protein returns to original shape

LO6f

Educational Goal:
Students will be able to describe how the sodium-potassium pump helps prevent animal cells from bursting.

Execution:

Audio
"Active transport is the pumping of solutes against their concentration gradient. The Sodium Potassium pump is one specific case of active transport. The pump changes between two conformational states in a pumping cycle that moves three Na+ ions out of the cell for every two K+ ions pumped into the cell. ATP powers the changes in conformation. By pumping sodium ions out of the cell, it lowers the cell's concentration of sodium. Thus less water enters the cell by osmosis."

Visuals

1. three sodium ions inside the cell bind to the pump
2. phosphate group removed from ATP and also binds to pump
3. the pump changes shape, transporting and releasing the sodium ions outside the cell
4. two potassium ions outside the cell bind to the pump
5. phosphate group is released, changing shape of pump and transporting and releasing the two ions

---

LO6g

Execution:
Student will be able to identify the terms *endocytosis* and *exocytosis* and distinguish between them.

Audio
"Large molecules generally cross the membrane by a mechanism involving vesicles. Endocytosis is the movement of such substances into a cell by a vesicle that pinches off from the membrane. These vesicles may fuse with lysosomes or other organelles. Exocytosis is the same movement but out of a cell (Endo = in; Exo = out)."

Visuals

1. focus on cut edge of membrane (3/4 view)
2. animate proteins or polysaccharides forming a pouch in the membrane at the cut edge
3. pouch pinches off
4. animate pouch fusing with lysosome
5. animate protein coming from golgi apparatus
6. vesicle fuses with cell membrane and releases contents

APPENDIX C
Animation Script

The Cell Membrane **Animation**
Script Draft 3: 9/20/2010

INTRO

The cell membrane controls traffic into and out of the cell it surrounds. Like all biological membranes, the cell membrane exhibits selective permeability; that is, it allows some substances to cross it more easily than others. This ability of the cell to discriminate in its chemical exchanges with its environment is fundamental to life, and it is the cell membrane that makes this selectivity possible.

In this video, you will learn about the structure of membranes and how the outer most membrane of a eukaryotic cell, the cell membrane or plasma membrane, controls the passage of substances. However, the same general principles of membrane traffic also apply to the many varieties of internal membranes that partition the eukaryotic cell.

COMPARTMENTATION

Membranes are found around the entire cell, the mitochondria, the Golgi apparatus, lysosomes, nucleus, and many other organelles. Membranes serve to separate the contents of a cell or organelle from its surroundings. Here you can see a lysosome, an enzyme-containing organelle, as it is digesting an old, worn out organelle. The membrane surrounding the digestive enzymes is necessary as a barrier between the digestive enzymes and the rest of the cell.

COMPONENTS AND STRUCTURE

The cell membrane is made up of 4 main components: carbohydrates, cholesterol, phospholipids, and proteins.

Phospholipids and the Hydrophobic Effect

Lipids form the barrier that separates the inside of a cell from the outside of a cell. The phospholipids are arranged in a double layer called a lipid bilayer. A pure phospholipid bilayer would allow a very limited number of substances, to pass through. Water can diffuse across because it is so small, but this is a slow process

Each phospholipid is made up of a phosphate group and two fatty acid tails. The hydrocarbon tails are nonpolar, unable to bond with water and are hydrophobic (hydro, water; phobic, fear). The polar phospholipid head has an affinity for water, and thus is hydrophilic. Think of a magnet. When a charge is introduced, one end repels, the other attracts. When phospholipids are added to water, they form assemblies that shield their hydrophobic portions from the water. See here the

formation of a lipid monolayer. Substrates which interact well with water (hydrophilic = water loving) would have a hard time crossing a phospholipid bilayer.

Cholesterol and Membrane Fluidity

Membranes are not static sheets of material locked rigidly in place. Most of the lipids and many of the proteins can drift about laterally. The cell membrane must be a dynamic structure if the cell is to grow and respond to environmental changes. Besides allowing diffusion, membrane fluidity also allows proteins that undergo shape changes to function properly.

Cholesterol is a lipid and is found between the phospholipids of the bilayer. It allows the phospholipids to pack more tightly to maintain the right fluidity of the membrane.

Proteins

Cell membranes contain proteins which provides several functions to the cell. Some proteins and their attached carbohydrates help immune cells recognize them as their one type. Transport proteins aid in the movement of substances into and out of the cell. We will cover the different types of transport proteins later on in this video. Receptor proteins bind specific substances, such as hormones, in the cell's environment, which can change cell function. Structural proteins are attached to microfilaments in the cytoskeleton which ensures stability of the cell. A particular membrane protein can simultaneously provide more than one of these functions.

Carbohydrates

As seen previously, the extracellular surface of the cell membrane is decorated with carbohydrate attached to components, producing glycolipids and glycoproteins. These linked carbohydrates consist of chains of 15 or fewer sugar molecules and are termed oligosaccharides. Oligosaccharides can confer stability to proteins, provide enzymatic function, comprise a receptor domain, or give a cell identity (for example., distinguishing self from non-self).

Lipid Rafts

Phospholipids and membrane proteins are not simply randomly distributed in cell membrane. Cell membranes are a complex mix of lipids and proteins designed to perform the functions cells require. To better coordinate these functions, the membrane is able to subcompartmentalize its components. Lipid rafts are assemblies of sphingolipid, cholesterol, and proteins that unite as one group, forming platforms that function in membrane signaling and trafficking. Lipid rafts are more ordered and tightly packed than the surrounding bilayer, but float freely in the membrane bilayer like wooden rafts on the ocean.

TRANSPORT

One of the main functions of the cell membrane is to regulate the exchange of substances.

PASSIVE TRANSPORT

Diffusion

Movement across the cell membrane that does not require energy from the cell is called passive transport. To understand how molecules diffuse across the membrane, it is important to understand what is meant by diffusion. Take the example of a sugar cube dropped in water. Particles of a substance in a solution move around randomly. If there is a concentration gradient in the solution, the substance will move from an area of higher concentration to an area of lower concentration, aka down the concentration gradient. This is called diffusion. Eventually the concentration of substance in solution will reach equilibrium, where the concentration of a substance is equal throughout the space. It is diffusion that propels many substances to passively enter or leave cells. They move from an area of high concentration to and area of low concentration until equilibrium is reached.

Osmosis

Water molecules are small and can diffuse through the cell membrane. Diffusion of water through a selectively permeable membrane is called osmosis. Like other forms of diffusion, osmosis involves the net movement of a substance--water--down its concentration gradient. The direction of water movement across the cell membrane depends on the relative concentration of free water molecules in the cytoplasm and in the fluid outside the cell. There are three possibilities for the direction of water movement: 1. Water moves out causing the cell to shrink. A solution which is added to cells that causes this is called a hypertonic solution. The fluid outside the cell has a lower concentration of free water molecules than the fluid inside the cell, so water diffuses out of the cell. 2. Water moves in, thus the cell swells. This solution is hypotonic. The fluid outside the cell has a higher concentration of free water molecules than the fluid inside the cell, so water diffuses into the cell. 3. If no net water movement occurs the solution is isotonic. The fluid outside and inside the cell have the same concentration of free water molecules so water diffuses into and out of the cell at equal rates. No net movement.

Specialized membrane water transporters, called aquaporins, are found in tissues with high water permeability. These proteins freely permit movement of water across the cell membrane and allow for higher levels of permeability in certain cells.

Channel Proteins

Proteins can help molecules across membranes either by forming channels or by carrying them across the membrane.

Most ions and polar molecules cannot pass across the cell membrane because they cannot pass through the nonpolar interior of the lipid bilayer. However, such molecules can cross the cell membrane when they are aided by transport proteins. This is a channel protein. Here you can see its atomic structure; it is composed of carbon, nitrogen, and oxygen. Channels provide polar passageways through which ions and small polar molecules can move across the cell membrane. During transit the channel hardly changes its shape, if it does at all.

Carrier Proteins

Another transport protein used to transport specific substances, such as amino acids and sugars, are carrier proteins. This method of passive transport is called facilitated diffusion. The carrier protein binds to specific substances on one side of the cell and releases them on the other side.

The carrier has to change its shape during this process. If the substrate is being transported down its concentration gradient, the process may not require extra energy. In this case it is called facillitated diffusion. Diffusion of the substrate can occur without the carrier protein, but it may take a very long time. It is helped, or 'facillitated', by the carrier protein.

ACTIVE TRANSPORT

Na+ K+ Pump

In contrast to facillitated diffusion, active transport is the pumping of solutes against their concentration gradient. The sodium-potassium pump is one specific case of active transport. The pump changes between two shapes or conformations in a pumping cycle that moves three sodium ions out of the cell for every two potassium ions pumped into the cell. ATP powers the changes in conformation. By pumping sodium ions out of the cell, it lowers the cell's concentration of sodium. Thus less water enters the cell by osmosis.

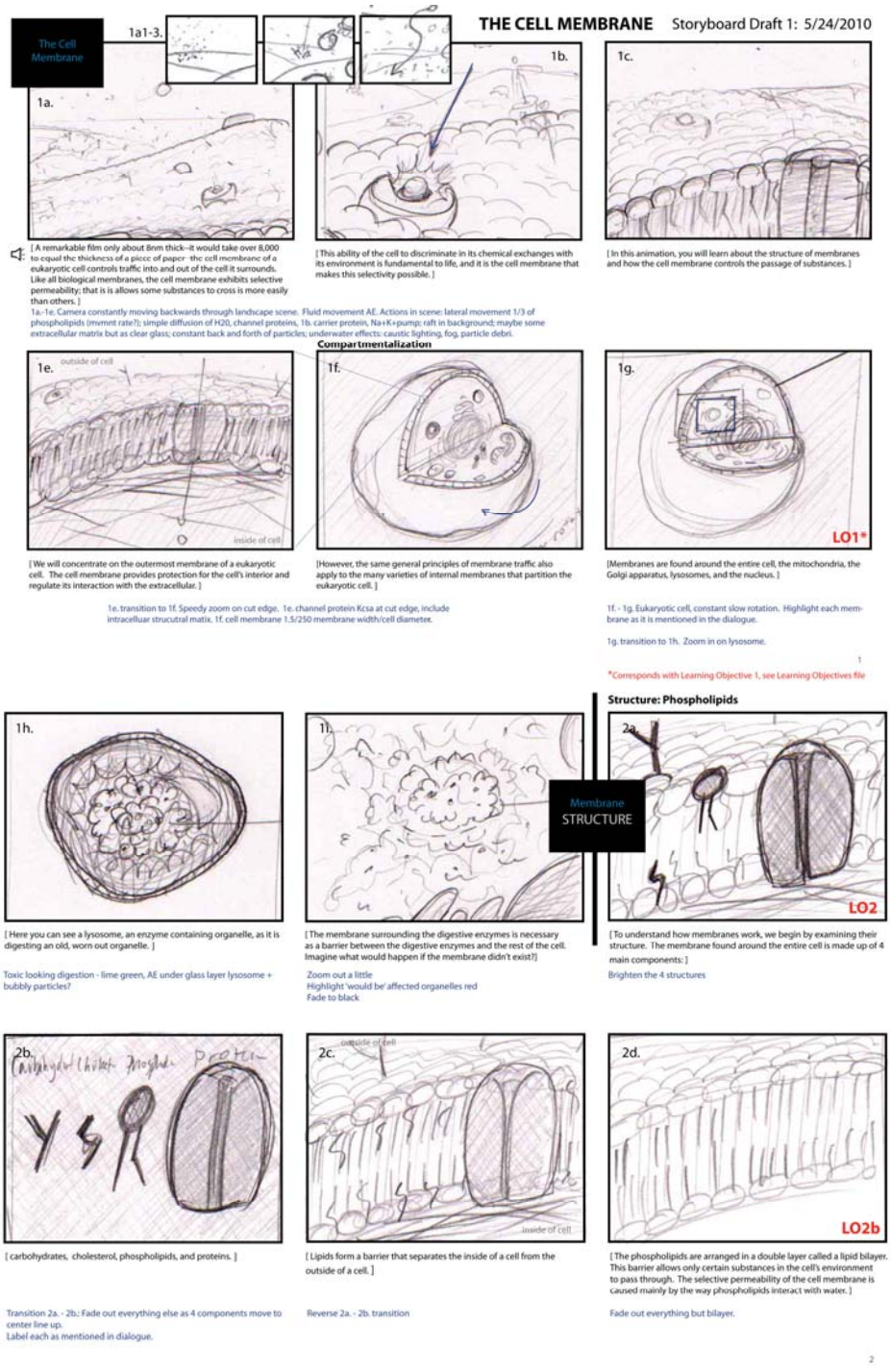
Large Molecule Transport

Large molecules generally enter cells by a mechanism involving vesicles. Endocytosis is the movement of such substances into a cell by a vesicle that pinches off from the membrane. These vesicles may fuse with lysosomes or other organelles. Exocytosis is the same movement but out of a cell (Endo, in; Exo, out).

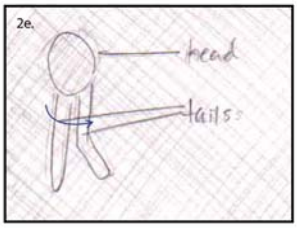
CONCLUSION

The cell membrane is the edge of life, the boundary that separates the living cell from its nonliving surroundings. It acts as both a barrier, enclosing and protecting the components of a cell, and a gate, controlling the flow of molecules in and out of the cell. The structure and corresponding functions of the cell membrane are fundamental to the life of every cell.

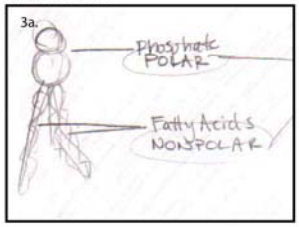
APPENDIX D
Animation Storyboard



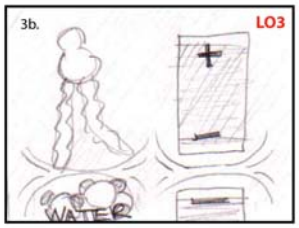
Hydrophobic Effect



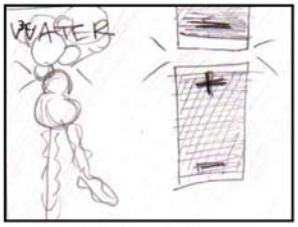
Fade out everything but one phospholipid.
360 spin



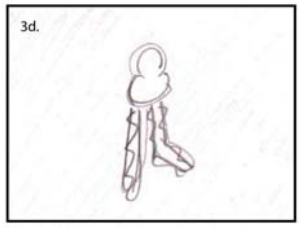
[Each phospholipid is made up of a phosphate group and two fatty acid tails.]



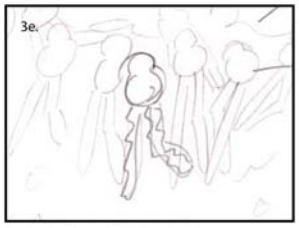
[The hydrocarbon tails are nonpolar, unable to bond with water and are hydrophobic (hydro=water, phobic=fear). Think of a magnet. When the same charge is introduced, one end repels, the other attracts.]



[The polar phospholipid head has an affinity for water, and thus is hydrophilic.]



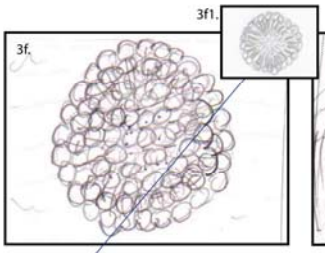
[When phospholipids are added to water, they self assemble into aggregates that shield their hydrophobic portions from water,]



[see here the formation of a lipid monolayer.]

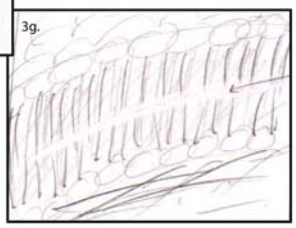
Water fades in as background
Phospholipds appear and congregate

3



[This forms a micelle, a lipid droplet.]

Micelle forms
Show cut edge

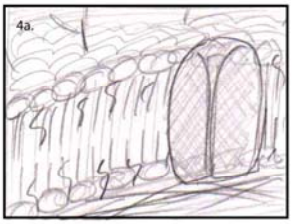


[Just as a monolayer can be formed, so too is the cell membrane bilayer of a eukaryotic cell. The center of the bilayer is the hydrophobic tails, repelling water,]

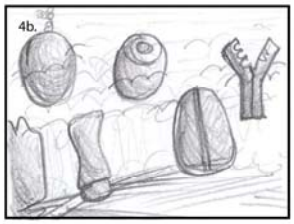
[while on the phospholipid heads has an affinity for water. (Talk about selective permeability here).]

H20 molecules appear as zoom in + are like glass
Fade to black

Structure: Proteins

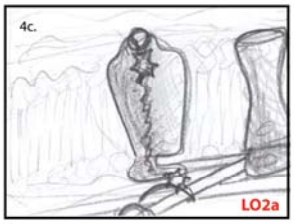


[Cell membranes contain different types of proteins.]



[Marker proteins, transport proteins, receptor proteins, structural proteins.]

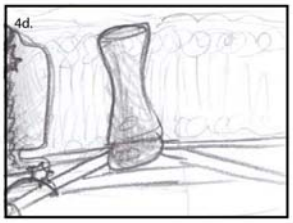
Camera move to section of cut edge with all protein types
Fade phospholipids to a transparent glass.
4d. - 4g. zoom in on each protein type, moving camera from type to type and showing function.



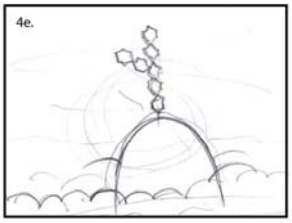
[Receptor proteins bind specific substances, such as signal molecules, outside the cell.]

GPCR

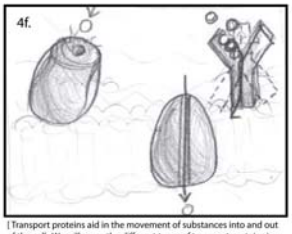
4



[Structural proteins are attached to microfilaments in the cytoskeleton which ensures stability of the cell.]

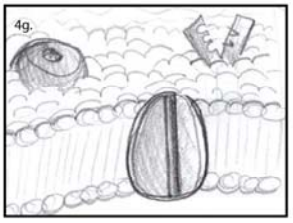


[Marker proteins attached to a carbohydrate on the cell's surface help cells recognize cells of their own type.]

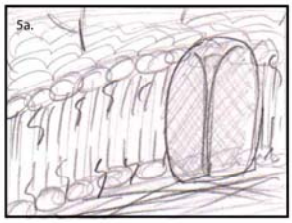


[Transport proteins aid in the movement of substances into and out of the cell. We will cover the different types of transport proteins in depth later on in this video.]

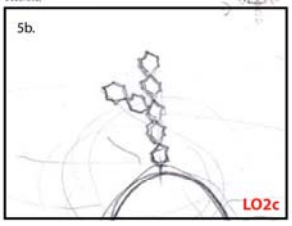
Actions of carrier protein and Na+K+ pump (carrier protein =-cannon, pump = hinge consult-make sure dramatization of action accurate)



Structure: Carbohydrates



The extracellular surface of the cell membrane is decorated with carbohydrate groups attached to lipids, glycolipids, or proteins(as seen previously), glycoproteins.

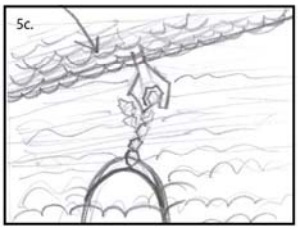


These short carbohydrates, or oligosaccharides, are usually chains of 15 or fewer sugar molecules.

Fade to black

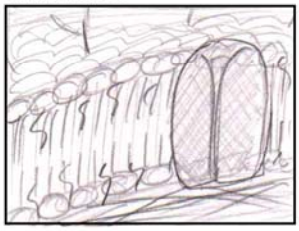
5

Structure: Cholesterol

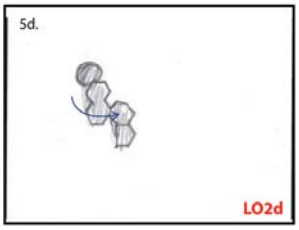


Oligosaccharides give a cell identity (i.e., distinguishing self from non-self).

Fade to black



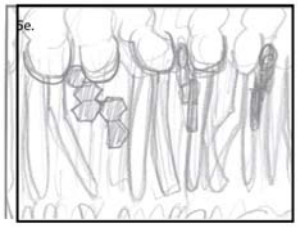
[Cholesterol is found between the phospholipids]



[of the bilayer to maintain fluidity by]

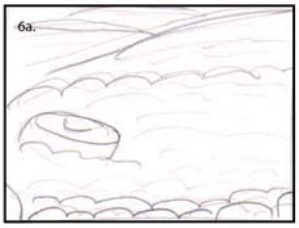
Zoom in while fading out everything but one cholesterol
360 spin

Fluidity

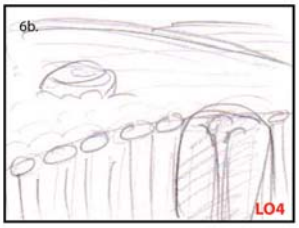


[preventing packing of the phospholipid fatty acid tails.]

Fade to black

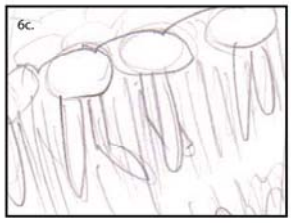


[Membranes are not static sheets of material locked rigidly in place.]



[Most of the lipids and some of the proteins can drift about laterally. The cell membrane must be a dynamic structure if the cell is to grow and respond to environmental changes. example…?]

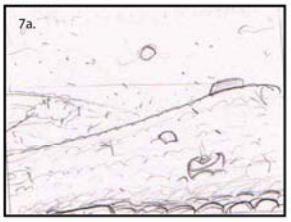
6



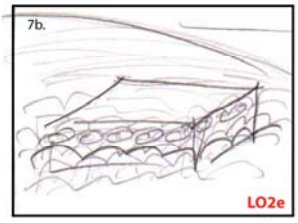
[A membrane is held together primarily by hydrophobic interactions, which are much weaker than covalent bonds.]

Zoom in on cut edge
Fade to black

Lipid Rafts



[Phospholipids and membrane proteins are not simply randomly distributed in cell membrane. Cell membranes are a complex mix of lipids and proteins designed to perform the functions cells require. To better coordinate these functions, the membrane is able to subcompartmentalize its components.]

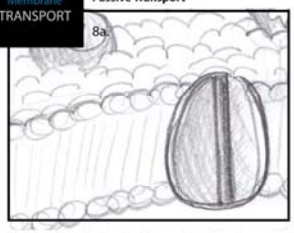


[Lipid rafts are assemblies of sphingolipid, cholesterol, and proteins that unite as one group, forming platforms that function in membrane signaling and trafficking. Lipid rafts are more ordered and tightly packed than the surrounding bilayer, but float freely in the membrane bilayer.]

Zoom into raft
Fade to black

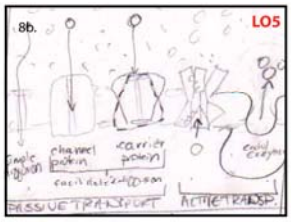
Membrane
TRANSPORT

Passive Transport

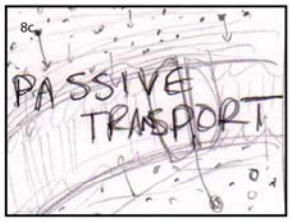


[The remainder of this animation focuses on the cell membranes ability to regulate transport across its surface.]

Show section with transport proteins

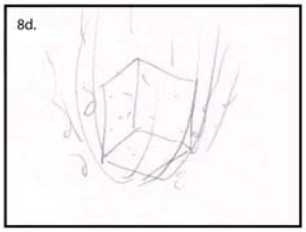


Schematic chart with 3D proteins
Highlight passive transport half of page

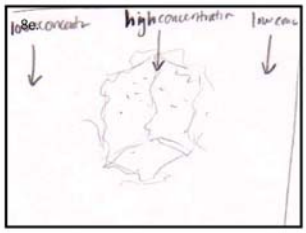


[Movement across the cell membrane that does not require energy from the cell is called passive transport.]

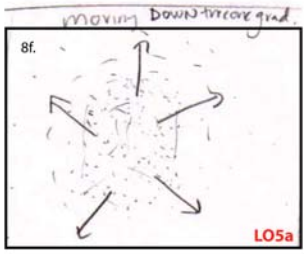
All passive transport actions happening in background



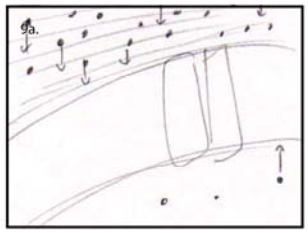
[To understand how molecules diffuse across the membrane, take the example of a sugar cube dropped in water. Particles of a substance in a solution move around randomly.]



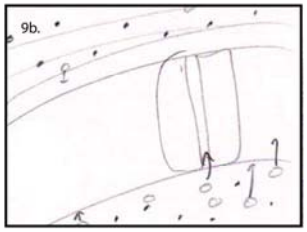
[If there is a concentration gradient in the solution, the substance will move from an area of higher concentration to an area of lower concentration, aka down the concentration gradient.]



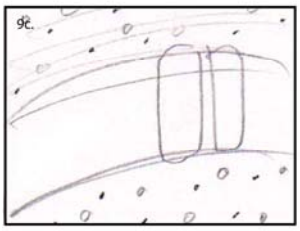
[Eventually the concentration of substance in solution will reach equilibrium, where the concentration of a substance is equal throughout the space.]



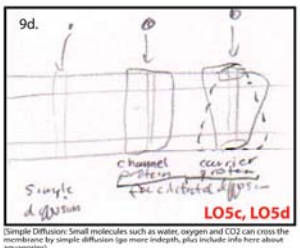
[Many substances enter or leave cells by diffusing across the membrane.]



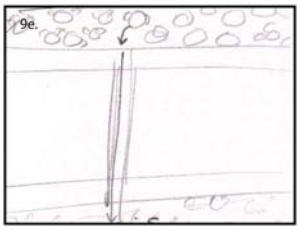
[They move from an area of high concentration to and area of low concentration]



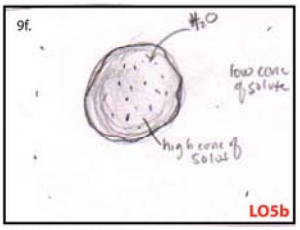
[until equilibrium is reached.



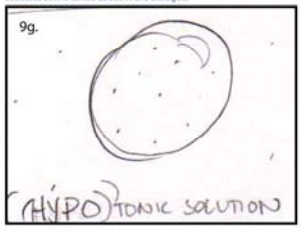
[Simple Diffusion: Small molecules such as water, oxygen and CO2 can cross the membrane by simple diffusion (go more indepth, plus include info here about aquaporins)
Channel Proteins: Most ions and polar molecules cannot pass across the cell membrane because they cannot pass through the nonpolar interior of the lipid bilayer. However, such molecules can cross the cell membrane when they are aided by transport protein. Transport proteins called channels provide polar passageways through which ions and polar molecules can move across the cell membrane]
Carrier Proteins: Another transport protein used to transport specific substances, such as amino acids and sugars, are carrier proteins. This method of passive transport is called facilitated diffusion. The carrier protein binds to specific substances on one side of the cell, carries the substance across the cell membrane and releases it, moving down the substance's concentration gradient and therefore not using the cell's energy]
Passive trasport section of chematic chart, each mode of transport activates as it is talked about in the dialogue.



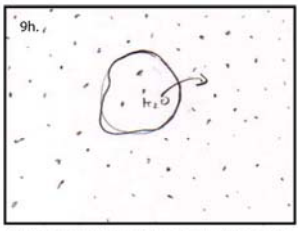
[As mentioned before, water molecules are small and can diffuse through the cell membrane. Diffusion of water through a selectively permeable membrane is called osmosis. Like other forms of diffusion, osmosis involves the net movement of a substance--water--down its concentration gradient.]



[The direction of water movement across the cell membrane depends on the relative concentration of free water molecules in the cytoplasm and in the fluid outside the cell.]

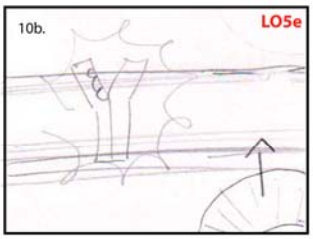


[There are three possibilities for the direction of water movement:. 1. Water moves in, thus the cell swells. This solution is hypotonic.]

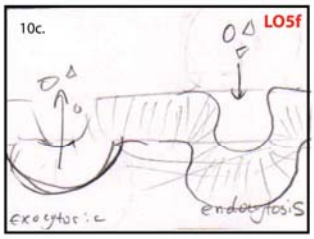


[2. Water moves out, thus the cell shrinks. A solution that causes this is called a hypertonic solution.]

[This type of transport requires energy from the cell.]



[The Sodium Potassium pump is one specific case of active transport. The pump changes between two conformational states in a pumping cycle that moves three Na+ ions out of the cell for every two K+ ions pumped into the cell. ATP powers the changes in conformation.]



[Large molecules generally cross the membrane by a mechanism involving vesicles. Endocytosis is the movement of such substances into a cell by a vesicle that pinches off from the membrane. These vesicles may fuse with lysosomes or other organelles. Exocytosis is the same movement but out of a cell (Endo = in; Exo = out).]

APPENDIX E
The Hydrophobic Effect Lab

THE HYDROPHOBIC EFFECT

Purpose
In this activity, you will use a model to demonstrate your understanding of the hydrophobic effect.

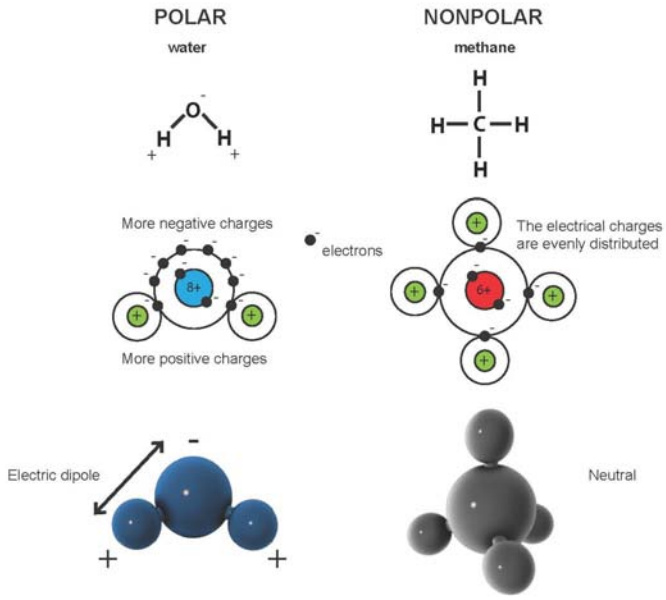
Materials
phospholipid models and colored pencils

Key terms: *Polar* *Non-polar* *Dipole* *Hydrophobic* *Bilayer* *Monolayer*

Part 1

Polarity

The arrangement or geometry of the atoms in some molecules is such that one end of the molecule has a positive electrical charge and the other side has a negative charge. If this is the case, the molecule is called a *polar* molecule, meaning that it has electrical poles. Otherwise, it is called a *non-polar* molecule.

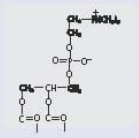


Molecular polarity is dependent on the difference in electronegativity between atoms in a compound and the asymmetry of the compound's structure. For example, a molecule of water is polar because of the unequal sharing of its electrons in a "bent" structure, whereas methane is considered non-polar because the carbon shares the electrons with the hydrogen atoms uniformly.

Now grab a partner and a phospholipid model!

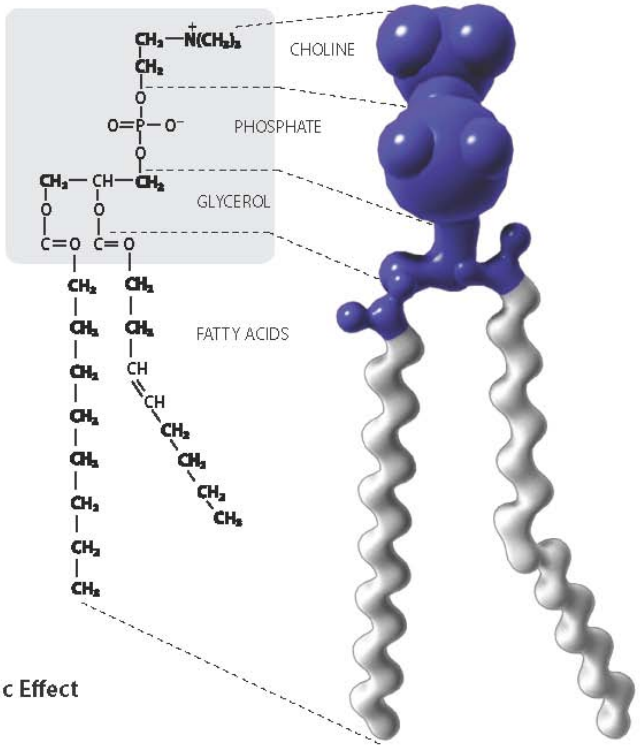
Take a look at the model in front of you. The phospholipid is unique in that one portion of it is polar and one portion of it is nonpolar!

Q1. Based on what you just learned about polarity, circle which you think is polar and which is nonpolar:



Polar
Nonpolar

Polar
Nonpolar



Polarity and the Hydrophobic Effect

Polar molecules can bond together due to *dipole–dipole* intermolecular forces between one molecule (or part of a large molecule) with asymmetrical charge distribution and another molecule also with asymmetrical charge distribution. Polar and nonpolar molecules don't interact well. The *hydrophobic* effect is the tendency of nonpolar groups to cluster so as to shield themselves from contact with an aqueous environment. The name arises from the combination of water in Attic Greek *hydro-* and for fear *phobos,* which describes the apparent repulsion between water and hydrocarbons.

Q2. Discuss with your partner what you predict would happen to a **phospholipid** in water??
Write your explanation here:

Part 2

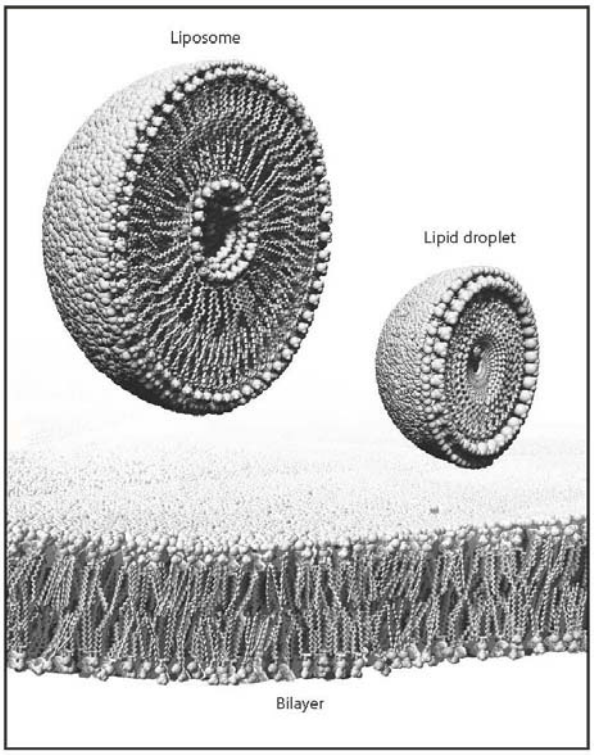
Between you and your partner, have one person take the phospholipid model to the front of the room. Along with your other classmates, form a phospholipid *bilayer* on the desk!

How **else** might phospholids congregate? Discuss with the class.

Next, the other partner will go to the front of the room, grab one phospholipid, and along with the class, rearrange the phospholids to create a lipid *monolayer*! A lipid droplet is a lipid monolayer with lipid in the center.

Monolayers can be found in lipid droplets while the cell membrane is a bilayer (see below).

Q3. On the images below, use a purple colored pencil to color the hydrophilic phospholipid heads, and a blue colored pencil to indicate where water would be found.



It is the phospholipids' hydrophobic interaction with water that creates these formations! The polar heads are hydrophillic (attract water) and the nonpolar tails are hydrophobic (repel water). At the molecular level, the hydrophobic effect is an important driving force for biological structures and is responsible for formation of lipid bilayer membranes, liposomes and lipid droplets.

TEACHER INSTRUCTIONS

Time Needed: 30 min

THE HYDROPHOBIC EFFECT

Lesson Goal

Lesson focuses on how the hydrophobic effect causes phospholipid monolayer and bilayer formation. Students learn about the phospholipid structure, polarity and the hydrophobic effect. Students work as partners to predict a phospholipid's behavior in water and then take part in a large scale phospholipid monolayer formation.

Lesson Objectives

- Students will explain polarity and identify polar and nonpolar portions of a phospholipid
- Students will explain the hydrophobic effect and its affect on the structural formation of membranes

Materials

20 phospholipid models
Student worksheets
Colored pencils

Procedure

1. Divide students into groups of 2 students, providing one phospholipid model per group. **(Note the number handed out for collection purposes at the end of the activity).**

2. Explain what the models are: phospholipids, the major component of a cell membrane.

3. Hand out the worksheet to each student.

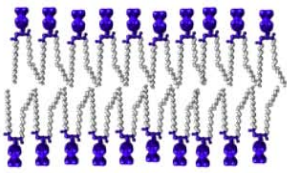
4. While students meet and work through the worksheet, make sure there is a place clear at the front of the classroom (desk, lab table).

5. Once all students have completed Part 1, go over answers as a class. (See Answer Key)

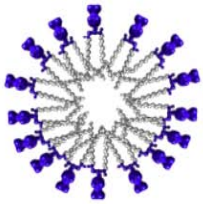
6. Have students start Part 2 of the worksheet.

7. Students will place their phospholipid models at the front of the room. Help facilitate the building of a bilayer and monolayer based on the images below.

Bilayer



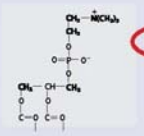
Monolayer



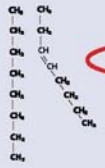
8. After activity is complete, collect and count all models.

ANSWER KEY

Q1. Based on what you just learned about polarity, circle which you think is polar and which is nonpolar:



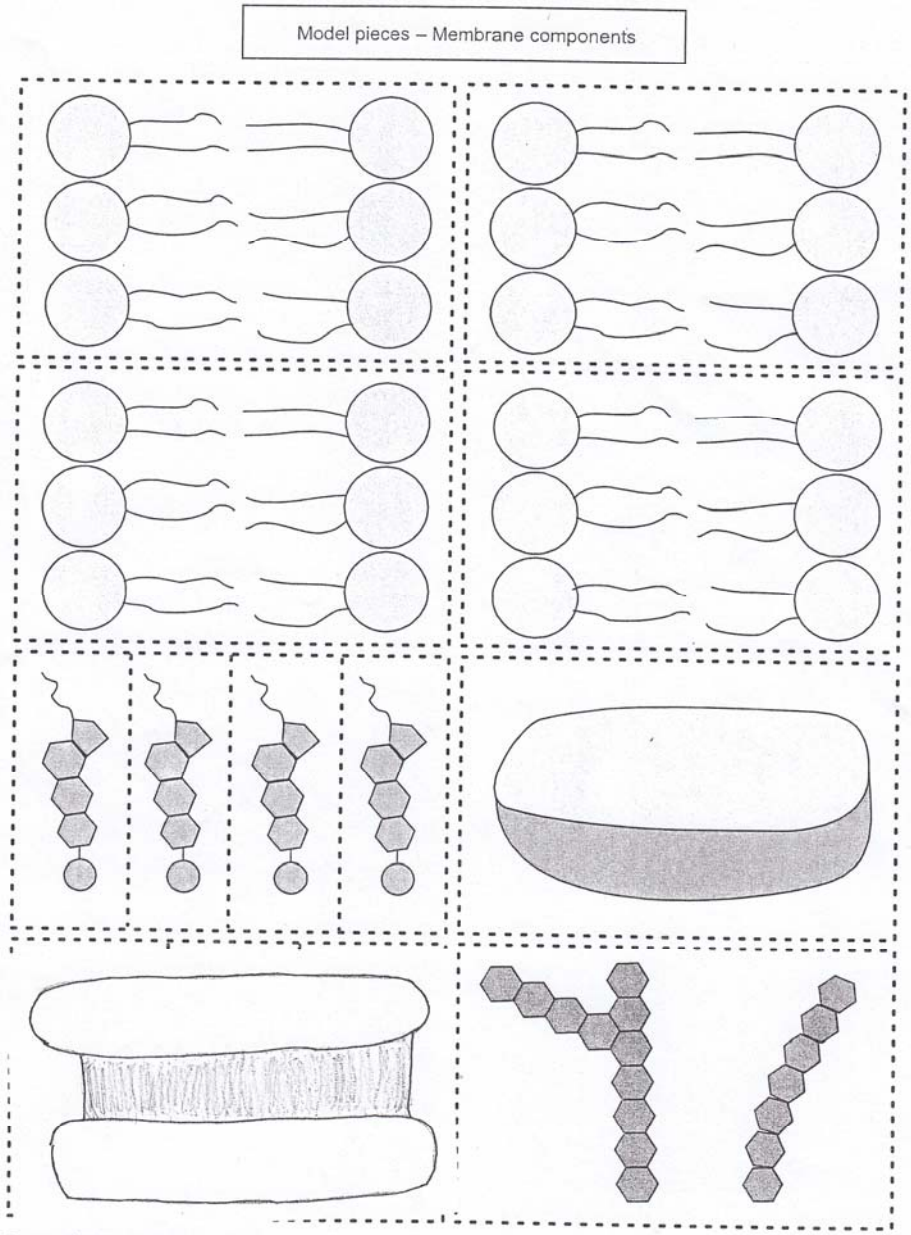
Polar
Nonpolar

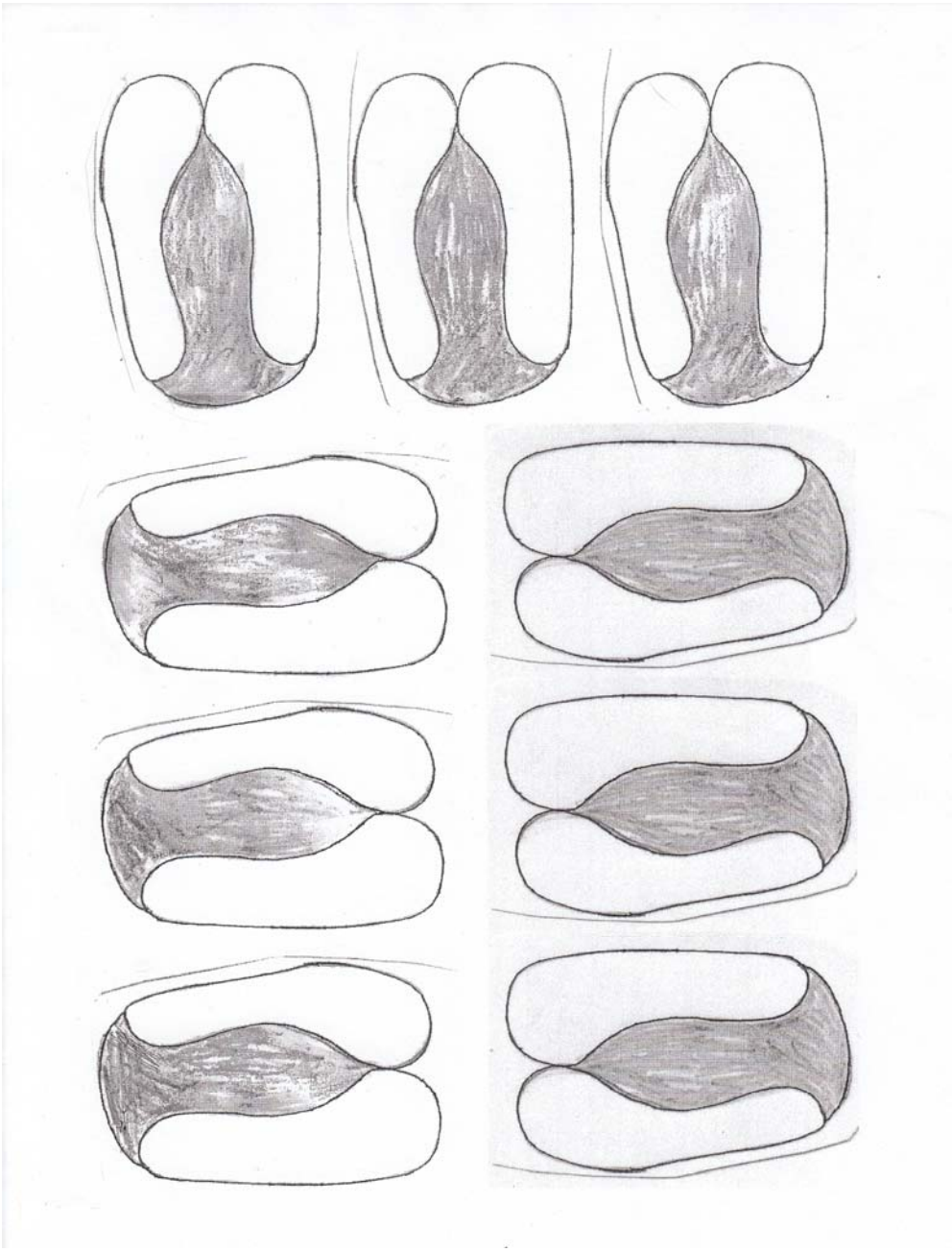


Polar
Nonpolar

Q2. Discuss with your partner what you predict would happen to a **phospholipid** in water??
Write your explanation here:
They would arrange themselves into two layers. The hydrophillic heads would face the water while the hydrophobic tails would hide inside the layers. Since the phospholipid molecules aren't bonded to one another, the layer would be fluid and individual molecules would easily move around.

APPENDIX F
The Fluid Mosaic Model Images





APPENDIX G
The Build-A-Membrane Lab

Build-A-Membrane

Purpose
In this activity, you will model and demonstrate your understanding of the structure of a cell membrane.

Materials
scissors
membrane component sheets

Part 1

The cell membrane is the boundary that separates the living cell from its nonliving surroundings. It acts as both a barrier, enclosing and protecting the components of a cell, and a gate, controlling the flow of molecules in and out of the cell. The structure and corresponding functions of the cell membrane are fundamental to the life of every cell.

The cell membrane is made up of four main components:

1. **Membrane Proteins**
   Proteins in the membrane may serve as transport proteins, receptor proteins, marker proteins, and structural proteins.
   - *Transport proteins* can help ions or small polar molecules across the membrane. Aquaporins are specialized membrane water transporters, found in tissues with high water permeability. These proteins freely permit movement of water across the cell membrane and allow for higher levels of permeability in certain cells.
   - *Receptor proteins* bind specific substances, such as hormones, in the cell's environment, which can change cell function.
   - *Marker proteins* and their attached carbohydrates help immune cells recognize them as their one type.
   - *Structural proteins* are attached to microfilaments in the cytoskeleton and collagen in the extracellular matrix, which ensures stability of the cell.
2. **Phospholipids** are made up of a phosphate group and two fatty acid tails and are arranged in a double layer called a lipid bilayer. A pure phospholipid bilayer would allow a very limited number of substances, to pass through. Water can diffuse across because it is so small, but this is a slow process. The phospholipids are not static but can move laterally within the membrane. This is why the membrane is said to be fluid.
3. **Cholesterol** is found between the phospholipids of the bilayer. It allows tighter packing of phospholipids which lowers the fluidity of the membrane.
4. **Carbohydrates** can confer stability to proteins, provide enzymatic function, comprise a receptor domain, or give a cell identity. The extracellular surface of the cell membrane is decorated with carbohydrate attached to components, producing glycolipids and glycoproteins.

The cell membrane controls traffic into and out of the cell it surrounds. Like all biological membranes, the cell membrane exhibits selective permeability; that is, it allows some substances to cross it more easily than others. This ability of the cell to discriminate in its chemical exchanges with its environment is fundamental to life, and it is the cell membrane that makes this selectivity possible.

Part 2

1. Find the three sheets of membrane components and cut out all the model pieces by cutting along the dotted lines.

2. After you've finished, listen for your teacher to read a description of each of the membrane components. As your teachers reads aloud, respond by holding up the membrane component described.

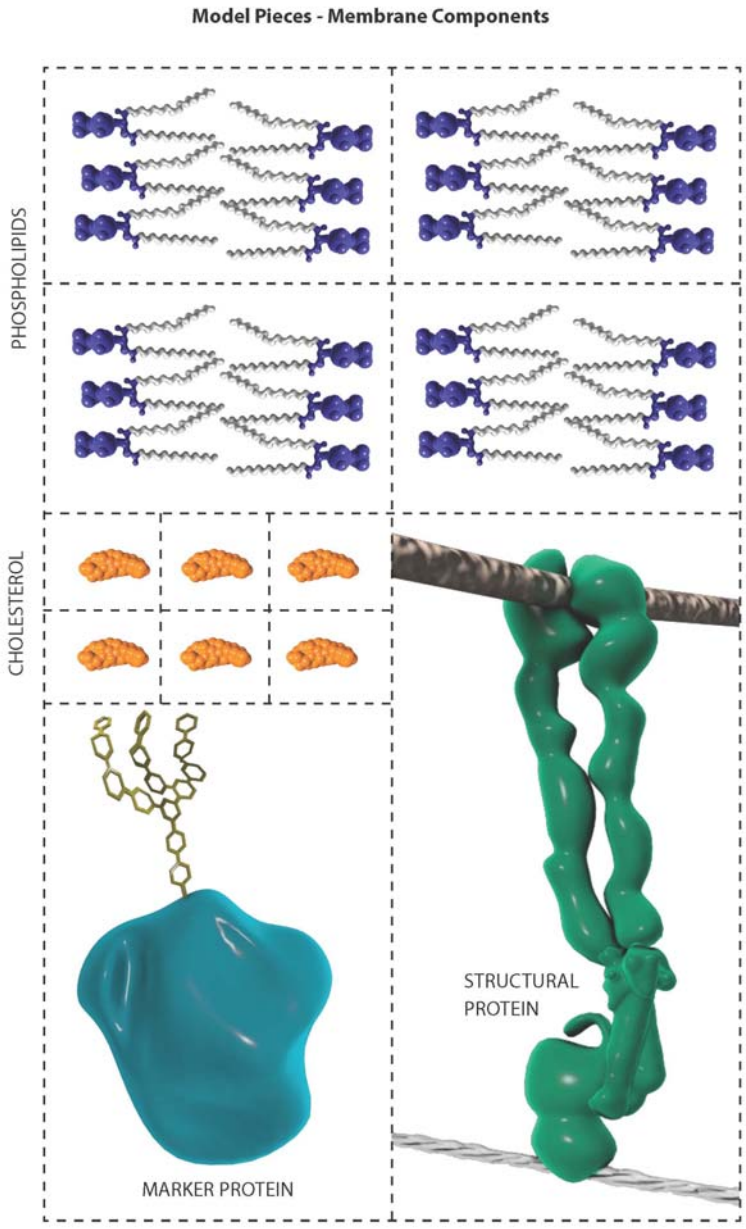
3. On your desk, piece together the components of a cell membrane to create a full membrane. Place the pathway of water arrows so that it passes through the phospholipids and the transport protein (remember, water sometimes passes through specialized water transporters called aquaporins). Place the pathway of potassium arrow so that it passes through only the transport protein. Place the hormone at the receptor protein.

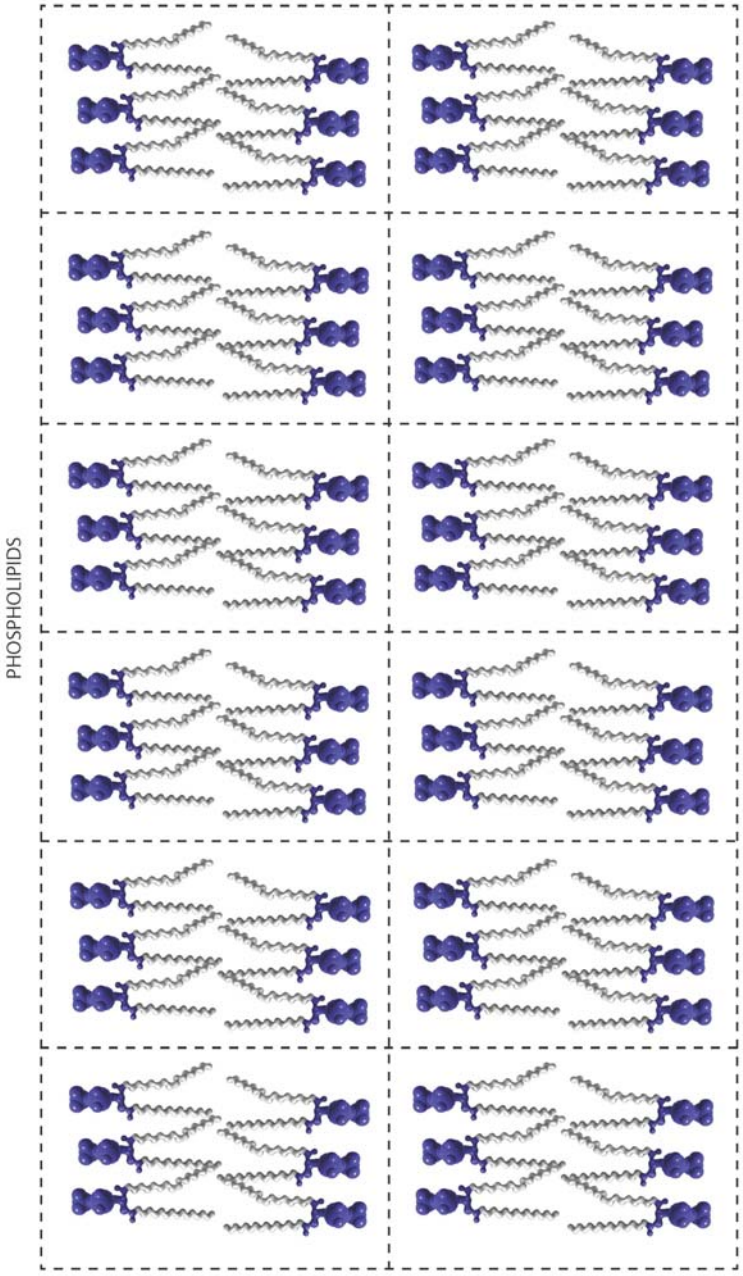
4. Look at the chart below. Using the information you have learned, identify the membrane component involved for each of the cell functions listed:

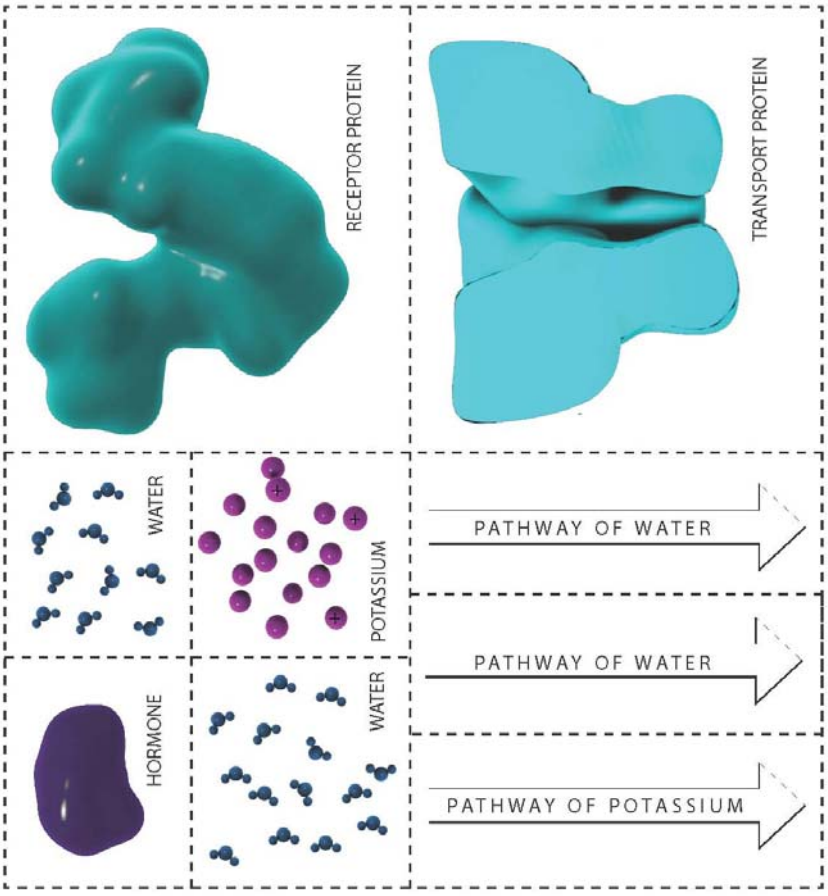
Functional Cellular Event	**Membrane Structural Component Involved**
The cell is recognized as belonging to a specific tissue.	_____
Water is entering the cell.	_____ and _____
Potassium is transported into the cell.	_____
The phospholipids are kept spaced apart to maintain the right fluidity of the cell.	_____
Actin filaments of the cytoskeleton are anchored in place.	_____
A hormone is activating a change in the cell.	_____

Reference:

The Fluid Mosaic Membrane. *Laying the Foundation in Biology*, 378-393. 2004.


Model Pieces - Membrane Components
PHOSPHOLIPIDS
CHOLESTEROL
STRUCTURAL
PROTEIN
MARKER PROTEIN


PHOSPHOLIPIDS


RECEPTOR PROTEIN
TRANSPORT PROTEIN
WATER
POTASSIUM
PATHWAY OF WATER
HORMONE
WATER
PATHWAY OF WATER
PATHWAY OF POTASSIUM

APPENDIX H
Teacher Manual: Suggested Lesson Plan

Suggested Five Day Lesson Plan

The Cell Membrane Science Suitcase includes:

The Cell Membrane DVD - A high-end 3D animation covering topics from membrane structure and function to lipid rafts and the hydrophobic effect!

The Hydrophobic Effect Activity - Students use hands on phospholipid models to recreate a lipid bilayer while learning about polarity and the hydrophobic effect.

The Build-A-Membrane Activity - Another hands on activity to help students understand membrane structure and function.

The Cell Membrane Lab - A brand new lab, be the first to use it in your classroom!

DAY 1	DAY 2	DAY 3	DAY 4	DAY 5
DVD chapters 1, 2* and **Hydrophobic Effect Activity**	**DVD chapters 3, 4, 5** and **Build-A-Membrane Activity**	**DVD chapters 6, 7, 8, 9**	**DVD chapters 10, 11**	**The Cell Membrane Lab**

*The Cell Membrane DVD Chapters:

1 Intro/Compartmentation	
2 Phospholipids and Hydrophobic Effect	(Membrane Structure)
3 Cholesterol and Membrane Fluidity	
4 Proteins and Carbohydrates	
5 Lipid Rafts	
6 Diffusion	(Passive Transport)
7 Osmosis	
8 Channel Proteins	
9 Carrier Proteins	
10 Na+ K+ Pump	(Active Transport)
11 Conclusion	

APPENDIX I
Teacher Manual: DVD Questions and Answers

DVD Questions and Answers

1. Intro/Compartmentation
Q: What are the four components of a cell membrane?
A: Carbohydrates, cholesterol, phospholipids, and proteins

2. Phospholipids and Hydrophobic Effect
Q: The head of a phospholipid is_____
A: Polar or hydrophilic
Q: The tail of a phospholipid is_____
A: Nonpolar or hydrophobic

3. Cholesterol and Membrane Fluidity
Q: What is the main function of cholesterol
A: It allows tighter packing of phospholipids which lowers the fluidity of the membrane.

4. Proteins
Q: Name four types of proteins?
A: Receptor, marker, transport, and structural

5. Carbohydrates
Q: What is another name for a carbohydrate?
A: Oligosaccharide

6. Lipid Rafts
Q: Is the cell membrane randomly organized? Explain.
A: No, a cell membrane can be organized by nanoassemblies called lipid rafts

7. Diffusion
Q: What is diffusion? And how does it relate to cell membrane transport?
A: Diffusion is the movement of molecules in a solution from an area of higher concentration to an area of lower concentration until equilibrium is reached. Many molecules can passively transport through the cell membrane by diffusion.

8. Osmosis
Q: What is osmosis?
A: Osmosis is the movement of water molecules through a semi-permeable membrane, down its concentration gradient.

9. Channel Proteins
Q: What do channel proteins transport?
A: Ions and small polar molecules.

10. Carrier Proteins
Q: What is facilitated diffusion?
A: Molecules are helped or facilitated across the membrane by a carrier protein. When the movement is down its concentration gradient it is called facilitated diffusion.

11. Sodium Potassium Pump
Q: What is active transport?
A: Active transport is the pumping of solutes against their concentration gradient.

BIBLIOGRAPHY

Armbruster P, Patel M, Johnson E, Weiss M. Active learning and student-centered pedagogy improve student attitudes and performance in introductory biology. CBE Life Sci Educ. 2009 Fall; 8 (3) :203-13.

Allen D, Tanner K. Putting the horse back in front of the cart: using visions and decisions about high-quality learning experiences to drive course design. CBE Life Sci Educ. 2007 Summer; 6 (2) :85-9.

Allen D, Tanner K. Approaches to biology teaching and learning: from a scholarly approach to teaching to the scholarship of teaching. Cell Biol Educ. 2005 Spring; 4 (1) :1-6.

Allen D, Tanner K. Infusing active learning into the large-enrollment biology class: seven strategies, from the simple to complex. Cell Biol Educ. 2005 Winter; 4 (4) :262-8.

Allen D, Tanner K. Approaches to cell biology teaching: mapping the journey-concept maps as signposts of developing knowledge structures. Cell Biol Educ. 2003 Fall; 2 (3) :133-6.

Allen D, Tanner K. Approaches to cell biology teaching: learning content in context--problem-based learning. Cell Biol Educ. 2003 Summer; 2 (2) :73-81.

Allen D, Tanner K. Approaches to cell biology teaching: questions about questions. Cell Biol Educ. 2002 Fall; 1 (3) :63-7.

Allen D, Tanner K. Approaches in cell biology teaching. Cell Biol Educ. 2002 Spring; 1 (1) :3-5. PubMed PMID:12587024;

Al-Abood SA, Davids KF, Bennett SJ. Specificity of task constraints and effects of visual demonstrations and verbal instructions in directing learners' search during skill acquisition. J Mot Behav. 2001 Sep; 33 (3) :295-305.

Ball P, Ruben M. Color theory in science and art: Ostwald and the Bauhaus. Angew Chem Int Ed Engl. 2004 Sep 20; 43 (37) :4842-6.

Berry LH, Dwyer FM. Interactive effects of color realism and learners' IQ on effectiveness of visual instruction. Percept Mot Skills. 1982 Jun; 54 (3 Pt 2) :1087-91. PubMed PMID:7110850.

Bockholt SM, West JP, Bollenbacher WE. Cancer cell biology: a student-centered instructional module exploring the use of multimedia to enrich interactive, constructivist learning of science. Cell Biol Educ. 2003 Spring; 2 (1) :35-50.

Brill G, Yarden A. Learning biology through research papers: a stimulus for question-asking by high-school students. Cell Biol Educ. 2003 Winter; 2 (4) :266-74.

Clark JJ, Skaff S. A spectral theory of color perception. J Opt Soc Am A Opt Image Sci Vis. 2009 Dec; 26 (12) :2488-502.

Couture M, Tremblay S. Exploring the characteristics of the visuospatial Hebb repetition effect. Mem Cognit. 2006 Dec; 34 (8) :1720-9.

Hartland W, Biddle C, Fallacaro M. Audiovisual facilitation of clinical knowledge: a paradigm for dispersed student education based on Paivio's Dual Coding Theory. AANA J. 2008 Jun; 76 (3) :194-8.

Hermann M. [3-dimensional computer animation--a new medium for supporting patient education before surgery Acceptance and assessment of patients based on a prospective randomized study--picture versus text]. Chirurg. 2002 May; 73 (5) :500-7.

Ishi H, Yamauchi H. A study of cognitive loading in dual-coding theory. Percept Mot Skills. 1994 Aug; 79.

Kantor A. Medical animation offers bold new way to communicate. Healthplan. 2002 Jul-Aug; 43 (4) :45-8.

Kraatz WC. Biology in College and High School. Science. 1946 May 10; 103 (2680) :598-9.

Leader JK. 3-d computer visualization and animation of medical images. Med Eng Phys. 2003 Apr; 25 (3) :169-70.

McClean P, Johnson C, Rogers R, Daniels L, Reber J, Slator BM, Terpstra J, White A. Molecular and cellular biology animations: development and impact on student learning. Cell Biol Educ. 2005 Summer; 4 (2) :169-79.

Mineo BA, Peischl D, Pennington C. Moving targets: the effect of animation on identification of action word representations. Augment Altern Commun. 2008; 24 (2) :162-73.

Ollivier D, Hervy B, Hartweg C, Point D. [The senses and animation]. Soins Gerontol. 2002 Mar-Apr.

Petrini L, Hennings K, Arendt-Nielsen L. The effect of visuo-spatial organisation in recognition-memory tasks. Perception. 2009; 38 (5) :763-74.

Ramos JM. Is spatial memory transformed during the consolidation process? Effect of reminding. Acta Neurobiol Exp (Wars). 2009; 69 (4) :545-51.

Sheppard K, Robbins DM. High school biology today: what the Committee of Ten actually said. CBE Life Sci Educ. 2007 Fall; 6 (3) :198-202.

Smith JI, Tanner K. The problem of revealing how students think: Concept inventories and beyond. CBE Life Sci Educ. 2010 Spring; 9 (1) :1-5.

Stith BJ. Use of animation in teaching cell biology. Cell Biol Educ. 2004 Fall; 3 (3) :181-8.

Tanner K, Allen D. Approaches to cell biology teaching: a primer on standards. Cell Biol Educ. 2002 Winter; 1 (4) :95-100.

Tanner KD, Chatman L, Allen D. Approaches to biology teaching and learning: science teaching and learning across the school--university divide--cultivating conversations through scientist-teacher partnerships. Cell Biol Educ. 2003 Winter; 2 (4) :195-201.

Tanner K, Chatman LS, Allen D. Approaches to cell biology teaching: cooperative learning in the science classroom--beyond students working in groups. Cell Biol Educ. 2003 Spring; 2 (1) :1-5. PubMed PMID:12822033; PubMed Central PMCID: PMC152788.

Tanner K, Allen D. Approaches to biology teaching and learning: from assays to assessments--on collecting evidence in science teaching. Cell Biol Educ. 2004 Summer; 3 (2) :69-74.

Tanner K, Allen D. Approaches to biology teaching and learning: learning styles and the problem of instructional selection--engaging all students in science courses. Cell Biol Educ. 2004 Winter; 3 (4) :197-201.

Tanner K, Allen D. Approaches to biology teaching and learning: on integrating pedagogical training into the graduate experiences of future science faculty. CBE Life Sci Educ. 2006 Spring; 5 (1) :1-6.

Tanner K, Allen D. Approaches to biology teaching and learning: understanding the wrong answers--teaching toward conceptual change. Cell Biol Educ. 2005 Summer; 4 (2) :112-7.

Tomanek D, Moreno N, Elgin SC, Flowers S, May V, Dolan E, Tanner K. Points of view: effective partnerships between K-12 and higher education. Cell Biol Educ. 2005 Spring; 4 (1) :28-37.

Tanner KD. Talking to learn: why biology students should be talking in classrooms and how to make it happen. CBE Life Sci Educ. 2009 Summer; 8 (2) :89-94.

Tanner KD. Learning to see inequity in science. CBE Life Sci Educ. 2009 Winter; 8 (4) :265-70.

Thatcher JD. Computer animation and improved student comprehension of basic science concepts. J Am Osteopath Assoc. 2006 Jan; 106 (1) :9-14.

Vernon T, Peckham D. The benefits of 3D modelling and animation in medical teaching. J Audiov Media Med. 2002 Dec; 25 (4) :142-8.

Walker MJ. Science and the High-School Student. Science. 1957 Dec 6; 126 (3284) :1200.

Wang W, Milgram P. Viewpoint animation with a dynamic tether for supporting navigation in a virtual environment. Hum Factors. 2009 Jun; 51 (3) :393-403.

Wefer SH, Sheppard K. Bioinformatics in high school biology curricula: a study of state science standards. CBE Life Sci Educ. 2008 Spring; 7 (1) :155-62.

Woo KL, Rieucau G. Considerations in video playback design: using optic flow analysis to examine motion characteristics of live and computer-generated animation sequences. Behav Processes. 2008 Jul; 78 (3) :455-63.