AN ILLUSTRATIVE APPROACH TO UNDERSTANDING THE DEVELOPMENTAL PROCESSES OF ATRIAL AND VENTRICULAR SEPTATION OF THE HEART DURING EMBRYOGENESIS AND HOW ERRORS IN THESE PROCESSES LEAD TO CONGENITAL SEPTAL HEART DEFECTS

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DEDICATION

I would like to first thank my professors and two of the members of my graduate committee, Lewis Calver and Kim Hoggatt Krumwiede for their expertise and guidance throughout this project and throughout the duration of the program. I would especially like to thank Dr. Deepak Srivastava, the third member of my committee, who was kind enough to share his time, input, and advice in providing all the scientific content for completion of this project.

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by

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THESIS

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The main objective of this thesis project is to visually communicate, through the use of two-dimensional animations, the normal developmental processes of atrial and ventricular septation, as well as the abnormal development of these processes that result in both atrial and ventricular septal defects. The use of animation, as opposed to two-dimensional illustrations, will possibly increase understanding of these subjects and lead to advances in the treatment and therapy of cardiovascular disease, specifically heart defects, in children, eventually leading to advances in the treatment of heart disease in adults. Five separate animations were created and evaluated by an audience knowledgeable in the field of cardiovascular research and development. This thesis describes the current need for animations of this subject matter, documenting the available resources already found in the field, and describing the background, research, project design, and technical implementation of the design process used to create the final animations.

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Congenital Heart Disease – Heart disease that presents itself at birth.

Embryogenesis – The development and growth of an embryo.

Septation – The division or partitioning of a cavity into parts by a septum.

Atrial septal defect (ASD): A hole in the septum or wall, between the upper chambers (atria) of the heart. Commonly called an ASD.

Ventricular Septal Defect (VSD): A hole in the septum or wall, between the lower chambers (ventricles) of the heart. Commonly called a VSD.

CHAPTER ONE
Introduction

Thesis Problem

The prominence of cardiovascular and congenital heart disease in the United States has continued to increase the need for advances in diagnosis and treatment of these problems. In order for these advances to occur, scientists and researchers must have a clear understanding of the genetic causes of heart disease and heart defects, including the cardiac developmental pathways that take place during embryogenesis. To assist researchers in understanding these concepts, clear literature must exist to visually communicate these processes. Can a series of illustrations to create two-dimensional animations visually communicate how regions of the heart develop during cardiac embryogenesis, thus aiding in the scientific community's understanding of these processes? More specifically, can an illustrative approach to the processes of atrial and ventricular septation, and how these processes can result in septal defects in the fetal heart, effectively increase knowledge on these subjects, possibly leading to advances in cardiovascular research?

Background Information

Heart disease is the leading cause of death in the United States in both children and adults. Congenital heart disease is the primary cause of non-infectious death in children. Each year in the U.S., about 40,000 infants are born with heart defects (about one of every 125 births).

Some of the more common of these heart defects are atrial septal defects (ASD) and ventricular septal defects (VSD). Despite these statistics, however, death rates from congenital heart defects are increasingly falling due to advances in diagnosis and surgical treatment. (March of Dimes, 2006) By better understanding the cardiac developmental pathways that occur during embryogenesis, doctors and researchers can continue to devise new therapies to treat children with heart defects, specifically ASD and VSD, possibly leading to advances in the treatment of cardiovascular disease in adults.

Atrial Septation

Partitioning of the atrium begins at approximately 30 days into development of the fetus, in a process known as atrial septation. From the roof of the atrium, a crescent shaped fold begins to form called the septum primum. As it continues to grow, there remains an opening between it and the endocardial cushions called the ostium primum. This fold, the septum primum, forms a partition as it fuses with the endocardial cushions that develop in the inferior and superior walls of the heart. Fenestrations that form within the septum primum coalesce, leaving an opening in the septum primum called the ostium secundum. To the right of the septum primum, another fold begins to grow from the roof of the atrium. This fold is known as the septum secundum. It too fuses with the endocardial cushion forming another partition, also incomplete due to an opening referred to as the foramen ovale. This opening and that of the ostium secundum, form a narrow cleft that allows blood to flow from the right to the left side of the fetal heart. The septum primum at this point acts as the valve for the foramen ovale. Since blood in the fetus is oxygenated at the placenta rather than the lungs, the foramen ovale is required to ensure that blood brought into the right atrium is circulated first to the left atrium, then to the left ventricle, and finally to the rest of the body. The foramen ovale closes immediately at birth once the child takes its first breath. The increase in pressure due to lung circulation causes the septum primum and septum secundum to fuse, thus closing the foramen ovale and thereby separating pulmonary and systemic circulation. This is the final step in the complete partitioning of the two atria. (Sadler, 1990)

Atrial Septal Defects

There are three main types of atrial septal defects. The first is an Ostium Secundum Atrial Septal Defect (ASD). This is the most common ASD, and it is found in the center of the septum between the right and left atrium. One form of this defect is called a patent foramen ovale. (© Mayo Foundation, 2006) The foramen ovale is a small hole that is present in the fetus before birth and allows blood to circulate and flow between the right and left sides of the heart. After birth, when the lungs begin to circulate and pressure increases within the heart, the valve that covers this opening fuses shut and normal blood circulation then begins within the heart. In about 20% of cases, however, the closure of the foramen ovale is incomplete, causing what is called a patent foramen ovale, which does not allow for intracardic shunting of blood, but rather allows blood to cross from the right to the left atrium directly. This can occur by one of two ways. First, if the septum secundum does not reach its full growth, the foramen ovale is too large and the septum primum, which acts as the valve for the foramen, cannot completely cover it. A hole then remains due to a channel between the foramen ovale and ostium secundum. Secondly, this defect occurs when excessive resorption of the septum primum causes too little of the septum primum to remain. The opening in the septum primum, called the ostium primum, is therefore too large and the septum primum can not overlap the foramen ovale to act as a valve. In both cases, a connection remains between the atria allowing right to left shunting of blood. (Sadler, 1990)

The second type of ASD is an Ostium Primum ASD. It is the next most common type of ASD and is located in the lower portion of the atrial septum. This defect occurs when the septum primum does not fully fuse with the endocardial cushions, thus leaving a small opening called the ostium primum. Unlike the ostium secundum ASD in which the ostium primum is too large and an opening remains in the septum primum, here the interventricular septum is closed and the ostium primum opening is instead found below it. (Sadler, 1990) It is also often associated with a mitral valve defect, or mitral valve cleft. (Eidem, 2004)

The third type of ASD is called a Sinus Venosus Atrial Septal Defect. It is the least common type of ASD and can be found in the upper portion of the atrial septum. This defect occurs with abnormal pulmonary vein connections, such as when a pulmonary vein from the right lung is abnormally connected to the right atrium instead of the left atrium. (© Mayo Foundation, 2006)

Ventricular Septation

Ventricular septation occurs at about 42 days into fetal development. Formation of the ventricles happens as a result of four separate elements growing and joining together to form the completed septum. The first of the four parts is the inlet septum which is derived from the coalescence of muscular trabeculations and the growth of the endocardial cushions. The second element is what will become the main body of the septum, and it is formed from an ingrowth of the anterior myocardial wall forming the apical and mid-muscular portions of the wall. The third part involved in the formation of the septum is the outlet septum, which grows downward from the conotruncal ridges and divides the arterial trunk. The place where these three elements join is known as the perimembraneous region of the heart, or membranous septum, which makes up the fourth and final component of the ventricular septum. (Eidem, 2004)

Ventricular Septal Defects

Defects found in the ventricular septum result from the incomplete closure by the seventh week of gestation of any one of the elements making up the septum. The precise process by which this closure is delayed is not known. The defects are usually categorized by the location in which they are found, namely the inlet, outlet, muscular, or membranous regions that make up the ventricular septum. (Eidem, 2004)

The most common VSD occurs in the membranous region, when the three other elements fail to fuse. The second most common is the muscular VSD and most often occurs in the cardiac apex. This defect may be caused by lack of merging of the walls of the muscular septum or excessive resorption of muscular tissue during ventricular growth and remodeling. Inlet defects occur inferior and posterior to the membranous septum, and may be caused by incomplete fusion of the right endocardial cushion with the muscular septum. Outlet defects are found beneath the pulmonary valve and are sometimes referred to as supracristal, infundibular, conal, or subpulmonary defects. (Eidem, 2004; Abdulla, 2006)

Significance of the Project

During my second year internship at the University of Texas Southwestern Graduate School, I worked in a cardiology lab with Dr. Deepak Srivastava, a pediatric cardiologist who is now the Director of The Gladstone Institute of Cardiovascular Disease in San Francisco, California. Dr. Srivastava's research focuses on understanding the genetic causes of heart disease and heart defects in order to create new treatments for children, which will ultimately lead to advances in the treatment of adults as well. While working with him, we discovered a need for several illustrations describing aspects of heart development not previously well visually communicated in the scientific community. Among these were concepts describing the developmental processes of atrial and ventricular septation, as well as how errors in these processes can lead to congenital atrial and ventricular septal defects. By better understanding these cardiac developmental pathways, doctors and researchers would possibly be able to devise new therapies to treat children with heart defects, specifically ASD and VSD. It is my opinion that an understanding of the above processes would best be communicated not only through the use of still diagrammatic illustrations, but by using these illustrations to create relatively simple two-dimensional animations describing these processes.

Goals and Objectives

The goal of this project was to visually communicate, through the use of two-dimensional animations, the developmental processes of heart septation of both the atria and ventricles, as well as the processes that describe how different types of atrial and ventricular septal defects form.

To achieve these goals, many objectives had to first be met. The first objective was to create two storyboards outlining the animations describing: (1) the major steps in the process of atrial septation of the heart during embryogenesis, and (2) the major steps in the process of ventricular septation of the heart during embryogenesis. Using the individual frames from these storyboards, the next objective was to create two diagrammatic series of illustrations. The third objective was to use these sequential illustrations as a basis to effectively animate (two-dimensionally) both processes. From these base animations showing normal development of both septa, several more illustrations were created or modified from the originals, and added or inserted in order to describe the development of each type of septal defect. In this case, it was decided that two atrial septal defects and four ventricular septal defects would be animated. The final objective was to survey a number of researchers and graduate students knowledgeable in cardiovascular research in order to determine the effectiveness of the animations, the ability to meet the needs of the target audience, and the ability to meet the goals and objectives set forth in this project.

Scope

The illustrations and animations produced within this project target scientists involved in cardiac research, including biologists, graduate students, and post-doctorates, as well as doctors. These materials will be used as teaching tools in a variety of settings, including scientific conferences, print and educational material, and on the web.

CHAPTER TWO
Review of the Literature

Currently Available Resources

Overall, the existing visuals describing development of the heart septa were found to consist mostly of schematic, two-dimensional diagrams, often black and white line drawings, and often showing only a few key steps in the developmental process. These diagrams often showed a cross-sectional view only, and sometimes both a frontal and side view, forcing the reader to spatially deduct for themselves how the objects appear three dimensionally. Other diagrams left out several steps in the process so that the reader was not able to fully understand how the process occurs from one step to the next, and must imagine for themselves how movement and change occur.

Langman's Medical Embryology

Langman's Medical Embryology textbook, by Thomas Sadler, has been recognized as the classic textbook in embryology, widely used in medical and health professions education programs. This book is well known for its emphasis on illustrations of developmental processes, accompanied by clear and concise supporting descriptions. This allows students to focus on key concepts rather than getting caught up in unnecessary text. It is known to include the scientific community's most valuable visual resources on embryology. That being said, however, its depiction of the developmental process of atrial septation and ventricular septation can, in some ways, be conceptually difficult to understand. For example, some illustrations show the atrial septa at various stages of development in both frontal and side cross-sectional views. (Figure 2-1) Unfortunately, it is not easy to

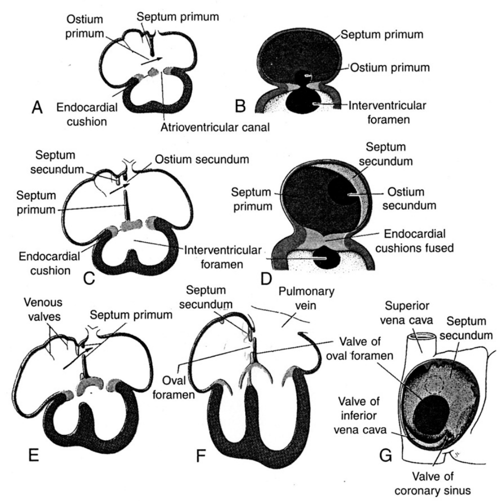


Figure 2-1 – Langman's depiction of the atrial septa at various stages of development. (Sadler, © 1990, with permission © Lippincott Williams & Wilkins. See Appendix E)

determine what this process would look like spatially in three dimensions. Similar illustrations from Langman's depict normal atrial septation as well as various atrial septal defects caused by problems in the septation process. (Figure 2-2) Images of ventricular septation as well as ventricular septal defects in this book were much the same as well. There is not as much literature that exists describing the mechanism of ventricular septation, at least not in the same detail as that for atrial septation, so images for these were even less clear.

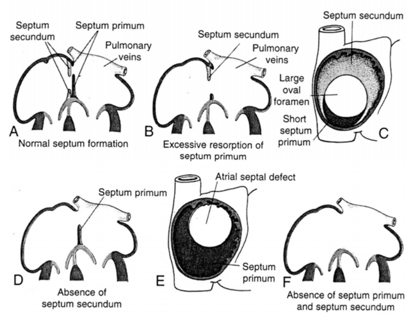


Figure 2-2 – Langman's depiction of the formation of atrial septal defects. (Sadler, © 1990, with permission © Lippincott Williams & Wilkins. See Appendix E)

Online Resources

Various internet websites provided resources on heart development. However, many of these visuals were crude cross-sectional drawings. (Figure 2-3) This series of steps was found on a university embryology class website, included in a slideshow of the development of the heart. It showed slight changes from step to step, all from a frontal or side view, with

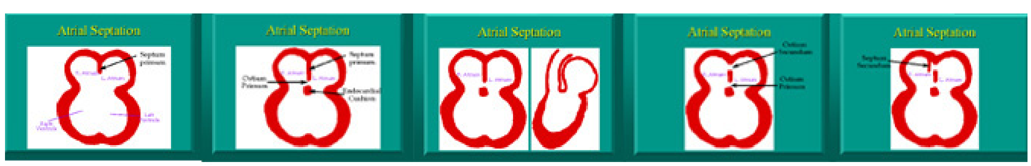


Figure 2-3 – Atrial septation. (Marino, 2005)

no indication of what this process looks like three dimensionally. Parts of the septum were shown as vertical lines and spaces were used to describe the openings present within the septum. (Marino, 2005)

Another online resource contained animations describing different aspects of heart development. This site had several three dimensional movies of heart septation, as seen in Figure 2-4, which shows a sample of the 3D model used in these animations. Although

Figure 2-4 - These images show a 3D model of one developmental stage of heart septation, which when animated, make one full rotation. (Hill, 2004)

animation is an excellent way to depict how objects move and change within a process, the models were not very detailed and showed only one stage of development at a time. The model in Figure 2-4 shows a heart with a septal defect, which when in motion, rotates 360 degrees. First of all, this does not describe all of the developmental steps in the process of septation, although it does allow some visualization of what the developing heart may look like in three dimensions. More importantly, however, it does not show the heart morphing from one step to the next in the developmental process. (Hill, 2004)

The few images found of ventricular septation were very unclear, especially since details of this process are not as clear as in atrial septation. Most of the existing images were of the heart shown from the right ventricular viewpoint, which seemed to be an effective vantage point for seeing how all of the elements involved combine to form the septa. However, nothing else within these illustrations was conceptually clear. For example, in Figure 2-5, the heart is shown as a ball-like object with three separate parts growing together to form the final ventricular septum. The star indicates where the three elements meet, the perimembraneous region of the heart. In looking at this diagram, however, there was no

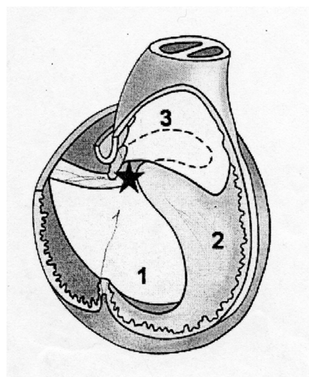
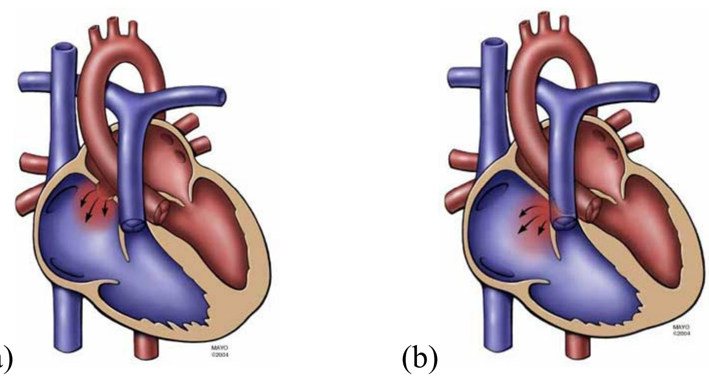


Figure 2-5 – Formation of the ventricular septum. 1 represents the inlet septum, 2 represents the muscular septum, and 3 represents the outlet septum. The star is the membranous septum where 1-3 combine. (Kirk, 2006)

sense of space or three dimensional quality, and it is quite unclear where the parts are located, how they move, or even what part is in front of the other. Overall, not much information could be gained in looking at this illustration.

In looking at representations of how atrial and ventricular septal defects occur, many of the resources only showed the location of these defects, in the form of a hole or space within the septa. However they did not describe by what mechanism these defects occurred, much less through an animated sequence. Much is not known as to the exact mechanism for the development of ventricular septal defects, but that of atrial septal defect formation is much better understood by the scientific community. Figure 6 shows some examples, from the © Mayo Clinic, of how defects are depicted in existing illustrations. Figure 2-6(a) shows the opening in the atrial septa caused by an ostium primum septal defect, and 2-6(b) shows the opening caused by an ostium secundum septal defect. Both are fairly accurate in describing



(a) (b)

Figure 2-6 – (a) Ostium Primum ASD (b) Ostium Secundum ASD (© Mayo Foundation, 2006, See Appendix E for copyright notice)

the location where the defects exist, but do not show how they developed. Many other online resources also described defects in this way, as merely a hole with no indication of its causes.

Biological Specimens

The most accurate representations of cardiac development are found in scanning electron micrographs and in looking at histological sections. However, these images are usually not very easy to interpret. Figure 2-7 shows an example of each of these. On the left is an electron micrograph and on the right is a histological section. Each shows the same specific step in the development of the atrial septa. Both of these could be quite confusing to the average student, or even a scientist not skilled in reading these types of images. Although the

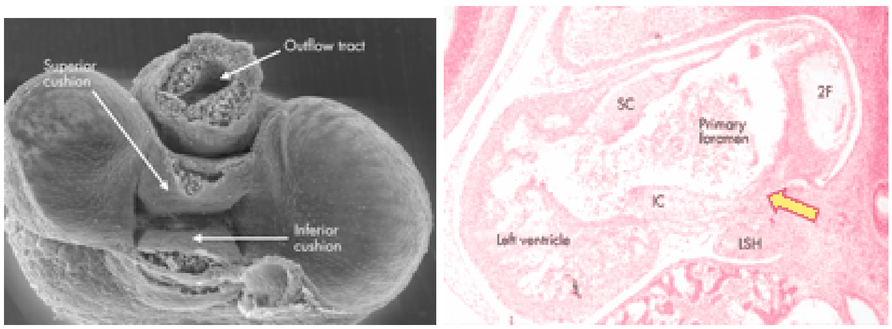


Figure 2-7 – An electron micrograph (left) and histological section (right) of one stage in the development of the atrial septa in a mouse embryo. (Anderson, 2003)

EM does well in showing the heart three dimensionally, only one stage at a time can be shown, and this can make it very difficult to conceptualize the entire developmental process. The histological sections show the types of cells and how they move, but once again, do not describe the developmental process.

Conclusion

After reviewing the literature, I realized that although diagrams of atrial and ventricular septation and ASD and VSD exist in the cardiovascular field, most of them are simple schematic illustrations shown from a single viewpoint at one stage in the process, making it spatially difficult to interpret, even by an audience with a scientific background. For these reasons, it was decided that a more three dimensional, fully rendered, colored set of illustrations should be created and then used as a basis to create several animations of these processes, which would possibly make it easier for an audience to visually understand it. By doing so, the scientific community could, perhaps, use this information to further their research and devise new ways of treating these heart defects.

CHAPTER THREE
Methodology

Purpose and Target Audience

In order to properly develop the design and concept for this project, it was necessary for me to determine the purpose of the project, as well as identify the target audience.

Purpose

The purpose of this project was to create a series of animations describing the processes of atrial and ventricular septation as well as several animations describing various atrial and ventricular septal defects. These materials would be used in executive and scientific presentations, scientific posters and other print materials such as magazines and journals, and as a web-based tool as well, if needed.

The concepts of atrial septation and atrial septal defects are well described in the scientific field, and the process of ventricular septation and formation of ventricular septal defects are also well described, though not nearly as precisely or in as much detail. However, neither process is very well visually communicated through the use of computer animated techniques. There are currently no animations, as per my literature review, that show how septal defects occur. Those illustrations that attempt to describe this process merely show spaces within an illustrated heart indicating where the defect would be located. By devising a series of illustrations that would give the audience a more three dimensional, spatial view of these processes, rather than the current schematic, cross sectional views, these drawings could then be combined to create a fluidly transitioning animation showing how both septa grow and change in normal development from the beginning to the end of the process. The use of these base animations combined with several added and modified illustrative steps would then be used to create several more animations describing how the atrial and ventricular septal defects occur within otherwise normal development. Animations would perhaps be the best way to visually communicate such a complex process, rather than still diagrammatic illustration.

By providing these illustrations and animations, students as well as scientists and researchers would gain a better understanding of these cardiac developmental pathways, which would hopefully encourage further research and discoveries in order to devise new therapies to treat children with heart defects and adults with cardiovascular disease.

Target Audience

This project was designed primarily to target scientists and researchers in the cardiovascular field as a learning tool for understanding cardiac developmental pathways. The secondary audience includes graduate students and post doctorates, as well as cardiologists.

Sources of Information

Information for the completion of this project was collected from many valuable sources.

The majority of the scientific research was gathered from my content expert, Dr. Deepak Srivastava, pediatric cardiologist and director of the Gladstone Institute of Cardiovascular Disease In San Francisco, California. Dr, Vidu Garg, an Associate Professor of Pediatrics at UT Southwestern also contributed valuable information. Lewis Calver, director of the Biomedical Communications graduate program at UT Southwestern, was the illustration expert that advised me in the creation of the illustrations that would be used in the final animations. Kimberly Krumwiede, associate Professor in the same program, was my technical expert, advising me on the technical aspects of creating the illustrations and animations, including sharing her expertise in many of the computer programs used to complete the project. Aside from these advisors, I collected other information through internet research, cardiovascular and anatomical atlases and textbooks, computer software manuals, and many other journal articles and books as listed in the bibliography.

Project Design

The first step in designing this project was to research and collect information on heart disease and heart defects and how these relate to septation of both the atria and ventricles of the heart. The literature review was continued by gathering a number of illustrations and visual representations of these processes that already existed in the cardiovascular field. All of this information was crucial in the planning and design of the illustrations that would be used to create the animations.

Concept and Planning

After completing the literature review, I began taking first steps in beginning the illustrations. In doing so, it was of great importance to first design the project to meet the needs of the target audience. This could be achieved keeping in mind that the illustrations needed to be both accurate and technical enough to appeal to a more mature scientific audience, but also simple enough to be understood by a graduate school level audience. It was determined that the illustrations needed to be more than just simple schematic drawings of cross sectional views of the heart, as this made it difficult to spatially visualize the heart in three dimensions. It was also decided that an animation, rather than a still diagram, would be a better tool for visualizing the process, as the audience would be able to see exactly how movement occurred from one step to the next. Thus a series of diagrammatic illustrations would be created and then used as a basis for the animations. Each step would be slowly dissolved into the next in a fluidly transitioning two-dimensional animation.

To plan how the illustrations would be designed visually, I assessed several illustrations currently available in the field in order to determine what worked or didn't work in each one. In terms of the illustrations for atrial septation, it was concluded from the literature, that many of the already existing drawings showed the heart from either a frontal or side view, or both. In looking at previous diagrams, the atrial septum was also represented in frontal and side views (separately) as a plate or disc. This disc seemed to work as a visual element in that the audience could spatially understand it. However, the best approach, in each of these situations, to showing these two views concurrently was to create illustrations of the developing heart and this plate like septum at a three quarter view. This would allow audiences at more than one level to visually interpret this and see the heart more three dimensionally, with both a partial frontal and partial side view, the two most important viewpoints needed to understand the process.

It was also decided that the illustrations needed to be fully rendered and not just simple line drawings. This too would add to the three dimensional quality of the drawings. Finally, the decision was made to make them in full color, creating a more visually pleasing and eye catching representation. Color would also add more information by emphasizing certain areas and deemphasizing others. For example, a muted color on the surface of the heart would allow a more saturated, brighter color, for parts of the septum, to appear more prominent and show greatest emphasis. A combination of several resources was also used to determine the shape of the heart at this embryonic stage.

For the ventricular septation diagrams, many of the same decisions were made in terms of color choice, degree of rendering, and three dimensionality. For this process, however, many of the existing drawings were done as viewed from the right ventricle, but most were still very simple, flat line drawings, giving no spatial quality to the illustrations, with a few showing a somewhat more modeled depiction of the fetal heart. It was decided that for the drawings of ventricular septation, the same right ventricular viewpoint would also be taken, focusing on a more modeled and rendered heart. Several resources were used to design the shape of the heart at this embryonic stage when the ventricles develop.

For the animations showing atrial and ventricular defects, it was decided that the base illustrations used to create the animations for normal atrial and ventricular septal development would be modified so as to be easily added or inserted within the base animations in order to create new animations describing how the defects occur within the normal septation process.

Knowing this, decisions were made as to which defects, if not all, would be animated. There are three types of atrial septal defects. However, the least common type, the sinus venosus ASD, is associated with abnormal connection of the heart vessels. Since the illustrations planned would not emphasize the vessels, it was decided that this defect would not be animated. Another of the atrial septal defects, the ostium secundum defect, has two different mechanisms by which it forms. For reasons of time constraint, only one of the two mechanisms describing this defect would be animated. The third atrial septal defect, the ostium primum defect, would also be animated. As for the ventricular septal defects, there are four main types categorized by the location in which they are found. All four could be shown from the viewpoint chosen, but the mechanisms are somewhat unclear. Therefore, it was decided that all of the ventricular defects be animated, but they would be represented simply by showing holes where the defects exist. The ventricular septal defects would also be shown in a fully matured heart, whereas ventricular septation would be shown in the fetal heart. A transition between embryonic and mature heart would also be shown to relate the two.

The next decisions to be made were exactly how the illustrations and animations would be created technically. It was decided that the first step would be to create several storyboards describing the sequence of steps for each animation. The illustrations would then be created from each frame of the storyboard as a simple hand done line drawing, which would then be translated onto the computer in Adobe Illustrator. These illustrator drawings would then be taken into Adobe Photoshop to be rendered and colorized. Once each step of the diagram was completed, Adobe Premiere would be used to dissolve from one step to the next, thus creating a fluid two-dimensional animation depicting the morphing process of septation and the processes describing each septal defect. Lastly, labels would be added to more clearly describe the events taking place.

Hardware and Software

The illustrations and animations were created on a 3.2 GHz Intel Pentium 4 processor home PC with 1 GB RAM. The operating system was Windows XP Professional, 2002. A Wacom Intuos2 drawing tablet was used to do all of the digital line drawings and renderings.

Adobe Illustrator was used to create outlines for each diagrammatic step that would be used to create the final animations. The illustrations were rendered and colorized in Adobe Photoshop. Adobe Premiere was used to put together the final animations as well as to create all of the labels and titling.

Storyboards and Sketches

Once the visual design for the illustrations was complete, I started by creating storyboards for the final animations, with each frame representing one of the illustrations, or diagrammatic steps, in the series (See Appendix A). Creating several steps (more than would be necessary for a still diagram) would insure a smooth transition during the animation process. Storyboards were made for the process of atrial septation and then the process of ventricular septation. From these storyboards, several extra frames were drawn that would be inserted into the original animations to show how the septal defects form. Once the storyboards were finalized the sketches were begun (See Appendix B). Each sketch was checked for accuracy, both scientifically and technically before being translated digitally to line in Adobe Illustrator. Figure 3-1 shows an example of a line drawing made in Adobe Illustrator, using

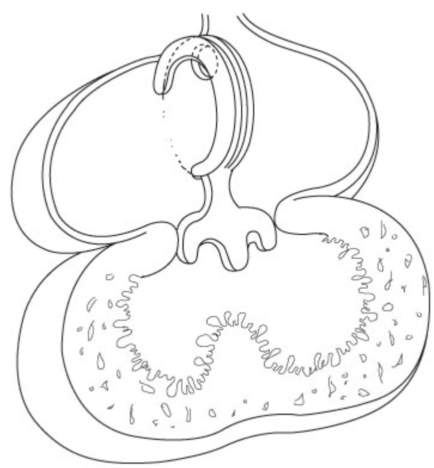


Figure 3-1 – Line drawing created in Adobe Illustrator.

my original sketch as a template. Following this, the line drawings were brought into Photoshop, masks were made, and the drawings were rendered in grayscale. Solid color was then layered on top of the grayscale and highlights were added to complete each illustration. Figure 3-2 shows an example of one of the completely rendered, full color images used in the atrial septation animations.

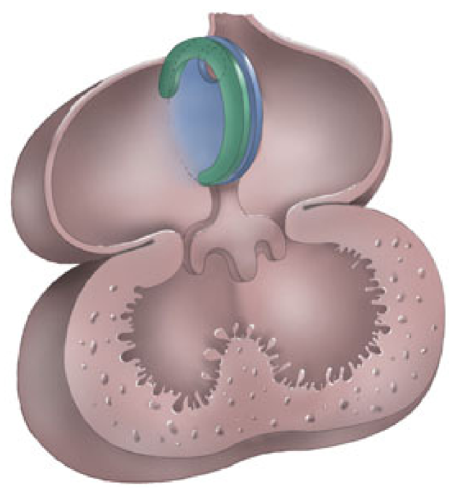


Figure 3-2 – Full color, rendered image used in the atrial septation animations.

Animation

The next step was to create the animations in Adobe Premiere. Five separate animations were created: 1) Normal Atrial Septation 2) Normal Ventricular Septation 3) Ostium Secundum Atrial Septal Defect 4) Ostium Primum Atrial Septal Defect 5) Formation of Ventricular Septal Defects. Before beginning, all of the single frame illustrations were formatted to fit the 720 by 480 px screen size in Adobe Premiere. Each illustration was then saved out as a jpeg and imported into Premiere. On the timeline, each image was added consecutively, with a cross dissolve effect transition between each one in order to ensure a smooth transition between frames (Figure 3-3). Then several titles were made for the

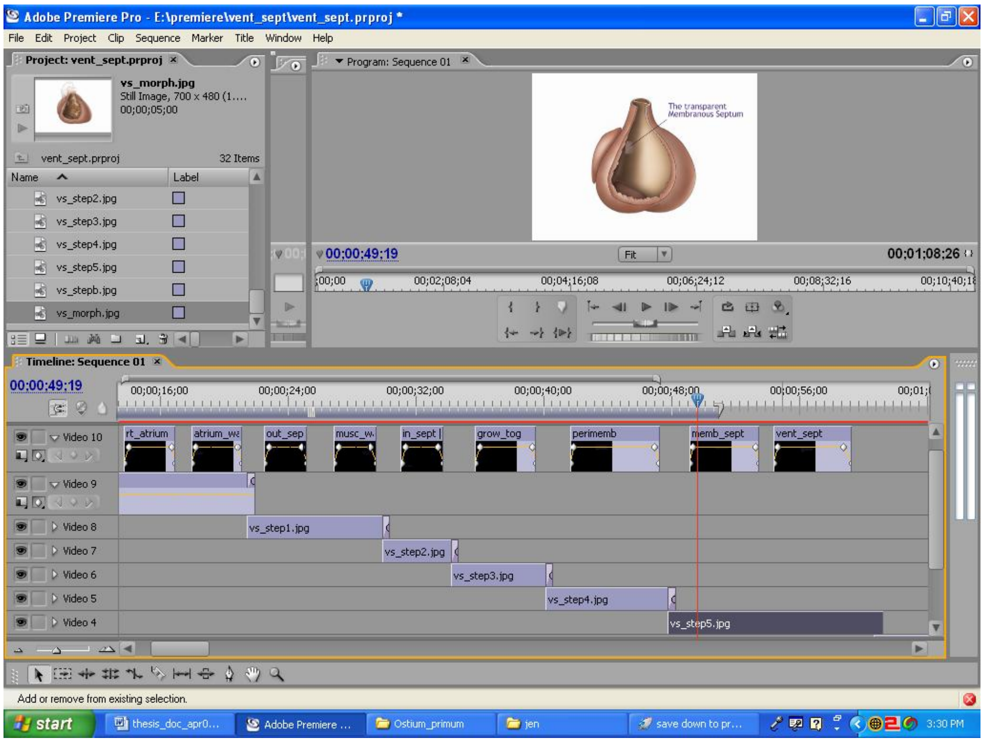


Figure 3-3 – Adobe Premiere Pro 2.0 Screenshot

labeling and added as needed to the animation sequences. The animations were then exported out as a 600 x 400 pixel QuickTime Movie using Sorenson 3 Compression at 100% quality. Another version of the animations was also exported for web delivery. These animations were reduced in sized, further compressed and reduced in quality in order to make them small enough to be downloaded and viewed in a reasonable amount of time, depending on the viewers internet connection speed. They were exported out as AVI movies, at a size of 300 by 200 pixels using cinepak codec compression at 50% quality.

CHAPTER FOUR
Results

Survey Development

After all five of the animations were completed, they were posted online in order to be evaluated by the target audience, consisting of researchers and scientists, doctorates, post-doctorates, and graduate students in the cardiovascular field. To evaluate the effectiveness of the animations, as well as determine whether the goals and objectives had been met, a survey was developed and distributed by email to accompany the animations (see Appendix C). The survey was created using a 5-point Likert scale ranging from Strongly Agree (SA) to Strongly Disagree (SD). Ten statements were given pertaining to the goals and effectiveness of the animations, and evaluators were asked to check the box that corresponded to their level of agreement with the statement. Also included in the survey, were four background questions regarding the type of computer used in viewing the animations, internet connection, browser, and the participant's position in the cardiovascular field. The survey was created in Microsoft Word using locked form fields, to ensure that the evaluators could not accidentally alter the questionnaire. Spaces were also provided for all survey participants' additional comments.

Survey Distribution

In order to distribute the survey to the correct audience for this project, my content advisor and committee member, Dr. Deepak Srivastava, was enlisted to send out both the questionnaire and the link to the ftp site containing the posted animations to his fellow colleagues and the members of his lab. After watching all five animations and completing the surveys, the participants were asked to email the survey back to me as an attachment.

Survey Results

Ten individuals in the cardiovascular field participated in the Heart Septation and Septal Defect Survey (See Appendix D). Of these ten, four were doctors, one was a PhD, four were post-doctorates, and two were graduate students. This was a very nice sampling of individuals all across the target audience. In compiling the results for each of the ten statements in the survey, the statistics were calculated, and a pie chart was created showing the percentages for agreement or disagreement of each statement. Finally, a graph summarizing the responses from all participants over all ten of the statements was created in order to get an overall feel for the effectiveness of the animations (Table 4-1).

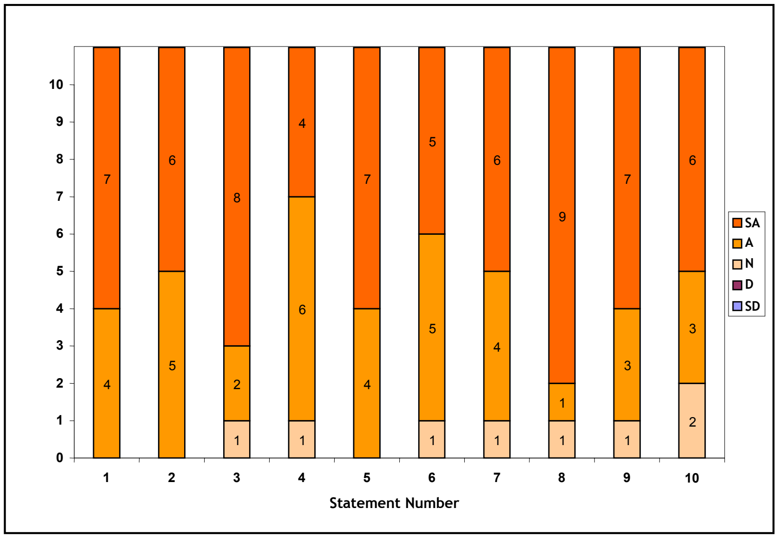


Table 4-1 – Summary of Responses

Statement 1

"The first animation (normal.avi) effectively depicts the process of atrial septation."

Given statement 1, 64% of participants strongly agreed and 36% agreed (Table 4-2). One participant who strongly agreed also commented, "Looks great, very clear!" Overall everyone agreed this was an effective way of describing the process of atrial septation.

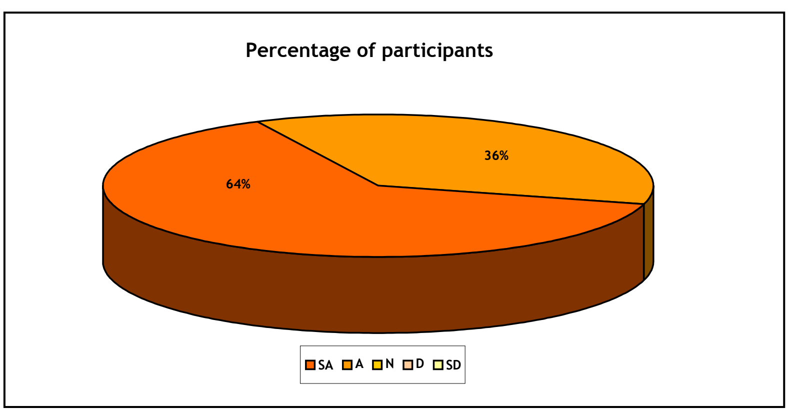


Table 4-2 – Statement 1 Results

Statement 2

"The second and third animations (ost_prim.avi and ost_sec.avi) effectively depict how certain atrial septal defects occur."

Given statement 2, 100% of participants agreed, 55% who strongly agreed and 45% who agreed (Table 4-3). Although there was an overwhelmingly positive response as to the

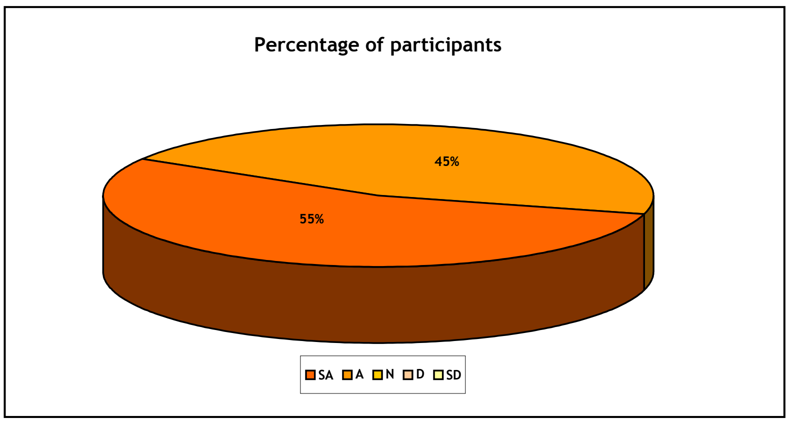


Table 4-3 – Statement 2 Results

effectiveness of these two atrial septal defect animations, one participant did say, "I hope you can draw more details for the septa."

Statement 3

"The colors chosen for the atrial septation animations were effective in highlighting specific areas of the developing heart."

Given statement 3, 73% strongly agreed, 18% agreed and 9% or one individual, was neutral (Table 4-4). The individual with a neutral response commented, "I like your base colors,

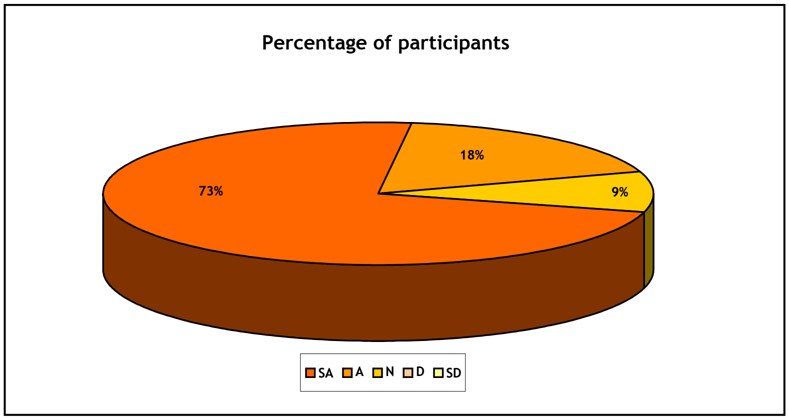


Table 4-4 – Statement 3 Results

but for septa and walls you may need to use bold colors to grab more attention from viewer." This participant also responded neutral to statement 6, which pertains to the colors chosen for the ventricular septation animations. Another comment made in regards to this statement pointed out a spelling error that was apparently overlooked during the creation process.

Statement 4

"The fourth animation (vent_sept.avi) effectively depicts the process of ventricular septation."

Given statement 4, 36% strongly agreed, 55% agreed and 9%, or one individual, was neutral (Table 4-5). The participant with a neutral response did not comment as to why he or she did not fully agree that the animation of ventricular septation was effective. However, one other participant did comment that "the inlet defect is a little unclear since the inlet is not really visible." No other participant made a comment stating that the inlet was not visible. The only other comment made for this statement was in regards to a grammatical error of

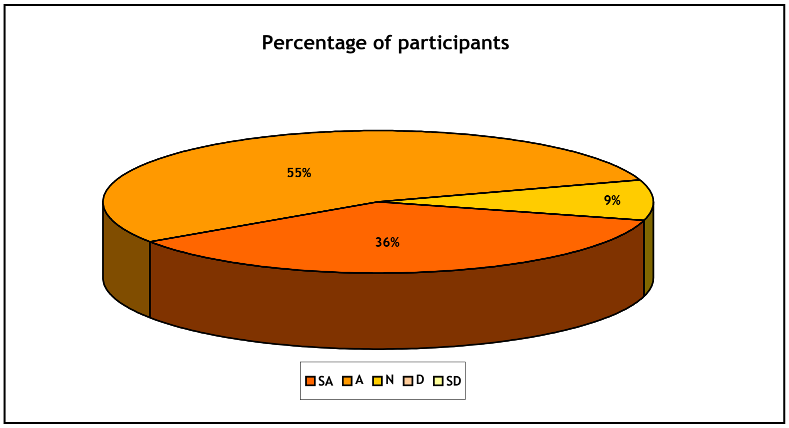


Table 4-5 – Statement 4 Results

noun/verb agreement that was easily corrected.

Statement 5

"The fifth animation (vs_defects.avi) effectively depicts the development of ventricular septal defects."

Given statement 5, 64% of individuals strongly agreed and 36% agreed (Table 4-6). This was an overwhelmingly positive response as to the effectiveness of the ventricular septal defect animation. There were no additional comments pertaining to this statement.

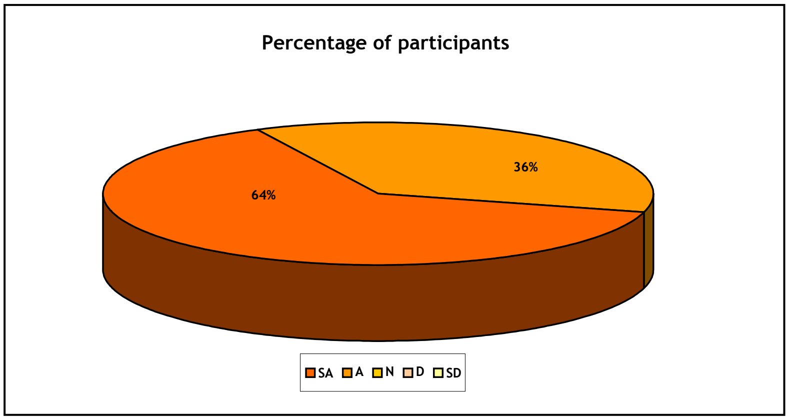


Table 4-6 – Statement 5 Results

Statement 6

"The colors chosen for the ventricular septation animations were effective."

Given statement 6, 46% strongly agreed, 45% agreed, and 9%, or one individual, was neutral (Table 4-7). For this statement, as mentioned above, the neutral respondent commented that the septa and walls should have a bolder color to draw more emphasis from the viewer.

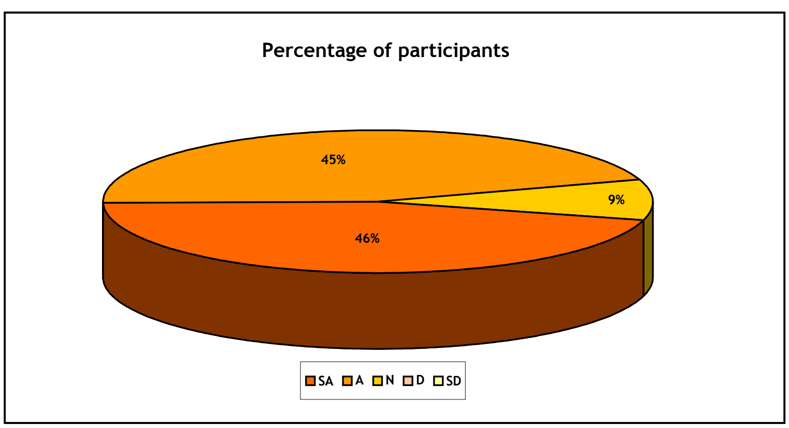


Table 4-7 – Statement 6 Results

Statement 7

"The labels used in the animations were appropriate and effective."

Given statement 7, 55% of participants strongly agreed, 36% agreed, and 9%, or one individual, was neutral (Table 4-8). The individual who answered neutral for this statement commented that the fonts should be larger. Another individual commented on the use of arrows within the labels, stating, "The blood flow shown with black arrows are very hard to see."

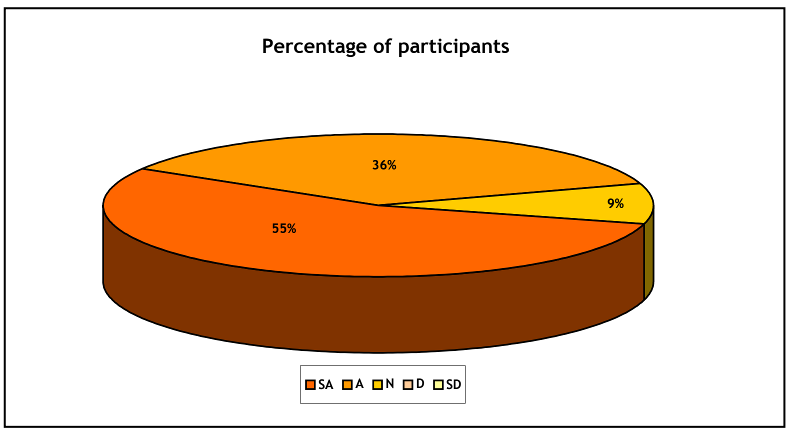


Table 4-8 – Statement 7 Results

Statement 8

"These animations are more useful than diagrams in understanding cardiac developmental processes."

Given statement 8, 82% of participants strongly agreed, 9% agreed, and 9% were neutral (Table 4-9). The majority of participants, therefore, strongly agreed. The individual that

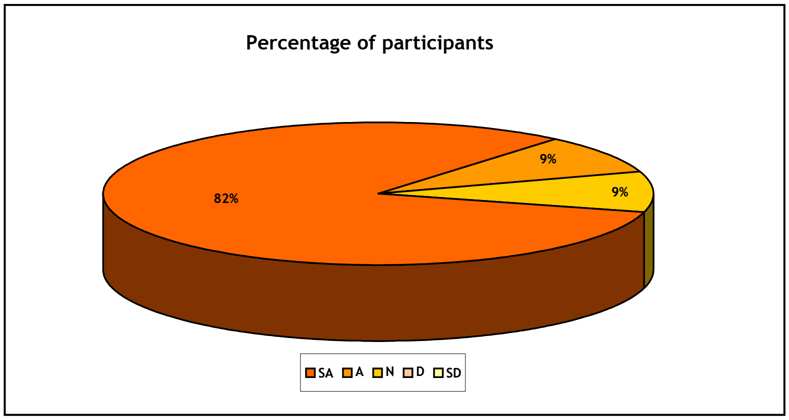


Table 4-9 – Statement 8 Results

responded neutrally to this statement did not indicate a reason for the response. One of the participants who strongly agreed, however, commented, “This is a fantastic way to learn cardiogenesis. Coupling these animations with histological sections of the heart at the same developmental time points would be a very complete way to learn this process.” This comment was made by a PhD in the cardiology field.

Statement 9

“Viewing these animations increased my understanding of heart septation and septal defects.”

Given statement 9, 64% of participants strongly agreed, 27% agreed, and only 9%, or one individual, was neutral (Table 4-10). In this case, the individual who answered neutral was a

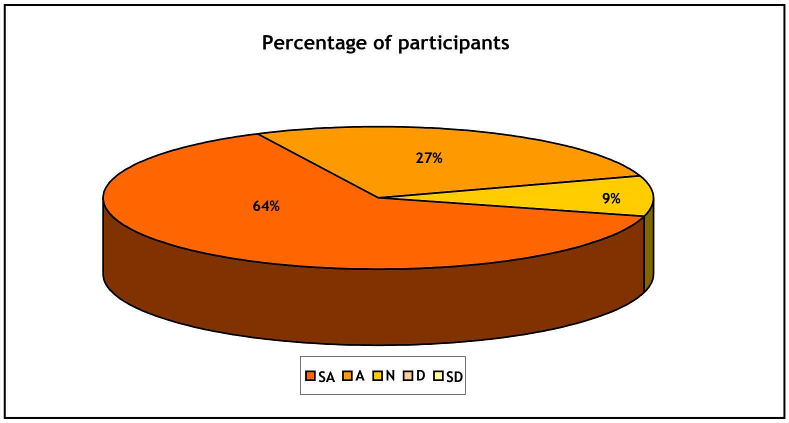


Table 4-10 – Statement 9 Results

medical doctor, who more than likely already has a much higher knowledge of these developmental processes than a post-doctorate or student would.

Statement 10

"The content of the animations was appropriate for an audience knowledgeable about cardiac development."

Given statement 10, 55% of the participants strongly agreed, 27% agreed, and 18% were neutral, the highest percentage of neutral response for any of the statements (Table 4-11). None of the neutral responders commented as to why they answered in this way. One participant who agreed did have a comment pertaining to this statement, saying, "I think it is also useful for an audience that is just learning about septal development."

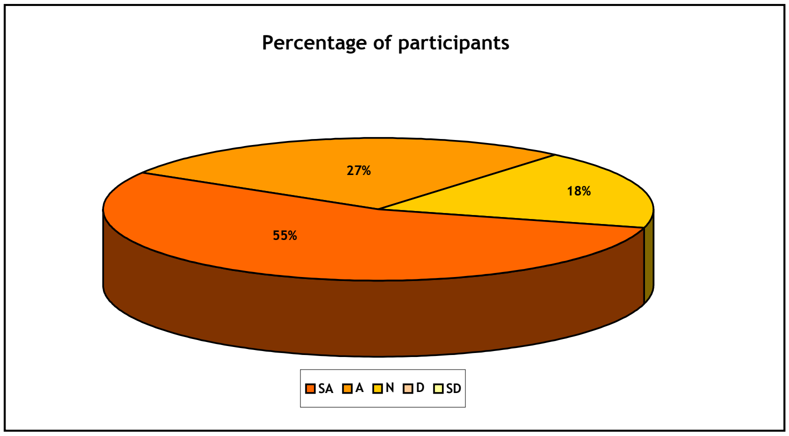


Table 4-11 – Statement 10 Results

Background Questions

Six of the survey participants viewed the animations on a Mac, four on a PC, and one failed to respond to this question. Seven of the participants used Internet Explorer and four of them used Safari as their browser. All ten of the participants viewed the animations using a high speed internet connection; eight with a T1/LAN connection, two using DSL/Cable, and one who was unsure. None of those who viewed the animations had comments regarding a difficulty or slowness in downloading them.

Suggestions and Additional Comments

None of the ten who participated in the Heart Septation and Septal Defect Survey provided any additional comments other than those pertaining to the ten individual statements. However, one participant's comment about the usefulness of animations as opposed to still diagrams, suggested that coupling the animations with histological sections at the same developmental time points would be an even more complete way of teaching cardiogenesis. This was the only additional comment or suggestion for furthering or expanding the project.

CHAPTER FIVE
Conclusions and Recommendations

Project Summary

The purpose of this thesis was to visually communicate, through the creation of two-dimensional animations, the developmental processes of heart septation of both the atria and ventricles, as well as the processes that describe how different types of atrial and ventricular septal defects form. It was thought that the use of animation, rather than two-dimensional diagrams, could possibly increase knowledge and understanding of these subjects and lead to advances in the cardiovascular field. By better understanding these cardiac developmental pathways, doctors and researchers may be able to devise new therapies to treat children with heart defects, specifically ASD and VSD, and this information could possibly then lead to advances in the treatment of heart disease in adults.

The target audience was identified, along with defining how the animations would be used in the scientific field. Research and a literature review were performed to further identify the content for the animations and specifically which defects would be animated. A project design of both visual and technical elements was completed and then implemented to create the final animations, which were then evaluated by an audience knowledgeable in the cardiovascular field.

Five animations describing cardiac developmental processes were completed. The first animation depicted the normal process of atrial septation during fetal development. The second and third animations described errors in this normal process, depicting development of an Ostium Secundum Atrial Septal Defect and Ostium Primum Atrial Septal Defect. The fourth animation described the normal process of ventricular septation during fetal development. The fifth and final animation described how several different ventricular septal defects develop and where they can be found in the mature heart.

For each animation, an initial storyboard was created, with each frame representing a single illustration in the process. Each frame was turned into a hand drawn sketch, which was then translated into line on the computer in Adobe Illustrator. Each line drawing was brought into Adobe Photoshop, rendered in black and white, and then colored. Once the illustrations had been formatted to the correct size, they were exported out of Photoshop and imported into Adobe Premiere Pro 2.0. The illustrations, or frames, were added sequentially onto the timeline and cross dissolved into one another to create a fluid transition between each frame and simulate the morphing of the heart during development. Once complete, the animations were exported out as QuickTime movies and posted on the web to be viewed and evaluated by the target audience.

Evaluations were completed based on a survey that was composed in Microsoft Word using form fields, in order to determine the effectiveness of the animations and how closely they achieved my goals and objectives. Ten individuals associated with the cardiovascular field participated in the survey and there was an overall positive response to all five of the animations.

Conclusion

Overall, the response to all five of the heart septation and septal defect animations was extremely positive, as was seen in the summary Table 4-1 in Chapter 4. There was an overall 93% agreement or strong agreement across the board for all ten statements in the survey. The majority of participants strongly agreed that the animations were a much more useful way of describing these developmental processes than still, schematic diagrams.

In summary, in terms of the design elements, it was concluded that the colors used to emphasize the septa could be made bolder to better catch the attention of the viewer. Also, the fonts could be made larger and the arrows somewhat clearer in showing blood flow in the atrial septation animations. Only one participant responded as to the size of the animations viewed on the web, asking whether they could be made larger. The animations were viewed somewhat smaller on the web, being reduced and compressed for quicker web delivery, which may have contributed to these participants' opinions of size and clarity. None of the participants commented on having slowness or difficulty viewing the animations over the internet, which led me to believe they were properly formatted for web use. The animations were also free of kinks, being viewed cross platform and from different types of browsers.

In terms of meeting the needs of the target audience, the animations may be somewhat simple for the very knowledgeable medical doctors, but seem to be quite useful as more of an educational tool for the graduate level audience. This could be seen by noting that the individual who stated neutrally that their knowledge was not increased through viewing the animations, was a medical doctor. Therefore, a response of neutral may not be surprising for someone at this high level of understanding. This being said, however, the other doctors who viewed the animations did not respond in this way, but rather agreed with this statement regarding an increase in knowledge. In response to statement 10 regarding whether or not the animations were effective for an audience knowledgeable about cardiac development, the highest percentage, 18%, were neutral. Because none of the neutral responders commented as to why they answered in this way, I could only assume that since the animations were not overly detailed or complicated, that they were too simplified for this audience. This leads me to believe that they would be better used as an educational teaching tool for the secondary target audience, graduate students. It was also stated by one individual that the septa should be more detailed. The animations were indeed created using a very simplified, somewhat schematic, but still fully rendered style, without a great amount of detail. This design was an attempt to strike a balance between technicality and simplicity in order to appeal to the entire target audience. In conclusion, all of the goals and objectives set forth in this project were met with an overwhelmingly positive response from viewers.

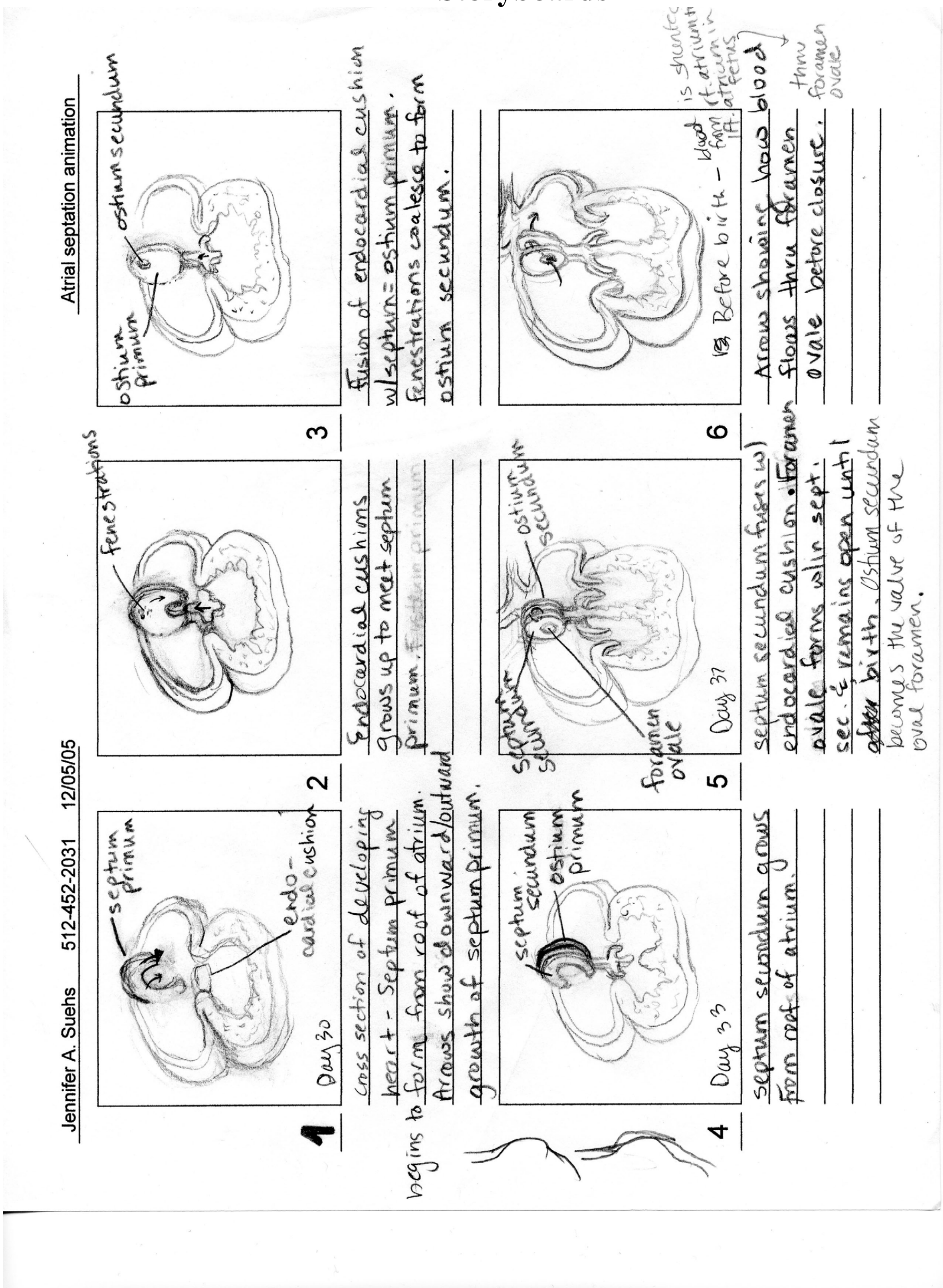
Suggestions for Further Research

Heart disease continues to be very prevalent in the United States as the leading cause of death in Americans of all ages. Congenital heart disease strikes 1 out of every 125 babies born in the U.S. (March of Dimes, 2006), but advances in treatment and therapies can help to decrease these startling statistics. These advances in research will require effective visual resources to be available to those in the cardiovascular field, in order to continue to educate them about these intricate developmental pathways. Thus, one obvious avenue for future research would be to complete the set of animations depicting septal defects to include those defects that were not animated within the scope of this project. Furthermore, advances in the research of mechanisms describing how the ventricular septal defects occur, could eventually allow the creation of animations showing the full developmental process, rather than just the location, where ventricular septal defects are found.

Another suggestion for further research would be the development of animations describing other developmental pathways that take place during cardiac embryogenesis. For example, animations could be created describing the processes of valve formation in the fetal heart. As of now, there is not much known about this process, but as research continues, these animations could provide vital information in the field, hopefully leading to the underlying cause of defects associated with different heart valves.

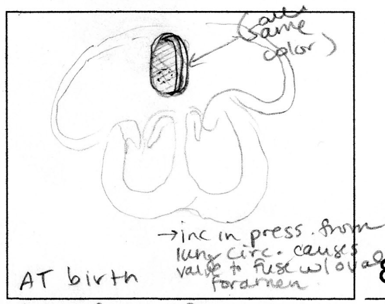
Based on suggestions from the surveys completed by the target audience, another area of future development could include a coupling of the animations with histological sections at the same developmental time points, as a more comprehensive way to teach cardiogenesis. There may also need to be a differentiation in the design of the animations for different target audiences. In this project, both a more advanced and secondarily, a less mature graduate level audience were targeted to be able to use and appreciate the animations. Although this project seemed to cover the secondary audience quite well, a more detailed depiction of the same processes may fair better for the more technical, scientific audience.

APPENDIX A
Storyboards



Jennifer A. Suehs 512-452-2031 12/05/05 DEFECT ① DEFECT② Atrial septation animation

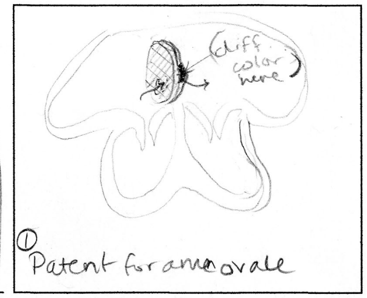
7



AT birth

Valve of oval foramen fuses w/ septum secundum to form final septum separating rt. & lft. atrium
Blood no longer passes b/n atria

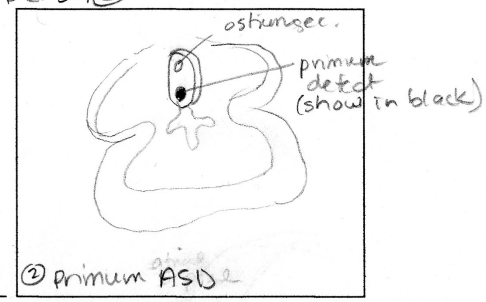
8



① Patent foramen ovale

Incomplete fusion at birth of ost. sec. & valve of for. ovale.
Show arrow for blood flowing b/n atria.

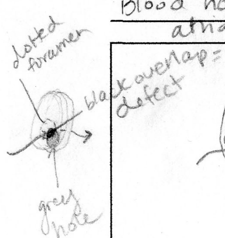
9

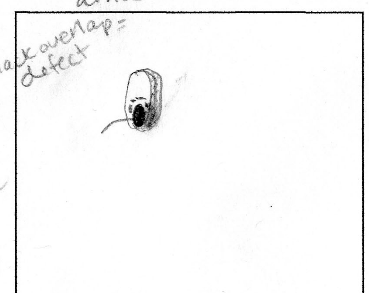


② primum ASD

Show slide 1, 2 ... in 3, extra hole forms in lower part of septum primum.

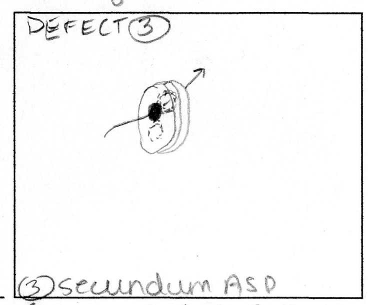
10





continue w/ slides 4, 5, 7 (fusion)
where foramen ovale & primum defect overlap, you have lft. to rt. shunting (show w/ arrow)

11



③ secundum ASD

Show slide 1, 2, 3, 4 ... in 5 show extra hole in middle of sept. sec. above foramen ovale ... slide 7 (fusion)
→ Arrow shows shunting of blood

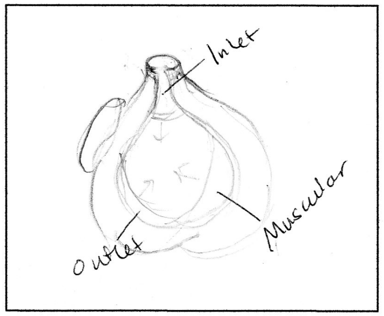
12

Jennifer A. Suehs 512-452-2031

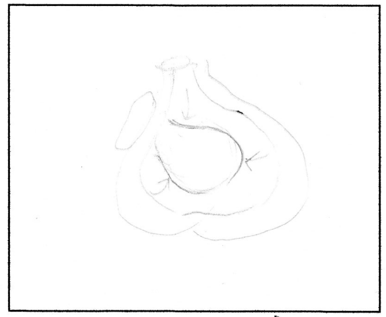
Ventricular septation animation

Insert Here w/nothing yet

1

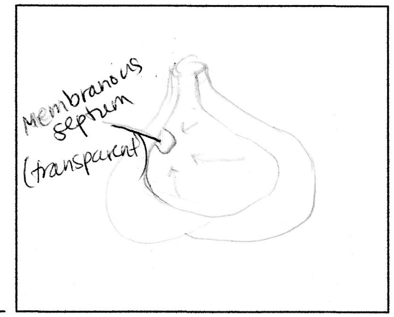


2



Continue to grow inward

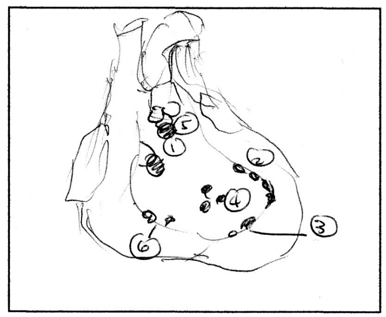
3



4

Morph to mature heart. –
Show muscular
trabeculations, etc

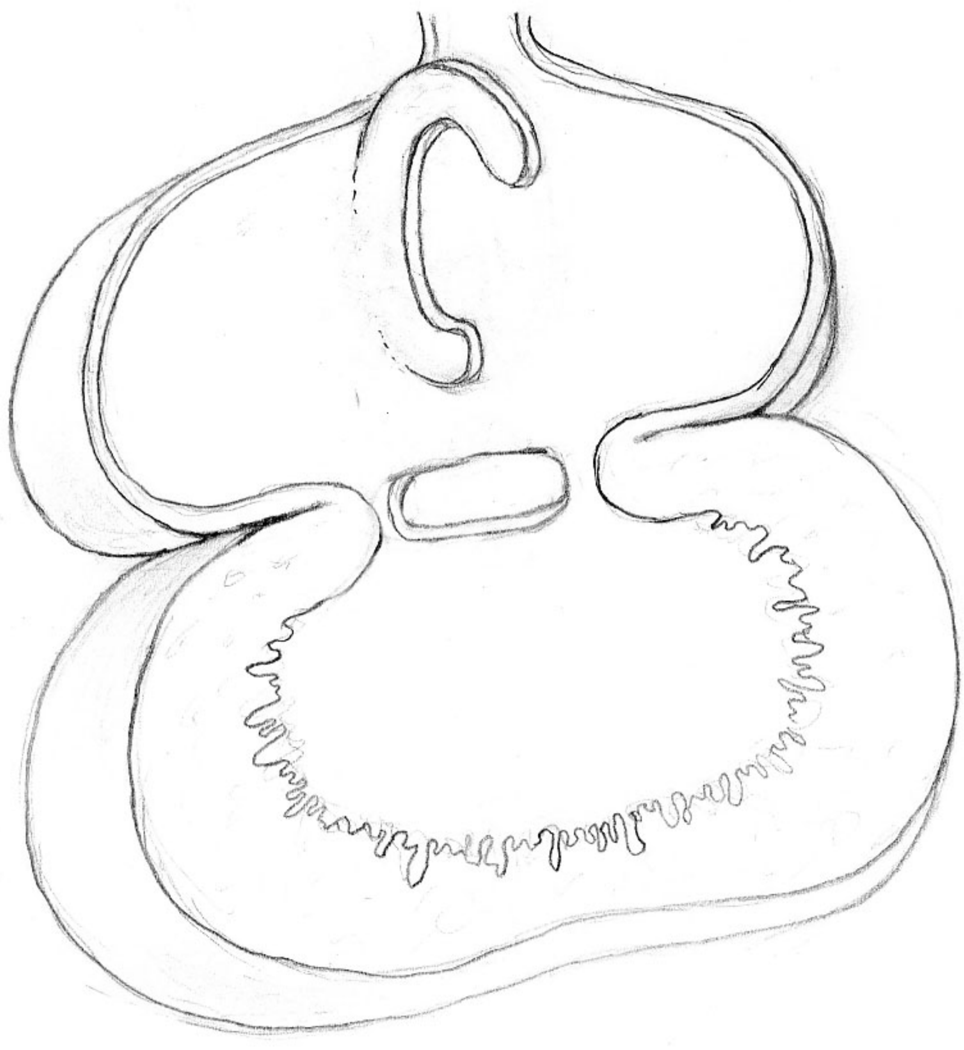
5

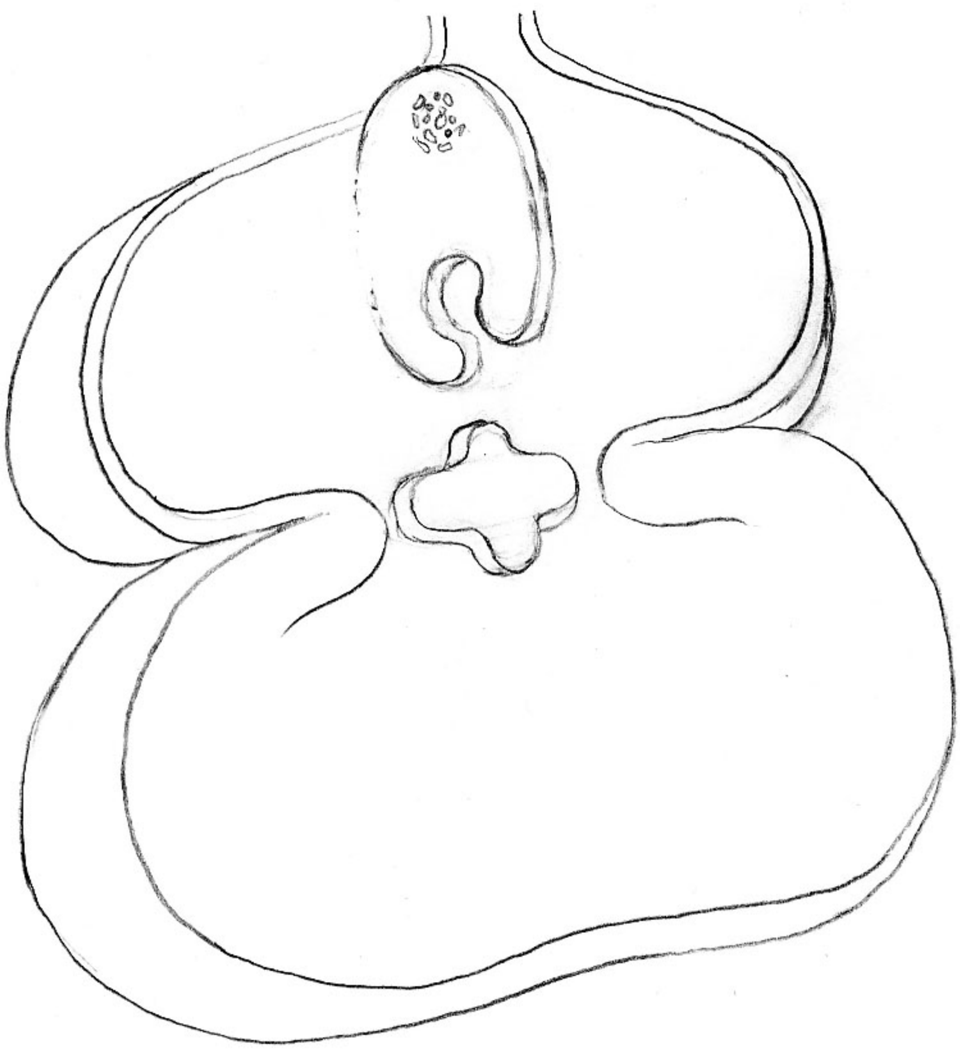


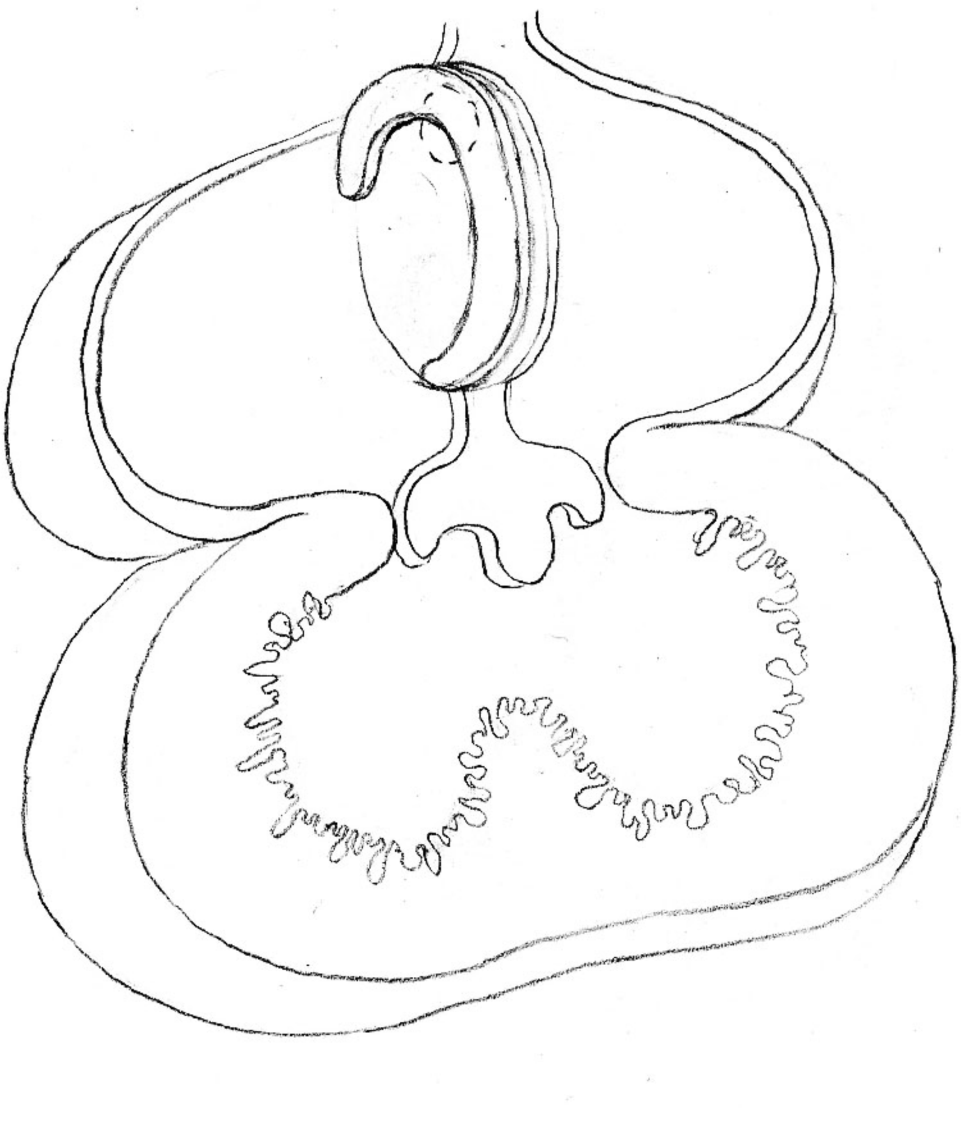
① Memb.
② Inlet
③ Apic
④ Mid muscular
⑤ Marginae
⑥ Outlet

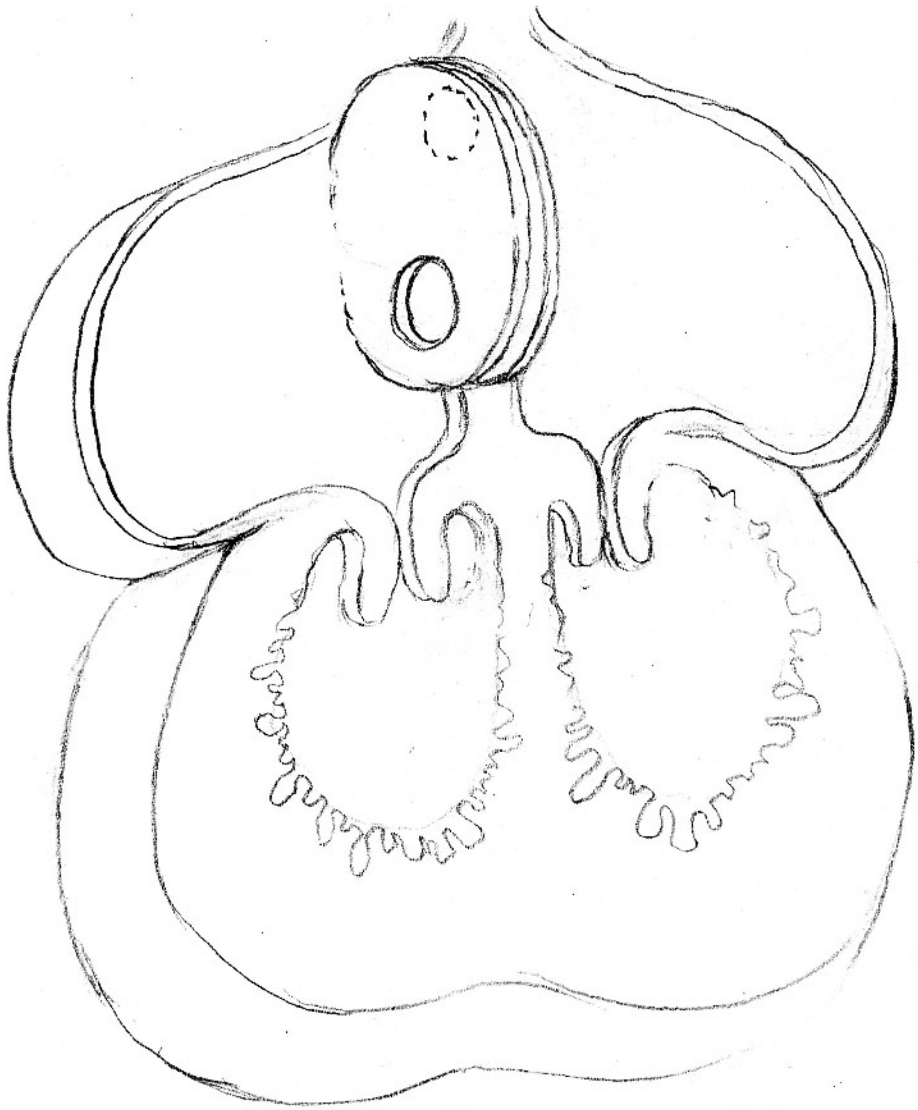
6

APPENDIX B
Sketches

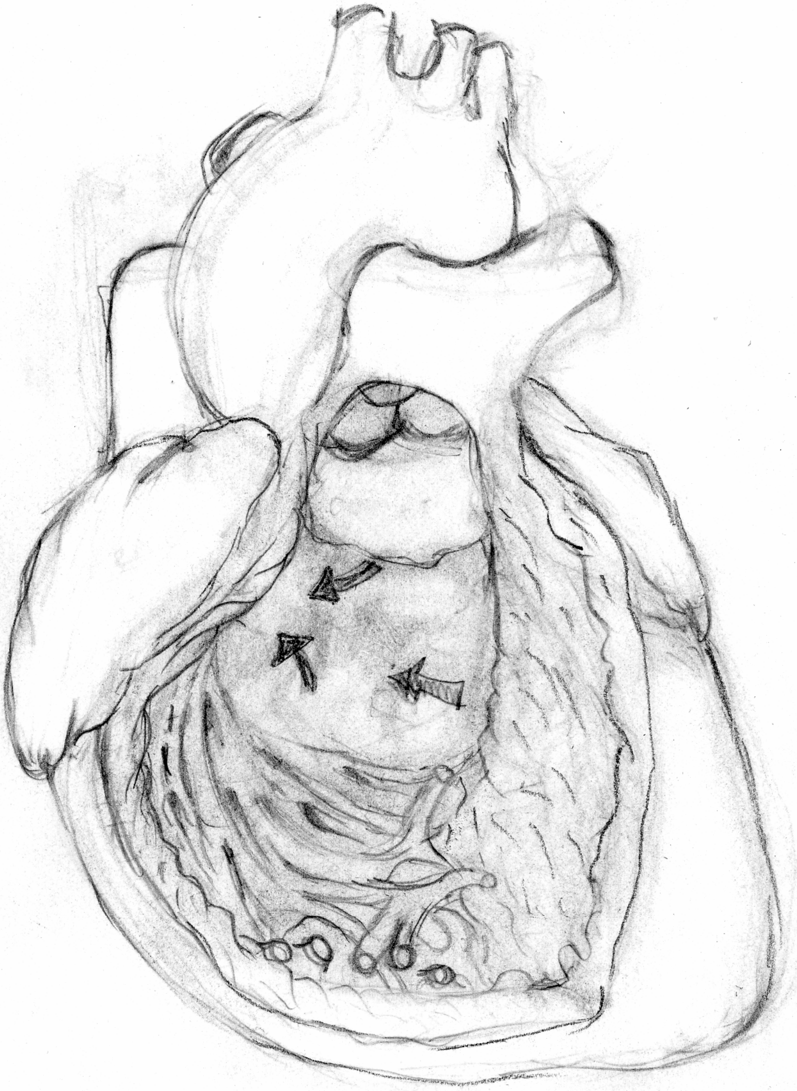









LV



APPENDIX C
Heart Septation and Septal Defect Animation Survey

Instructions: Please check the box that corresponds to your level of agreement with the statement to the left (SA=strongly agree, A=agree, N=neutral, D-disagree, SD=strongly disagree). Please feel free to provide additional comments in the spaces provided.

	SA	A	N	D	SD
1. The first animation (normal.avi) effectively depicts the process of atrial septation.	☐	☐	☐	☐	☐

Comments:

	SA	A	N	D	SD
2. The second and third animations (ost_prim.avi and ost_sec.avi) effectively depict how certain atrial septal defects occur.	☐	☐	☐	☐	☐

Comments:

	SA	A	N	D	SD
3. The colors chosen for the atrial septation animations were effective in highlighting specific areas of the developing heart.	☐	☐	☐	☐	☐

Comments:

	SA	A	N	D	SD
4. The fourth animation (vent_sept.avi) effectively depicts the process of ventricular septation.	☐	☐	☐	☐	☐

Comments:

	SA	A	N	D	SD
5. The fifth animation (vs_defects.avi) effectively depicts the development of ventricular septal defects.	☐	☐	☐	☐	☐

Comments:

	SA	A	N	D	SD
6. The colors chosen for the ventricular septation animations were effective.	☐	☐	☐	☐	☐

Comments:

	SA	A	N	D	SD
7. The labels used in the animations were appropriate and effective.	☐	☐	☐	☐	☐

Comments:

	SA	A	N	D	SD
8. These animations are more useful than diagrams in understanding cardiac developmental processes.	☐	☐	☐	☐	☐

Comments:

9. Viewing these animations increased my understanding of heart septation and septal defects.	☐	☐	☐	☐	☐

Comments:

10. The content of the animations was appropriate for an audience knowledgeable about cardiac development.	☐	☐	☐	☐	☐

Comments:

Additional Background Questions:

What type of computer did you use to view the animations? (Mac, PC, etc.)

What browser did you use to view the animations?

- ☐ Internet explorer
- ☐ Safari
- ☐ Netscape
- ☐ Firefox
- ☐ Other

What type of internet connection did you use to view the animations? (if you are using a UTSW computer, you are using a T1/LAN internet connection)

- ☐ Dial-up
- ☐ DSL/Cable modem
- ☐ T1/LAN
- ☐ Unsure

What is your position in the cardiovascular field? (PhD, Post-doc, graduate student, etc.)

Thank you for your time and participation!

APPENDIX D
Completed Surveys

Heart Septation and Septal Defect Animation Survey

Instructions: Please check the box that corresponds to your level of agreement with the statement to the left (SA=strongly agree, A=agree, N=neutral, D-disagree, SD=strongly disagree). Please feel free to provide additional comments in the spaces provided.

	SA	A	N	D	SD
1. The first animation (normal.avi) effectively depicts the process of atrial septation.	X				

Comments:

	SA	A	N	D	SD
2. The second and third animations (ost_prim.avi and ost_sec.avi) effectively depict how certain atrial septal defects occur.	X				

Comments:

	SA	A	N	D	SD
3. The colors chosen for the atrial septation animations were effective in highlighting specific areas of the developing heart.	X				

Comments:

	SA	A	N	D	SD
4. The fourth animation (vent_sept.avi) effectively depicts the process of ventricular septation.		X			

Comments:

	SA	A	N	D	SD
5. The fifth animation (vs_defects.avi) effectively depicts the development of ventricular septal defects.	X				

Comments:

	SA	A	N	D	SD
6. The colors chosen for the ventricular septation animations were effective.	X				

Comments:

	SA	A	N	D	SD
7. The labels used in the animations	X				

were appropriate and effective.

Comments:

	SA	A	N	D	SD
8. These animations are more useful than diagrams in understanding cardiac developmental processes.	☒	☐	☐	☐	☐

Comments:

	SA	A	N	D	SD
9. Viewing these animations increased my understanding of heart septation and septal defects.	☒	☐	☐	☐	☐

Comments:

	SA	A	N	D	SD
10. The content of the animations was appropriate for an audience knowledgeable about cardiac development.	☒	☐	☐	☐	☐

Comments:

Additional Background Questions:

What type of computer did you use to view the animations? (Mac, PC, etc.)
Mac

What browser did you use to view the animations?
☐ Internet explorer ☐ Firefox
☒ Safari ☐ Other
☐ Netscape

What type of internet connection did you use to view the animations? (if you are using a UTSW computer, you are using a T1/LAN internet connection)
☐ Dial-up ☒ T1/LAN
☐ DSL/Cable modem ☐ Unsure

What is your position in the cardiovascular field? (PhD, Post-doc, graduate student, etc.)
pediatric cardiologist

Thank you for your time and participation!

Heart Septation and Septal Defect Animation Survey

Instructions: Please check the box that corresponds to your level of agreement with the statement to the left (SA=strongly agree, A=agree, N=neutral, D-disagree, SD=strongly disagree). Please feel free to provide additional comments in the spaces provided.

	SA	A	N	D	SD
1. The first animation (normal.avi) effectively depicts the process of atrial septation.	☒	☐	☐	☐	☐

Comments:

2. The second and third animations (ost_prim.avi and ost_sec.avi) effectively depict how certain atrial septal defects occur.	☐	☒	☐	☐	☐

Comments:

3. The colors chosen for the atrial septation animations were effective in highlighting specific areas of the developing heart.	☒	☐	☐	☐	☐

Comments:

4. The fourth animation (vent_sept.avi) effectively depicts the process of ventricular septation.	☒	☐	☐	☐	☐

Comments:

5. The fifth animation (vs_defects.avi) effectively depicts the development of ventricular septal defects.	☒	☐	☐	☐	☐

Comments:

6. The colors chosen for the ventricular septation animations were effective.	☐	☒	☐	☐	☐

Comments:

7. The labels used in the animations were appropriate and effective.	☐	☐	☒	☐	☐

Comments:Need to use larger fonts

8. These animations are more useful	☐	☒	☐	☐	☐

than diagrams in understanding cardiac developmental processes.					

Comments:

	SA	A	N	D	SD
9. Viewing these animations increased my understanding of heart septation and septal defects.	☒	☐	☐	☐	☐

Comments:

10. The content of the animations was appropriate for an audience knowledgeable about cardiac development.	☒	☐	☐	☐	☐

Comments:

Additional Background Questions:

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- ☐ Dial-up
- ☒ T1/LAN
- ☐ DSL/Cable modem
- ☐ Unsure

What is your position in the cardiovascular field? (PhD, Post-doc, graduate student, etc.)
Gradutae Student

Thank you for your time and participation!

Heart Septation and Septal Defect Animation Survey

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Comments:

	SA	A	N	D	SD
2. The second and third animations (ost_prim.avi and ost_sec.avi) effectively depict how certain atrial septal defects occur.	☒	☐	☐	☐	☐

Comments:

	SA	A	N	D	SD
3. The colors chosen for the atrial septation animations were effective in highlighting specific areas of the developing heart.	☒	☒	☐	☐	☐

Comments:There is a spelling error when "Outflow septum divides the outflow tract in two" appears. It says "outlfow"

	SA	A	N	D	SD
4. The fourth animation (vent_sept.avi) effectively depicts the process of ventricular septation.	☐	☒	☐	☐	☐

Comments:noun/verb don't agree in "Problems in development of ventricular septum causes various ventricular septal defetcts to occur." Should say "cause." It would be difficult to fix, but the inlet defect is a little unclear since the inlet is not really visible.

	SA	A	N	D	SD
5. The fifth animation (vs_defects.avi) effectively depicts the development of ventricular septal defects.	☐	☒	☐	☐	☐

Comments:

	SA	A	N	D	SD
6. The colors chosen for the ventricular septation animations were effective.	☐	☒	☐	☐	☐

Comments:

	SA	A	N	D	SD
7. The labels used in the animations were appropriate and effective.	☐	☒	☐	☐	☐

Comments:

	SA	A	N	D	SD
8. These animations are more useful than diagrams in understanding cardiac developmental processes.	☒	☐	☐	☐	☐

Comments:

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Comments:

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☐ DSL/Cable modem ☐ Unsure

What is your position in the cardiovascular field? (PhD, Post-doc, graduate student, etc.)
Post-doc

Thank you for your time and participation!

Heart Septation and Septal Defect Animation Survey

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Comments:

	SA	A	N	D	SD
6. The colors chosen for the ventricular septation animations were effective.	☐	☒	☐	☐	☐

Comments:

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Comments:

	SA	A	N	D	SD
8. These animations are more useful	☒	☐	☐	☐	☐

than diagrams in understanding cardiac developmental processes.					

Comments:

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9. Viewing these animations increased my understanding of heart septation and septal defects.	☐	☒	☐	☐	☐

Comments:

10. The content of the animations was appropriate for an audience knowledgeable about cardiac development.	☐	☐	☒	☐	☐

Comments:

Additional Background Questions:

What type of computer did you use to view the animations? (Mac, PC, etc.)
PC

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☐ Safari ☐ Other
☐ Netscape

What type of internet connection did you use to view the animations? (if you are using a UTSW computer, you are using a T1/LAN internet connection)

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☐ DSL/Cable modem ☐ Unsure

What is your position in the cardiovascular field? (PhD, Post-doc, graduate student, etc.)
Graduate student

Thank you for your time and participation!

Heart Septation and Septal Defect Animation Survey

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Comments:

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Comments:

	SA	A	N	D	SD
6. The colors chosen for the ventricular septation animations were effective.	☒	☐	☐	☐	☐

Comments:

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Comments:

	SA	A	N	D	SD
9. Viewing these animations increased my understanding of heart septation and septal defects.	☒	☐	☐	☐	☐

Comments:

10. The content of the animations was appropriate for an audience knowledgeable about cardiac development.	☒	☐	☐	☐	☐

Comments:

Additional Background Questions:

What type of computer did you use to view the animations? (Mac, PC, etc.) PC

What browser did you use to view the animations?	
☒ Internet explorer	☐ Firefox
☐ Safari	☐ Other
☐ Netscape	

What type of internet connection did you use to view the animations? (if you are using a UTSW computer, you are using a T1/LAN internet connection)	
☐ Dial-up	☒ T1/LAN
☐ DSL/Cable modem	☐ Unsure

What is your position in the cardiovascular field? (PhD, Post-doc, graduate student, etc.) Post-Doc, MD

Thank you for your time and participation!

Heart Septation and Septal Defect Animation Survey

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Comments:

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Comments:

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Comments:

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Comments:

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Comments:

10. The content of the animations was appropriate for an audience knowledgeable about cardiac development.	☐	☐	☒	☐	☐

Comments:

Additional Background Questions:

What type of computer did you use to view the animations? (Mac, PC, etc.)
mac

What browser did you use to view the animations?
☐ Internet explorer ☐ Firefox
☒ Safari ☐ Other
☐ Netscape

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☐ Dial-up ☐ T1/LAN
☒ DSL/Cable modem ☐ Unsure

What is your position in the cardiovascular field? (PhD, Post-doc, graduate student, etc.)
MD

Thank you for your time and participation!

Heart Septation and Septal Defect Animation Survey

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Comments:

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Comments:

	SA	A	N	D	SD
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Comments:

	SA	A	N	D	SD
4. The fourth animation (vent_sept.avi) effectively depicts the process of ventricular septation.	☒	☐	☐	☐	☐

Comments:

	SA	A	N	D	SD
5. The fifth animation (vs_defects.avi) effectively depicts the development of ventricular septal defects.	☒	☐	☐	☐	☐

Comments:

	SA	A	N	D	SD
6. The colors chosen for the ventricular septation animations were effective.	☒	☐	☐	☐	☐

Comments:

	SA	A	N	D	SD
7. The labels used in the animations were appropriate and effective.	☒	☐	☐	☐	☐

Comments:

	SA	A	N	D	SD
8. These animations are more useful than diagrams in understanding cardiac developmental processes.	☒	☐	☐	☐	☐

Comments:

	SA	A	N	D	SD
9. Viewing these animations increased my understanding of heart septation and septal defects.	☒	☐	☐	☐	☐

Comments:

	SA	A	N	D	SD
10. The content of the animations was appropriate for an audience knowledgeable about cardiac development.	☒	☐	☐	☐	☐

Comments:

Additional Background Questions:

What type of computer did you use to view the animations? (Mac, PC, etc.)

What browser did you use to view the animations?

☒ Internet explorer ☐ Firefox
☐ Safari ☐ Other
☐ Netscape

What type of internet connection did you use to view the animations? (if you are using a UTSW computer, you are using a T1/LAN internet connection)

☐ Dial-up ☒ T1/LAN
☐ DSL/Cable modem ☐ Unsure

What is your position in the cardiovascular field? (PhD, Post-doc, graduate student, etc.)
postdoc

Thank you for your time and participation!

Heart Septation and Septal Defect Animation Survey

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	SA	A	N	D	SD
1. The first animation (normal.avi) effectively depicts the process of atrial septation.	☒	☐	☐	☐	☐

Comments:

	SA	A	N	D	SD
2. The second and third animations (ost_prim.avi and ost_sec.avi) effectively depict how certain atrial septal defects occur.	☒	☐	☐	☐	☐

Comments:

	SA	A	N	D	SD
3. The colors chosen for the atrial septation animations were effective in highlighting specific areas of the developing heart.	☒	☐	☐	☐	☐

Comments:

	SA	A	N	D	SD
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Comments:

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Comments:

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6. The colors chosen for the ventricular septation animations were effective.	☒	☐	☐	☐	☐

Comments:

	SA	A	N	D	SD
7. The labels used in the animations were appropriate and effective.	☒	☐	☐	☐	☐

Comments:

	SA	A	N	D	SD
8. These animations are more useful	☒	☐	☐	☐	☐

than diagrams in understanding cardiac developmental processes.					

Comments:

	SA	A	N	D	SD
9. Viewing these animations increased my understanding of heart septation and septal defects.	☒	☐	☐	☐	☐

Comments:

10. The content of the animations was appropriate for an audience knowledgeable about cardiac development.	☐	☒	☐	☐	☐

Comments:

Additional Background Questions:

What type of computer did you use to view the animations? (Mac, PC, etc.)
PC

What browser did you use to view the animations?

- ☒ Internet explorer
- ☐ Firefox
- ☐ Safari
- ☐ Other
- ☐ Netscape

What type of internet connection did you use to view the animations? (if you are using a UTSW computer, you are using a T1/LAN internet connection)

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- ☐ DSL/Cable modem
- ☒ Unsure

What is your position in the cardiovascular field? (PhD, Post-doc, graduate student, etc.)
postdoc

Thank you for your time and participation!

Heart Septation and Septal Defect Animation Survey

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	SA	A	N	D	SD
1. The first animation (normal.avi) effectively depicts the process of atrial septation.	☒	☐	☐	☐	☐

Comments: Looks great, very clear!

	SA	A	N	D	SD
2. The second and third animations (ost_prim.avi and ost_sec.avi) effectively depict how certain atrial septal defects occur.	☒	☐	☐	☐	☐

Comments:

	SA	A	N	D	SD
3. The colors chosen for the atrial septation animations were effective in highlighting specific areas of the developing heart.	☒	☐	☐	☐	☐

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Comments:

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6. The colors chosen for the ventricular septation animations were effective.	☐	☒	☐	☐	☐

Comments:

	SA	A	N	D	SD
7. The labels used in the animations were appropriate and effective.	☒	☐	☐	☐	☐

Comments:

	SA	A	N	D	SD
8. These animations are more useful	☒	☐	☐	☐	☐

than diagrams in understanding cardiac developmental processes.					

Comments: This is a fanatastic way to learn cardiogenesis. Coupling these animations with histological sections of the heart at the same developmental timepoints would be a very complete way to learn this process.

	SA	A	N	D	SD
9. Viewing these animations increased my understanding of heart septation and septal defects.	☒	☐	☐	☐	☐

Comments:

10. The content of the animations was appropriate for an audience knowledgeable about cardiac development.	☐	☒	☐	☐	☐

Comments: I think it is also useful for an audience that is just learning about septal development.

<u>Additional Background Questions:</u>

What type of computer did you use to view the animations? (Mac, PC, etc.)
PC

What browser did you use to view the animations?

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What is your position in the cardiovascular field? (PhD, Post-doc, graduate student, etc.)
PhD

Thank you for your time and participation!

Heart Septation and Septal Defect Animation Survey

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Comments:

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Comments:

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Comments:

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Comments:

10. The content of the animations was appropriate for an audience knowledgeable about cardiac development.	☐	☒	☐	☐	☐

Comments:

Additional Background Questions:

What type of computer did you use to view the animations? (Mac, PC, etc.)
mac

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What is your position in the cardiovascular field? (PhD, Post-doc, graduate student, etc.)
postdoc

Thank you for your time and participation!

Heart Septation and Septal Defect Animation Survey

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Comments:

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	SA	A	N	D	SD
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Comments:

	SA	A	N	D	SD
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Comments:

	SA	A	N	D	SD
9. Viewing these animations increased my understanding of heart septation and septal defects.	☒	☐	☐	☐	☐

Comments:

10. The content of the animations was appropriate for an audience knowledgeable about cardiac development.	☒	☐	☐	☐	☐

Comments:

Additional Background Questions:

What type of computer did you use to view the animations? (Mac, PC, etc.)
Mac

What browser did you use to view the animations?
☒ Internet explorer ☐ Firefox
☐ Safari ☐ Other
☐ Netscape

What type of internet connection did you use to view the animations? (if you are using a UTSW computer, you are using a T1/LAN internet connection)
☐ Dial-up ☒ T1/LAN
☐ DSL/Cable modem ☐ Unsure

What is your position in the cardiovascular field? (PhD, Post-doc, graduate student, etc.)
faculty

Thank you for your time and participation!

APPENDIX E
Written Permissions for Image Reuse

PERMISSION REQUEST #1

On 13/04/2006, at 9:20 AM, Jennifer Angelo wrote:

Dr. Hill,

I am a graduate student at The University of Texas Southwestern Medical School in Dallas, Texas. I am writing to request permission to reproduce an image from your Embryology website of one of your 3D Heart Septation Movies. I would like to use a still image in my thesis project, for educational purposes only. The thesis would be filed both electronically and in paper form at the University. Would it be possible for me to have permission for reuse in one or both of these areas? I would not be reproducing it for any other reasons. I would greatly appreciate it.

Thank you,
Jennifer Angelo
Department of Biomedical Communications

Reply------

Dear Jennifer,

Many thanks for your email. I am happy for you to use images from my site in your thesis and lecture presentations for educational use.

I am always happy to support educational projects and presentations, I usually give permission for educational image use, but **not on the web**.
I understand that your university may have an electronic submission requirement, so in this case you may still use the image electronically. Please cite the original source, AMA format would be as shown below, you may wish also too include the actual page the image is from.

Hill, M.A. UNSW Embryology. 2006. Available at: http://embryology.med.unsw.edu.au/. Accessed (insert date here).

The reason I generally do not allow material to be republished on the web elsewhere is that I cannot control the content associated with the images and in addition web searches for embryology topics then show multiple listings of the same image. http://embryology.med.unsw.edu.au/disclaimer.html

Good luck with your thesis!

Dr Mark Hill
Cell Biology Laboratory
School of Medical Sciences
The University of New South Wales
Sydney NSW 2052
AUSTRALIA

p: +612 9385 2477
e: m.hill@unsw.edu.au
http://cellbiology.med.unsw.edu.au/cbl.htm

PERMISSION REQUEST #2

Original Message-----

From: Jennifer Angelo [mailto:Jennifer.Angelo@UTSouthwestern.edu]
Sent: Wednesday, April 12, 2006 6:14 PM
To: Schwartz, Roberta J.
Subject: copyright reuse permission

I am writing to request permission to use one of the images found on the Mayo website. I am a graduate student at the University of Texas Southwestern Medical School in Dallas, TX, and would like to use an image off of your site (of atrial septal defects) within my thesis paper, solely for educational purposes. The thesis will be filed both electronically and in paper form. Is there any way to gain permission for either one or both of these avenues? What would I need to do?
Thank you,
Jennifer Angelo

Reply---------

Ms. Angelo,

I am responding to your request to use graphics or photos on the Mayo Clinic Web site (mayoclinic.org). You may use the graphics you requested as long as you follow these guidelines: (1) you do not alter or modify the materials in any way; (2) you include all applicable notices and disclaimers (including copyright notices); and (3) you do not use the materials in a way that suggests an association with a provider or an affiliated Mayo entity.

Thank You for contacting Mayo Clinic.

Amos Kermisch || Web Unit Manager || Mayo Clinic || 200 First Street SW, Rochester, MN 55905 || kermisch.amos@mayo.edu || 507.266.9027 || http://www.mayoclinic.org

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PERMISSION REQUEST #3

Original Message-----
From: Jennifer Angelo [mailto:Jennifer.Angelo@UTSouthwestern.edu]
Sent: 18 April 2006 21:19
To: Kirk, Richard
Subject: copyright permission

Mr. Kirk,

I am a graduate student at The University of Texas Southwestern Medical School in Dallas, Texas. I am writing to request permission to reproduce an image from your website of Ventricular Septation found at this link:

http://www.crkirk.com/thumbnail/index.htm

I would like to use this image in my thesis project, for educational purposes only. The thesis would be filed both electronically and in paper form at the University only. Would it be possible for me to have permission for reuse in one or both of these areas? I would not be reproducing it for any other reasons. I would greatly appreciate it.

Thank you,
Jennifer Angelo
Department of Biomedical Communications

Reply--------

Jennifer –
You are very welcome to use the image for your thesis in what ever way you wish.

Best wishes

Richard

Dr Richard Kirk MA FRCP FRCPCH
Consultant Pediatric Cardiologist
Freeman Hospital, Newcastle upon Tyne NE7 7DN, UK
+44 (0)191 213 7499

PERMISSION REQUEST #4

APR-13-2006 10:18 LWW PERMISSIONS 21555218466 P.01/01

Wayne, Marie

From: Jennifer Angelo [Jennifer.Angelo@UTSouthwestern.edu]
Sent: Wednesday, April 12, 2006 11:22 PM
To: permissions@LWW.com
Subject: EDUCATIONAL USE

Biomedical Communications Graduate Program UT Southwestern Medical Center at Dallas
5323 Harry Hines Blvd.
Dallas, TX 75390-8881

To- Jennifer Angelo Suehs
(214) 648-5353 fax
jennifer.angelo@utsouthwestern.edu

Sadler, T.W. Langman's Medical Embryology, 8th ed. Philadelphia. Lippincott Williams & Wilkins; 2000: pp. 222, 228

Figure 11.13, Figure 11.18

These two figures will be used in my graduate student thesis paper for educational purposes only. The thesis will be filed electronically with the University of Texas Southwestern Medical School, as well as in paper form. I am requesting permission for use in one or both of these formats.

Thank you,
Jennifer Angelo Suehs

Permission is granted to reproduce the requested material for use in your academic thesis/dissertation. Permission is granted provided a prominent credit line is placed stating the original source and copyright owner, © Lippincott Williams & Wilkins.

Marie Wayne date: 4/13/06

material must be original to our publication

TOTAL P.01

PERMISSION REQUEST #5

Original Message-----
From: Jennifer Angelo [mailto:Jennifer.Angelo@UTSouthwestern.edu]
Sent: Wednesday, April 26, 2006 11:53 AM
To: marino@temple.edu
Subject: copyright permission

Dr. Marino,

I am a student at the University of Texas Southwestern Medical School in Dallas, TX. I was writing to ask your permission to use an image off of your embryology course website that describes atrial septation. I would only be using it in my master's thesis paper for educational purposes only, and it would be filed both electronically through the university and in paper format. It would be properly cited back to you. Please let me know if I can use the image in either or both formats.

Thank you,
Jennifer Suehs
Department of Biomedical Communications, UTSW
512-731-5458

Reply-------

Hi Jennifer

That would be fine to use the image. And good luck with your thesis.

Dr. Marino

Thomas A. Marino, Ph.D.
Professor of Anatomy and Cell Biology
Temple University School of Medicine
3400 North Broad Street
Philadelphia, PA 19140
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http://www.temple.edu/marino

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VITAE

Jennifer Angelo Suehs was born in Spring, TX, on April 23, 1980, the daughter of Jacob and Diana Angelo. After completing her work at Klein High School, Klein, Texas in 1998, she entered the University of Texas (UT) at Austin. While attending UT, she also attended night school at Austin Community College, taking a variety of art classes in preparation for further education in the art field. She received the degree of Bachelor of Science in Human Biology from UT in 2003. In May of 2003, she continued on with her education by attending The University of Texas Southwestern Graduate School, studying Biomedical Communications. During her time at UT Southwestern, in August of 2005, she married Brandon Thomas Suehs of Austin, Texas. In May of 2006, she was awarded the degree of Master of Arts in Biomedical Communications. She is currently looking for employment in Austin, Texas in the field of Medical Illustration.

Permanent Address: 4106 Avenue D
Austin, TX 78751