

**CREATION OF AN INSTRUCTIONAL ANIMATION SHOWING THE
DEVELOPMENT OF THE HUMAN PLACENTA FROM
IMPLANTATION TO TERM**

APPROVED BY SUPERVISORY COMMITTEE

Lewis E. Calver, M.S.,C.M.I, F.A.M.I.

Angela M. Diehl, M.A.

Barbara L. Hoffman, M.D.

DEDICATION

I would like to thank my thesis committee, Dr. Barbara Hoffman, Angela Diehl, and Lew Calver, for all the help throughout the creation of this project. I would also like to thank my classmates for all the encouraging words and help when I needed it. Last but not least I would like to thank my family who has had the unfortunate circumstance of dealing with me while I have worked on this project.

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by

JAMES MONTGOMERY

DISSERTATION / THESIS

Presented to the Faculty of the Graduate School of Biomedical Sciences

The University of Texas Southwestern Medical Center at Dallas

In Partial Fulfillment of the Requirements

For the Degree of

MASTER OF ARTS

The University of Texas Southwestern Medical Center at Dallas

Dallas, Texas

December, 2012

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JAMES SCOTT MONTGOMERY, BS/BA

The University of Texas Southwestern Medical Center at Dallas, 2012

LEWIS E. CALVER, MS/CMI/FAMI

This project was created to fill a need in available placental development instructional tools. In the current literature, there are few three-dimensional representations of placental villous tree structure. This animation provides an overview of placental development and includes a three-dimensional depiction of a placental villous tree. Following creation of this animation, a survey was administered to assess the helpfulness of both the animation and the three-dimensional villous tree representations. Survey responses were overwhelmingly positive and show that this tool aids in the development of an accurate mental model of true placental villous tree form.

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Introduction

Complexity of Placental Development

Understanding the process of placental development can help students comprehend how different pathologies affect the placenta. Moreover, an ability to envision its three-dimensional form can explain why the morphological changes from pre-eclampsia, gestational diabetes, and many others are so detrimental.

Placental development is a complex process in that morphological changes, which continue throughout pregnancy, are difficult to observe. Most methods of study involve two-dimensional or static cross sectional drawings and histological slides, which can hinder an understanding of the actual three-dimensional architecture of the placental villous tree.

Review of Literature

I conducted an extensive search of resources available to students and residents studying obstetrics and gynecology. Many resources are available regarding placental form and development, but most are written text or two-dimensional static images. One example, "*Pathology of the Human Placenta*" (Benirschke), I used heavily during research for this project.

Numerous animations available are now available online that offer the advantage of showing conformational change rather than requiring inference of

this change (Ruiz). Of existing available animations, *Penn Medicine* <pennterapeutics.org> served as a valuable resource. The “Placental Formation” animation, which can be found at this website, has excellent foundational information. Although a bit dated, this animation is very attractively rendered, but provides only limited detail and lacks a three-dimensional component.

The animation by Mary Kate Carlton on the *Lucina Foundation* <lucinafoundation.org> website is well drawn and has valuable content, but is inadequate for medical student education. Its depiction of placental villous tree structure is two-dimensional and overly simplified. Stanford’s SIMBRIO (Ecker) is an amazing resource without narration, but in addition to being cost prohibitive, contains too much breadth and detail regarding the entire process of embryological development. These animations also made me aware of the need for audio narration. People learn through both visual and verbal pathways and, when both are used, comprehension is improved compared with either pathway alone (Rieber).

In sum, all of the animations I reviewed had a common limitation. None had a three-dimensional representation of a villus. They ranged from being too general to being too detailed. Some had audio, while others did not.

The Project

From my literature review, I constructed the fundamentals of my project: an animation that presents an extensive overview of placental development, that is directed to a medical student and resident audience, that contains a complimentary narration, and that displays three-dimensional placenta villous tree structure.

Methodology

Content and Pre-production

Dr. Barbara Hoffman, associate professor of obstetrics and gynecology at University of Texas Southwestern Medical Center, and I wrote a script that covers the topics required to adequately describe placental development from implantation to term. We emphasized the roll of extravillous cytotrophoblasts, the process of villous tree branching, and the three-dimensional structure of the placental villous tree, all things that were lacking in other resources. The target audience consists of students and residents on the obstetrics and gynecology service, who already have prior exposure to the topic. The animation is intended as a review, so the complexity of the subject is mitigated by the prior knowledge base of the audience. Targeting an experienced audience minimizes the chances of pushing the cognitive load too far and increases the likelihood that the animation will convey the relevant information (Ruiz).

Once the academic content was defined, a story board (figure 1) was created. The story board was evaluated by the thesis committee and several others to develop the final animation blueprint. A temporary scratch audio track was created using a normal microphone and QuicktimePro for the purposes of building a pre-production test video. The temporary audio was also used in building the final animation until the final audio arrived. The scratch audio files and digital storyboard were composited together using Adobe AfterEffects CS 5.5

into a pre-production animatic (figure2) that was used to correct timing and content issues before production of the final assets began.

Production

Once the pre-production animatic was created, production of the final assets began. Three-dimensional assets (figure 3) were created in Autodesk Maya 2012 and animated using blend shapes (figure 4) and other general rigging techniques. The joints and controls used in the rigging process are simple but numerous, so to streamline production a MEL script (figure 5) was used to create the large number of control curves. Where three-dimensional assets do not add to the animation, the two-dimensional approach was taken. The two-dimensional assets (figure 6) were created using Adobe Photoshop CS 5.5. The script was narrated by Dr. Hoffman in a recording studio at the University of Texas Southwestern Medical Center. Then the audio file was edited in Adobe Audition CS 5.5 (figure 7). The three-dimensional animation sequences were rendered using Mental Ray and brought into Adobe AfterEffects CS 5.5 with the two-dimensional assets and the final audio narration files. In addition to the compositing, most animation was done within AfterEffects for production of the final animation.

Throughout the creation process, clips of the developing animation were uploaded to *Vimeo* <Vimeo.com> (figure 8). A link to the work in progress was e-mailed out to members of my thesis committee so they could be involved in sending feedback as the creation process moved forward.

Method of Evaluation

Once production and revisions were completed, selection of an evaluation tool was required. A fast and effective solution was provided by *Survey Monkey* <surveymonkey.com>. Due to my academically advanced audience's limited time, both a pretest and posttest evaluation was not logistically feasible. Thus, a short six-question survey (figure 9) was developed to determine the audience's opinion regarding the value of the animation. The survey consisted of five five-point Likert questions and one open-ended "what would improve this animation?" question. A link to the animation and the survey was sent to twenty-three residents, students, and fellows known to Dr. Barbara Hoffman in the Obstetrics and Gynecology department. These physicians were given three weeks to complete the review and survey on their own time. Over those three weeks, seven survey responses were collected.

1. Day 7-8 P.C. post coitus
Apposition/implantation
- Blastocyst spinning -



2. **Trophoblast** - cells making up outer wall of the blastocyst
Embryoblast - inner cell mass forms the embryo anlagen + umbilical cord.
Contributes to placenta via embryoblast-derived mesodermine
- half of Blastocyst distends to reveal structure -



3. Implantation at upper posterior region of uterus during the short period 30 time when both the apical surface of the endometrial epithelium + the blastocyst are sticky, the implantation occurs
- Blastocyst moves + comes in contact with the endometrium -



4. - Cytotrophoblast layer of implantation/embryoblast pole proliferate and fuse to form double layer, w syncytiotrophoblast layer. (Blastocyst begins to flatten a little as it penetrates) -



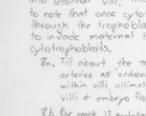
5. (lacunar stage)
Day 9 P.C. vasculature begins to appear, vasculature grows and merge as syncytiotrophoblast grows out from the implantation pole.
By 12 P.C. epithelium closes over implantation site.



7. Day 12 P.C. Primary villi are invaded by cytotrophoblasts
- Trophoblast shell - what becomes chorionic plate + what becomes basal plate



8. Mesenchyme begins to invade within cytotrophoblast signaling their transformation into secondary villi. This also a good place to note that once cytotrophoblasts break through the trophoblast shell they continue to invade maternal tissue as extravillous cytotrophoblasts.
2a. Till about the sixth week extravillous cytotrophoblasts block spiral arteries as endovascular trophoblasts, during the hypertic and coarctated within villi ultimately determining the placenta size and probability villi + embryo from oxidative damage.
2b. By week 12 redefine the role of extravillous cytotrophoblasts has changed from restricting blood flow to increasing it. They become interstitial trophoblasts that dilate the spiral arteries by replacing the muscular artery walls with fibrinoid.



9. 5th week p.m. vasculature develops from allantois + forms the villus tree (Don not miss villous tree!)
At about the 5th week post menstruation secondary villi start vascularization and they become known as tertiary or mesenchymal villi. Don which all other villi types develop. By the 6th week most secondary villi have vascularized and become mesenchymal villi, during this time the vasculature from the early sagittal zone has fused with the chorionic plate developing as far as the trunk of larger villi.



10. 7th week p.m. At about the 7th week BM mesenchymal villi begin increasing in diameter and maturing into Immature Intermediate villi. These Immature Intermediate villi act as an important growth center for the villus tree. This is where most branching occurs.
New branches develop starting at a spiral spot + a spiral spot invaded by cytotrophoblasts, a villous spot of same mesenchymal tissue and closely with the appearance of vasculature + mesenchymal villi.



11. 8th-9th P.C.
At about week 8 p.c. Immature Intermediate villi begin the gradual transition to stem villi. Central vessels form a compact expanding adventitia, when the fibrous tissue around a central axis the cellular tissue the villi is classified as a stem villi. Also reticular cells + fibroblasts become cytotrophoblasts.



12. 3rd Trimester
At the beginning of the 3rd trimester mesenchymal villi degenerate, Immature villi and start becoming the long slender Mature Intermediate villi and begin forming terminal villi.



13. Once Mature Intermediate villi begin forming angiogenesis within villi changes from a branching to nonbranching and the rate of capillary growth exceeds the growth of the villus. The capillaries begin to coil + form bulges through the wall of the mature intermediate villi forming a terminal villus. The forces involved in this capillary coiling and bulging are responsible for the zig zag pattern seen in mature intermediate villi.

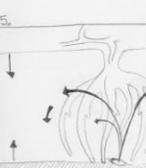


14. show growth of entire villous tree. (Maybe use color coding and gradients to show development of different villus types)
Show various planes of cuts on villus tree that can be clicked to show what might be seen in a microscopic slide, both diagrammatic and the actual slide images.



14a stem villi
14b immature intermediate
14c mature intermediate
14d terminal villi

15. Wrap up animation by showing entire villus tree in context.
Show blood circulating through intravillous space, (particulate matter)
Maybe show and describe function of myofibrils in stem villi, shrinking inter villous space and how it relates to maternal circulation



16. show credits.

Figure 1: original story boards

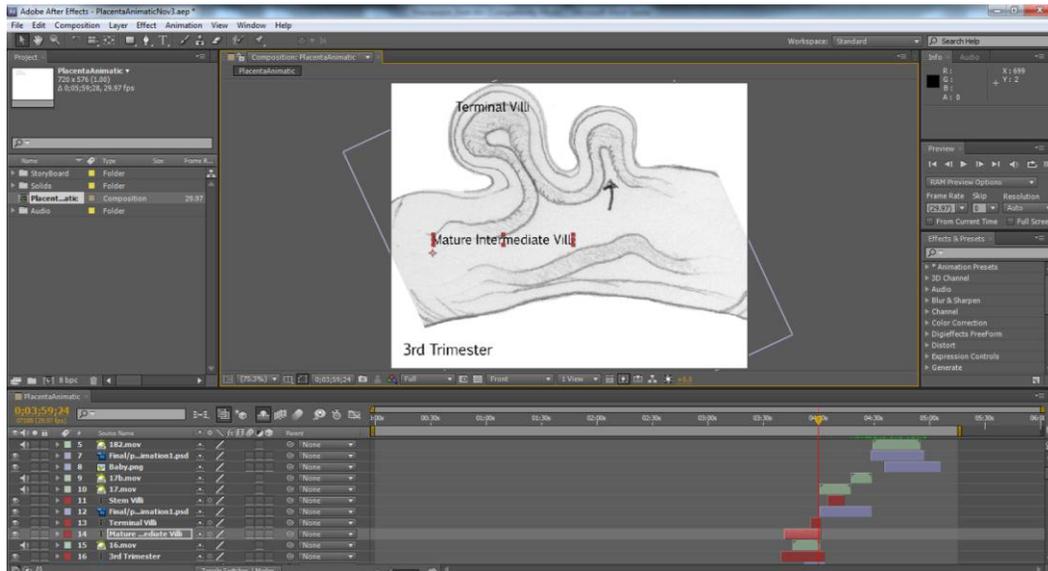


Figure 2: Pre-production animatic in Adobe AfterEffects CS 5.5

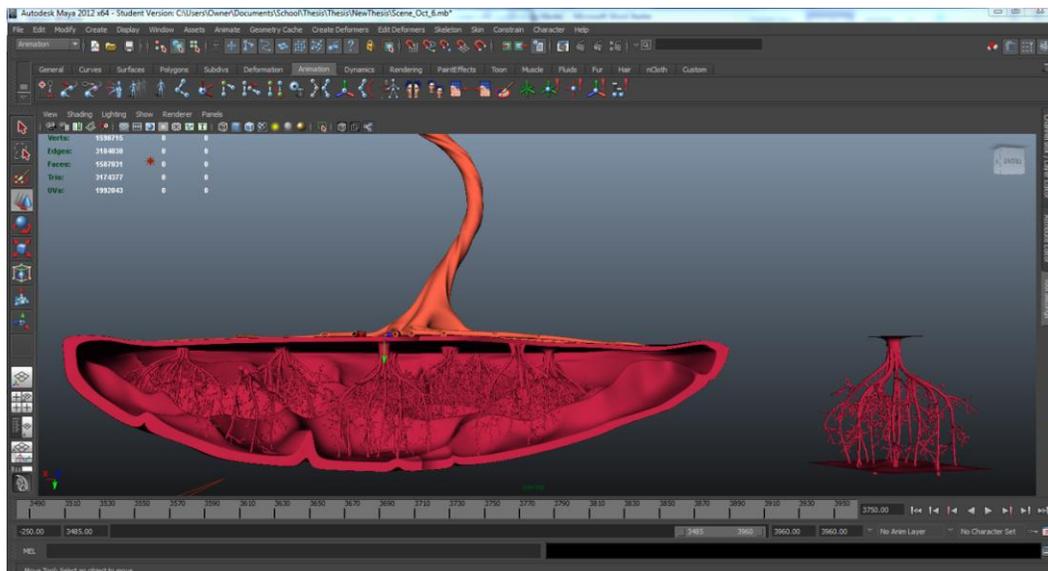


Figure 3: 3D asset construction in Autodesk Maya 2012

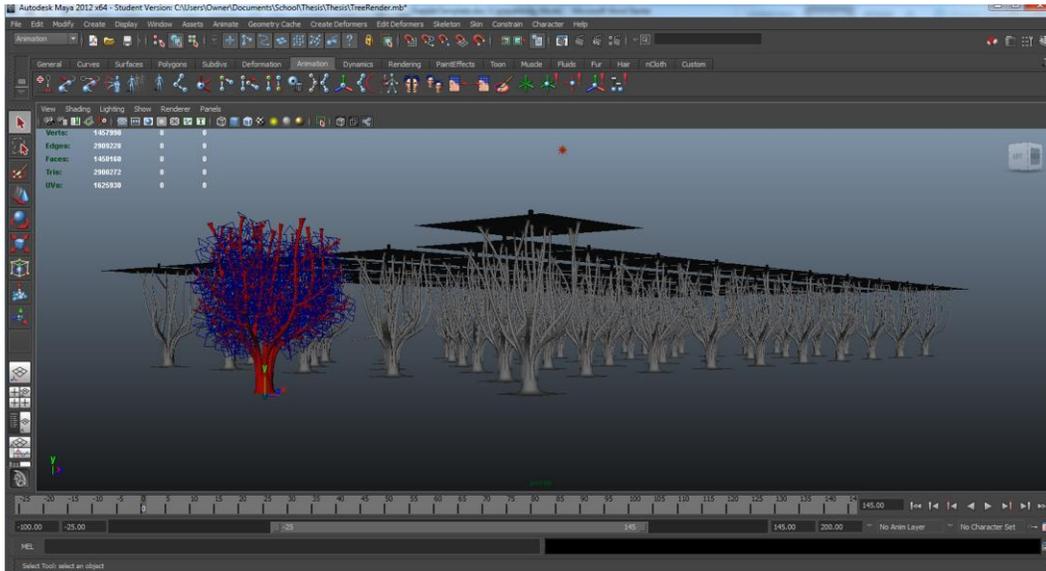


Figure 4: Blend shapes created in Autodesk Maya 2012 that represent the growth of each branch in the villus trees development

```

global proc jam_fkBuilder() {

    string $selectedJoint[] = `ls -sl`;
    pickWalk -d up;
    string $parentJoint[] = `ls -sl`;
    string $jointName = $selectedJoint[0];
    string $nameParts[];
    tokenize $selectedJoint[0] "_" $nameParts;
    print $nameParts;

    string $suffix = $nameParts[1] + "_" + $nameParts[2];
    string $groupName = "grp_" + $suffix;
    string $ctrlName = "cc_" + $suffix;
    string $parentConstT = "temporaryConstraint";

    circle -n $ctrlName -c 0 0 0 -nr 1 0 0 -sw 360 -r 0.05 -d 3 -ut 0
    -tol 0.01 -s 8 -ch 1;

    group -n $groupName; xform -os -piv 0 0 0;

    parentConstraint -n $parentConstT -weight 1 $jointName
    $groupName;
    delete $parentConstT;

    orientConstraint -n ("OC_" + $suffix) -weight 1 $ctrlName
    $jointName;

    parentConstraint -n ("PC_" + $suffix) -mo -weight 1 $parentJoint
    [0] $groupName;
}

```

Figure 5: MEL Script as seen in WordPad

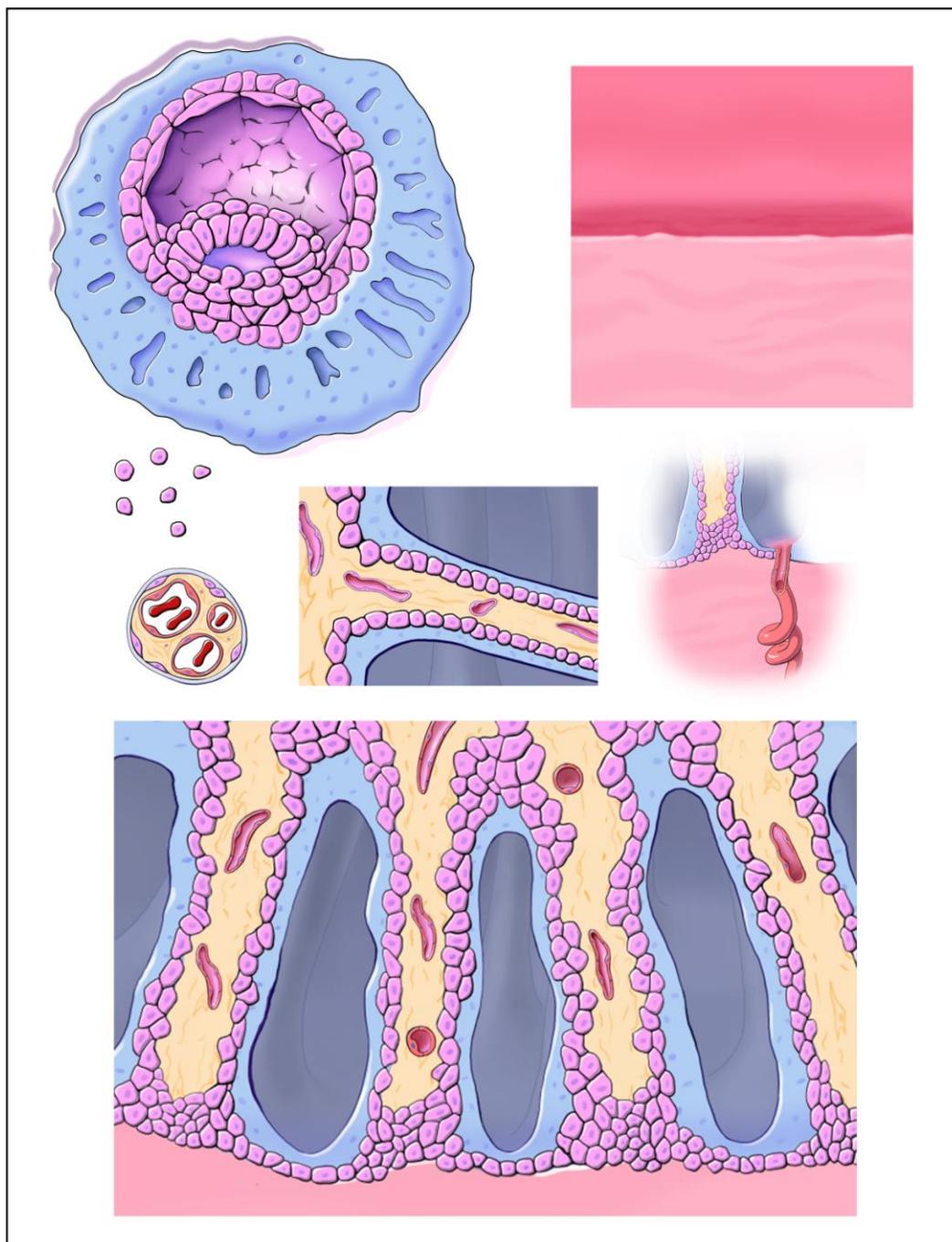


Figure 6: 2D created in Adobe Photoshop for final animation

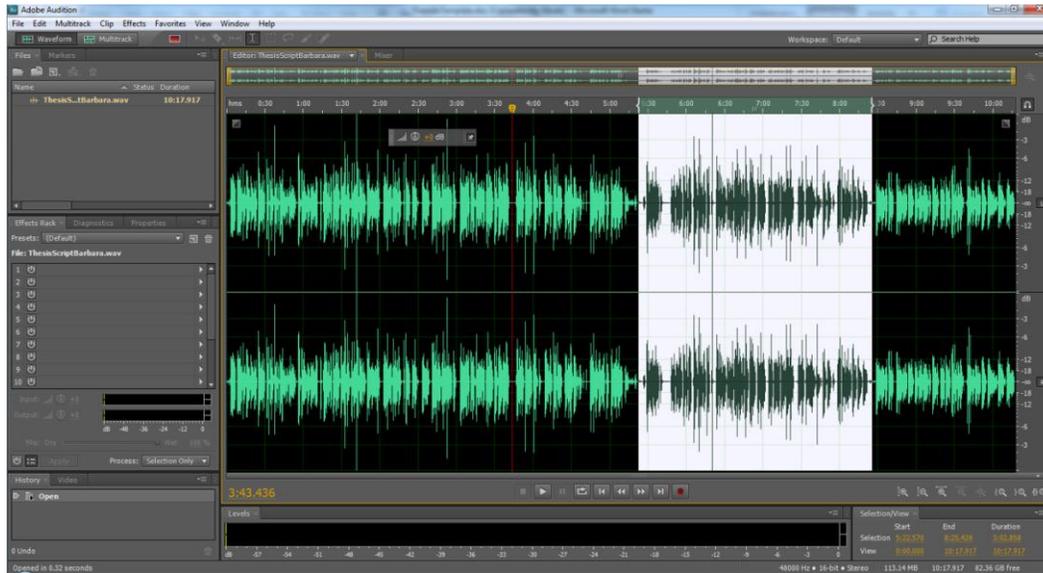


Figure 7: Audio editing in Adobe Audition CS 5.5

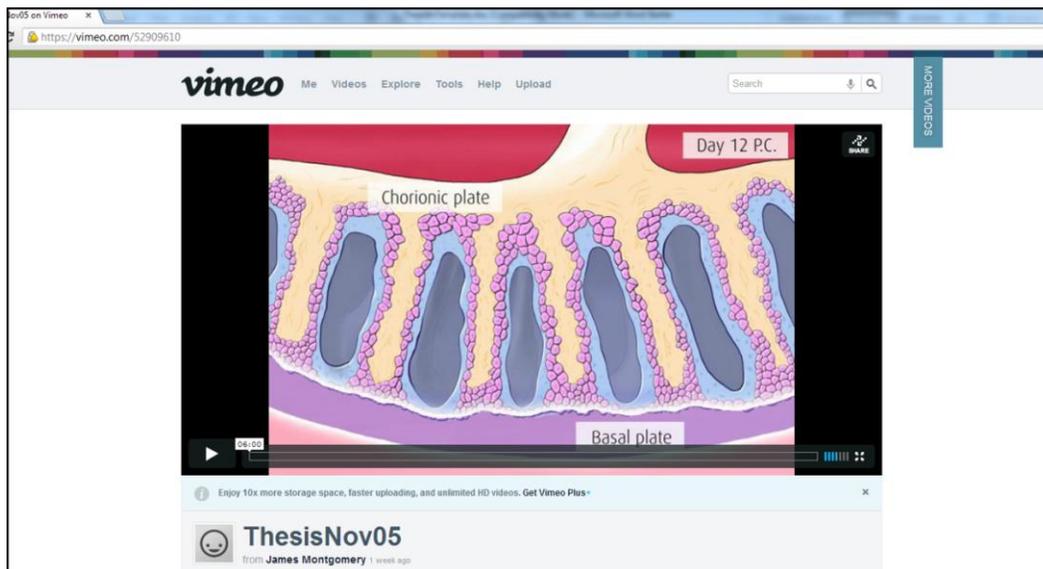


Figure 8: Screenshot of placenta animation posted to Vimeo

[SURVEY PREVIEW MODE] Placental Development Animation Assessment Survey - Google ...

www.surveymonkey.com/s.aspx?PREVIEW_MODE=DO_NOT_USE_THIS_LINK_FOR_COLLECTION&sm=R80a

Placental Development Animation Assessment

1. How visually appealing is the animation?

- Extremely appealing
- Very appealing
- Moderately appealing
- Slightly appealing
- Not at all appealing

2. How clear is the information available on the animation?

- Extremely clear
- Very clear
- Moderately clear
- Slightly clear
- Not at all clear

3. How likely are you to recommend the animation to others?

- Extremely likely
- Very likely
- Moderately likely
- Slightly likely
- Not at all likely

4. How likely are you to use this animation?

- Extremely likely
- Very likely
- Moderately likely
- Slightly likely
- Not at all likely

5. Did you find the the 3 dimension quality of the animation helpful to understanding the architecture of a villus tree?

- Extremely helpful
- Very helpful
- Moderately helpful
- Slightly helpful
- Not at all helpful

6. What changes would most improve this animation?

Figure 9: *surveymonkey.com* evaluation survey

RESULTS

Over the course of the three weeks, seven OBGYN students and residents viewed the video and completed the survey. Results (figures 10, 11) were overwhelmingly positive. Seven out of seven people who took the survey found the animation at least “very appealing” and the three-dimensional quality of the animation at least “very helpful” in understanding the architecture of a villous tree. Of those completing the survey, 85% replied that they would be very likely to use the animation. Four of the seven people who participated responded with very positive comments and criticism.

This is an excellent animation and I plan to replay and study from it. Sometimes the P.C. day appears a bit early (P.C. day 12 appears early) and that may lead to slight confusion- but otherwise everything is wonderful.

11/18/2012 8:15 AM [View Responses](#)

To keep a timeline (a graphic on the side or the top of the screen) to keep track of the step by step developments. Also try to place arrows or color coding when mentioning the different components of the trophoblasts at the beginning of the animation. The video is great and it has a lot of potential, thanks

11/17/2012 10:22 AM [View Responses](#)

I was a little confused regarding where the embryo went in this illustration. Maybe one or two pictures showing the embryo in relation to the forming placenta would be helpful though I know this is not the point of the illustration. Overall I think it's great and clearly depicts formation of the placenta.

11/7/2012 11:09 AM [View Responses](#)

It's great

10/18/2012 11:39 AM [View Responses](#)

Figure 10: Some comments and feedback from the survey

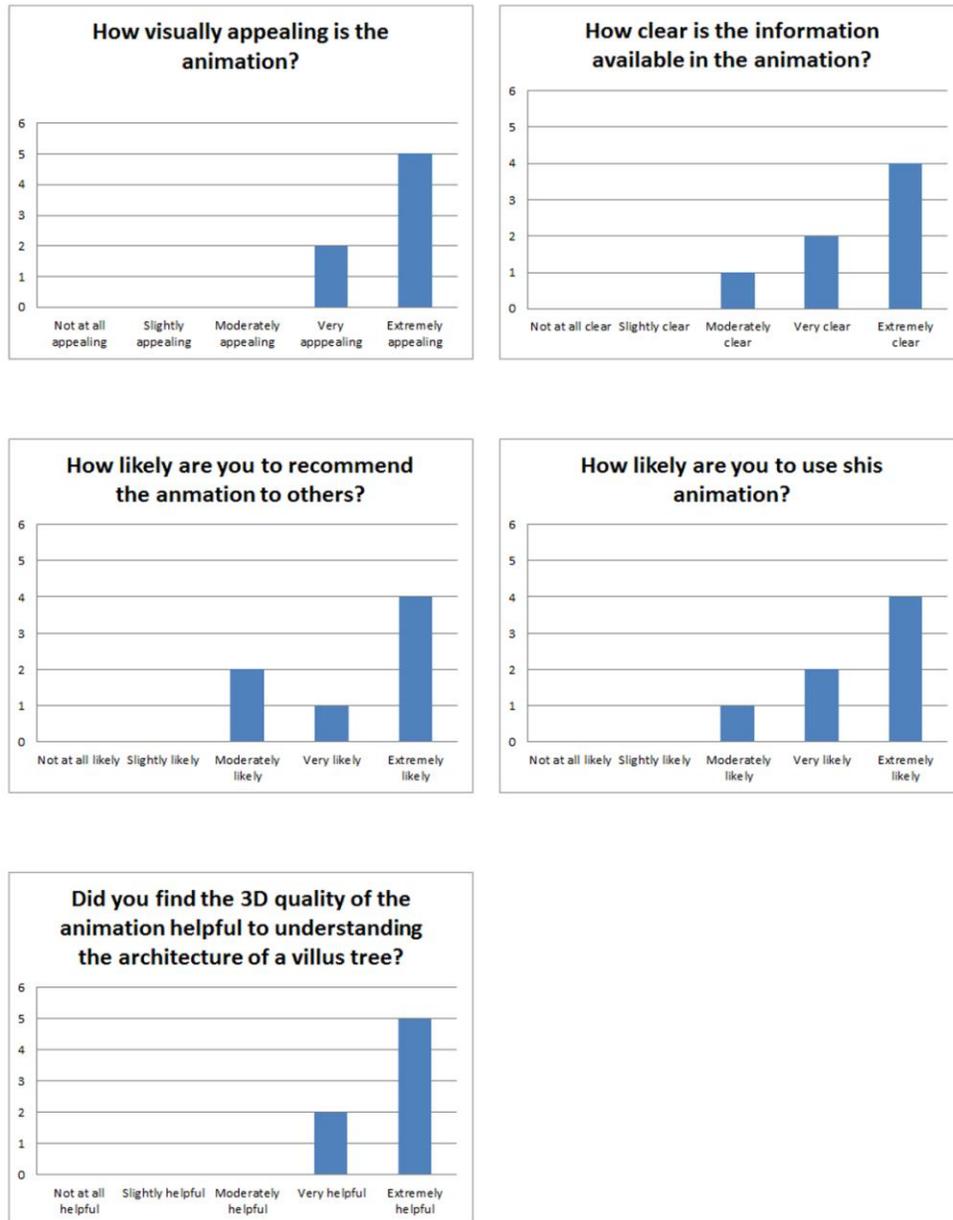


Figure 11: Results of online survey

DISCUSSION

Placental development can be difficult to understand and hard to visualize in three-dimensional space. The goal of this investigation was to see if a three-dimensional representation of the villous tree in an animation would improve a student's understanding of villous tree structure. Responses were overwhelmingly positive in favor of this three-dimensional model. This indicates that people felt that it was visually appealing, the information was clear, they would use it, and would likely recommend it to others. Although the survey results were positive, this study had some limitations.

Only seven of the twenty-three people responded to the animation and survey. This suggests that, without a great deal of incentive, a large part of my target audience is too busy to take advantage of this animation or to take the survey. It is important to note that the participants in the study unanimously found the animation to be helpful. Even as well-received as the animation was, there is always room for improvement.

Some of the participants in the study had good ideas to improve the animation, and those suggestions could be implemented to clarify some of the concepts. Suggestions included a more constant macro scale orientating graphic, more arrows, and color coding. The study itself could be augmented by including the animation and survey more directly into the obstetrical curriculum. Including

the animation in classes or as a resource available in multiple classes would likely significantly increase the number of survey participants. Another interesting investigation would be to find students willing to take pre- and post-tests to investigate how much information was retained from watching the animation. At this point, although with limited data, there is support from this research to suggest that a three-dimensional model of villous tree structure can help students create a more accurate mental model of actual placental architecture.

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VITAE

James Scott Montgomery grew up in the small town Dayton, Iowa. He attended collage at Iowa State University in Ames and after sometime graduated in 2006 with a BS in genetics and again in 2009 with a BA in biological/pre-medical illustration. After a year break I was accepted into the UT Southwestern Medical Center's Biological Communications program in spring 2010.

Permanent Address: 223 Garden Ct.
Henderson, NV 89002