BME Design-Fall 2021 - Kendra Besser
Complete Notebook

PDF Version generated by

Charlie ZHU

on

Dec 15, 2021 @03:28 PM CST

Table of Contents

Team contact Information

Charlie ZHU - Oct 20, 2021, 1:45 AM CDT

Last Name	First Name	Role	E-mail	Phone	Office Room/Building
Brace	Chris	Advisor	clbrace@wisc.edu	6082624151	1111 Highland Ave
Green	Chris	Client	cggreen@wisc.edu		
Besser	Kendra	Leader	kbesser@wisc.edu	6512527872	
Lukic	Milica	Communicator	mlukic@wisc.edu	2244334531	
Gurumoorthy	Darshigaa	BSAC	dgurumoorthy@wisc.edu	3127767063	
Houle	Alex	BWIG	arhoule@wisc.edu	2623888330	
Zhu	Charlie	BPAG	xzhu333@wisc.edu	6083382748	

Project description

Kendra Besser - Oct 20, 2021, 12:22 AM CDT

Course Number:

BME 200/300

Project Name:

Teaching Model for Ventilation and Perfusion Mismatching

Short Name:

V/Q mismatching model

Project description/problem statement:

Ventilation and perfusion mismatching is the most predominant cause of hypoxemia. However, medical students often have a very difficult time understanding this concept. Other than a textbook diagram by John West in his text Respiratory Physiology [1], there are no relevant representations of ventilation/perfusion mismatching. Our goal is to improve a prototype completed by previous UW Madison students to create an effective teaching model of ventilation/ perfusion mismatching to be studied by medical students for a deeper understanding of hypoxemia.

About the client:

Client, Dr. Chris Green, is a retired pediatric pulmonologist at UW-Health who teaches medical students. He has seen many students struggle to grasp the concept of ventilation perfusion mismatching and he is determined to find an interactive teaching model that will help students learning outcomes.

2021/09/20 - Questions for Client Meeting 1

Charlie ZHU - Oct 20, 2021, 1:39 AM CDT

Title: Questions for Client Meeting 1

Date: 09/20/2021

Content by: the whole team

Present: the whole team

Goals: Raise questions which could be asked during the first client meeting in order to better understand the goal of our project

Content:

Questions

Scheduling:

- Do we want to meet weekly or when needed?
  - Can we set up a regular meeting time every two or three weeks?
- Do you have a specific timeline in mind for the project?

Previous semester's work:

- How do we acquire last semester's prototype?
- Should we continue off of previous semester's work or try something new? Specifically, should we use LEDs to model blood flow and O2 levels?
- What changes would you like to see from the previous semester's work? What did or didn't work?

Budget/purchasing:

- What is the budget?
- How is purchasing materials handled?
- What is our target product cost?

Requirements for the model: （Specific and measurable ）

- How will the device be used?
- What are your performance requirements for the device?
- What are your safety requirements for the device?
- How long should the device be in service?
- What is the shelf life of the device?
- What should the size be?
- What should the weight be?

- Are there specific materials you would like us to use?
- How many of the devices should we create?

Conclusions/action items: Those are the questions which could be asked during the client meeting. Not all of them are necessary be answered, but the more we ask, the better understanding of the project we will get.

2021/09/21 - Client Meeting 1

MILICA LUKIC - Oct 20, 2021, 2:52 PM CDT

Title: Client Meeting 1

Date: 9/21/21

Content by: Alex, Milica, Kendra

Present: Alex, Milica, Kendra, Charlie

Goals: Discuss project details, ask Dr. Green our questions, and hear from him what specifically he has in mind for this semester.

Content:

Questions:

Scheduling:

- Do we want to meet weekly or when needed?
    - Can we set up a regular meeting time every two or three weeks?
- Do you have a specific timeline in mind for the project?

Previous semester's work:

- How do we acquire last semester's prototype?
- Should we continue off of previous semester's work or try something new? Specifically, should we use LEDs to model blood flow and O2 levels?
- What changes would you like to see from the previous semester's work? What did or didn't work?

Budget/purchasing:

- What is the budget?
- How is purchasing materials handled?
- What is our target product cost?

Requirements for the model: (Specific and measurable)

- How will the device be used?
- What are your performance requirements for the device?
- What are your safety requirements for the device?
- How long should the device be in service?
- What is the shelf life of the device?
- What should the size be?
- What should the weight be?
- Are there specific materials you would like us to use?
- How many of the devices should we create?

Meeting Notes

- Project Details
    - When should we give oxygen?
    - Mechanisms:
        - Breathing a lower partial pressure of oxygen
        - Diffusion block of alveoli capula
        - Hyperventilation
        - Shunt
            - When the alveoli fill up with fluid

        - Ventilation/Perfusion mismatch (?)
            - High ventilation/low perfusion or vice versa
            - High V/Q = wasted ventilation, low V/Q = hypoxemia
- What's been done so far
    - 1st: Made software model
        - Graphic on the computer of what would happen at different ratios
    - Last 6 months (ongoing)
        - Pure computer animation
    - Last year's students
        - Used LEDs, flash one color to show blood flow, one for airflow
        - Made a 3D printed frame
        - Wanted to do more, ran out of time
        - Discrete ratios
- Wants/improvements:
    - Sliders to move ratio around
    - Have output that shows oxygenation (client will help with calculations)
    - Show display for numbers (or show on computer screen)
    - Size of dinner plate that would be able to be showed in lecture hall with doc camera, have sliders to change ratio
    - Not necessarily realistic, but able to understand what's happening
- <u>Big Goal: Have 2 alveoli so ratio could be different, see what oxygenation comes up</u>
- Next steps: take a look at hardware from last year, how to advance/improve it
    - Start with one alveoli, maybe move into 2 mid-semester
    - Talk to prof. Brace to see how he feels about computer animation vs physical product, adding to old product vs making new product
    - Milica with client (tomorrow, september 21st at 10:30 at Union South) to get last year's supplies
- Questions we asked:
    - Should we build off last semester, or brainstorm brand new ideas and make a new product?
        - Take a look at last year's product, have a discussion about it, if we have new ideas maybe make a new product.
    - Did you find that the LED lights did a good job to show the ratio?
        - Pretty good, similar to computer animation, not perfect but it works
    - Regular time to meet
        - Update client on availability, either schedule weekly time and cancel when necessary or every 2 weeks (use WhenToMeet)

Conclusions/action items: Meet with client next week to update him on progress and ask more clarification questions that come up while we are working this upcoming week.

2021/09/29 - Client Meeting 2

Kendra Besser - Sep 30, 2021, 2:06 PM CDT

Title: Client Meeting 2

Date: 9/29/2021

Content by: Alex Houle

Present: Alex, Milica, Charlie

Goals: Meet with client to discuss our progress, ask recent questions about design, and plan next steps/weekly goals.

Content:

- Briefed about professor Brace
    - Talked about resources regarding programming
    - Physical aspect (sliders) and computer programming aspect (math to alter ratio)
    - Use Arduino (maybe)

- Budget
    - Able to spend up to $1000 last year
    - Able to buy LEDs, Arduino, etc
    - Talk to Erin Ryan
        - Tell her what it is and where, she will order and pay
    - Makerspace has our names already
        - Limit is $500

- Last year's project
    - Extra plastic backboard that LEDs were to be put on last year's project is included, didn't fully like current one so reprinted
    - LED lights flashed to display flow, liked that
    - Last year thought about sliders and display, didn't have time
    - Think about physical vs software implementation

- Working with Tammy Greko, using software implementation
    - Get V/Q ratio into PO2/V2
        - Lots of lots of alveoli in the lungs, all can have different V/Q ratio
        - P_AO_2 Arterial partial pressure (mm Hg), should be 95, 100, 105+ (hyperventilation).
    - Using logistic equation
    - Quotient of two quadratic equations, using A, B, C, D variables
    - Set up meeting with her (maybe)

- Next steps
    - <u>Client will send us some articles to look at about V/Q ratio</u>
    - <u>Physical vs software</u>
        - Physical:
            - If we have a slider, slider for V and Q separate (0-x)? Or overall V/Q (0-infinity)?
        - Software:

            - In terms of programming, use downloadable file on computer, not too difficult
            - To picture flow of blood/oxygen animation, not very hard either
    - Multicompartment model in the future
        - <u>Output overall P_AO_2 if we were to have multiple</u>
            - Will get more direct math equations later
        - How much oxygen gets in the blood related to P_AO_2 ,
            - Related to hemoglobin saturation and blood flow
            - P_AO_2 of two streams coming together
                - If one stream has 100% hemoglobin saturation, one has 50% saturation, average would be 75%
                - Cannot directly average P_AO_2 levels
                    - <u>Research Hemoglobin dissociation curve</u>

Conclusions/action items: Meet with client next week (potentially last meeting before preliminary presentation) to check in again and keep him updated on our progress.

2021/10/22 - Client Meeting 3

Kendra Besser - Nov 04, 2021, 4:13 PM CDT

Title: Client Meeting

Date: 10/22/2021

Content by: Kendra, Alex, Milica

Present: Kendra, Alex, Charlie, Milica, Darshigaa

Goals: The goal of client meeting notes is to record questions/ answers and conversations between the group and the client.

Content:

- Order different LEDs if we want
- Order through Erin?? I think her name is Erin and i have her email
- Questions from Client
  - Work towards continuous adjustment
  - Last year didn't get to display PAo2
  - Add SAO2 (saturation) if we can find equation
- Should we display PCO2 as well?
  - In big picture, its relevant, but not completely necessary to avoid over-complication
- Should device be shaped like an alveoli?
  - Client can measure area of camera display zone
  - Document camera platform is square shape
- Make sure the display is well visible under the doc camera
- Okay to do single display for all values?
  - Yes as long as display is clear (well labeled)
  - And that all numbers can be seen at once
- Should we test a prototype midway through the semester with students?
  - Would be helpful but we might not get a lot of feedback from students
  - Dr. Green's coworker could ask like five students instead
  - At least 3 weeks before final exams
- If we have multiple alveoli, should one be from the top of the lung and the other from the bottom?
  - Lump parameter model (compressing multiple alveoli into one)
  - Top and bottom would work
  - Or low vs high or low vs normal V/Qs
  - Show overall blood flow out (or something like that, i missed exactly what he said)
  - If we finish one alveolus soon we can move on to trying two alveoli

Conclusions/action items: After this meeting we had a better understanding of were to go with fabrication and testing plans. We will revise our design to fit our clients needs and desires and continue forward fabricating then testing our model.

2021/11/12 - Client Meeting 4

Kendra Besser - Dec 09, 2021, 5:06 PM CST

Title: Client Meeting

Date: 11/12/2021

Content by: Alex, Charlie, Kendra, Milica

Present: Alex, Kendra, Charlie, Milica, Darshigaa

Goals: This client meeting was intended to ask questions about design details such as visual aspects, display values, and respiration information necessary to know to understand the model.

Content:

- **Questions**
    - Range for dials: fully customizable? Same range for ventilation as perfusion? Input minute ventilation, or input respiration rate, etc
    -
- 5L Normal Ventilation value
- Only represents a piece of the lung, not the whole lung
- Depends on Cardiac output 0-30 L normal range
- V/Q ratio needs to be able to vary from 0-infinity
- V/Q ratio is unitless number
- Perfusion and ventilation unit: Liters/Minutes
- Dead space leads to V does not equal to V (Alveolar)
    -
- Minimum for both 0
- Max perfusion: infinity or 1000 as a high number
- Max ventilation (minute ventilation):
    - Alveolar ventilation
    -
- Display:
    - Partial pressure oxygen (P_aO_2)
        - Ex: 50
    - V/Q ratio
    - Saturation (S_aO_2)
        - Ex: 85%
    - Ventilation rate
    - Perfusion rate
    -

New design feedback

- Capillaries are a net around the alveolus (reality)
- Focus on oxygenation (oxygen flow is in one direction and CO2 is in the opposite direction)
- Should we do multiple oxygen channels? That would be more realistic, it would be more complicated but the students would recognize what is going on. Might be hard to show the air movement (we need to show it moves in and out of alveolus).
    - Get rid of the circle lights in alveolus if we can (show where air flows)
    - Make lines of green light going into the oxygen channels then down to the blood flow
- Blood show go in blue and come out red, if oxygenated (keep these colors for teaching purposes)
- Blue = less oxygenated
- Red = more oxygenated
- Purple = not well oxygenated (?) (maybe depict both blue and red?)

- **Remember the goal** is to explain what is happening during V/Q mismatching (what's happening when someone has low oxygenation)

Conclusions/action items: After the client meeting with Dr. Green, we have a better understand of where to take our designs and are ready to continue in the fabrication plans. The next steps are to redesign our sketches to fit the needs and likes of Dr. Green then use the revised design during fabrication plans.

2021/09/17 - Advisor Meeting 1

MILICA LUKIC - Sep 20, 2021, 9:31 PM CDT

Title: Advisor Meeting 1

Date: 9/17/21

Content by: Milica Lukic

Present: Alex Houle, Charlie Zhu, Darshigaa Gurumoorthy, Kendra Besser, and Milica Lukic

Goals: Discuss project background, expectations, and scheduling

Content:

Notebook Expectations:

Reasoning behind the choices we make should come through in our notebook

Create entires whenever working on design; want to be able to look back through what we did and why

How often should we meet with the client?

Ask our client what they would prefer or if we can set up a regular meeting schedule

Regular meetings are better for scheduling for everyone, every 2-3 weeks

Come up with questions for client meeting:

- what is the budget and how is purchasing handled?

- logistics

- details of the project

- should we continue off of previous semesters work or should we try something new

- what changes does he want to see, what did he like or not like from previous semesters

- tell Professor Brace if we feel like there aren't enough design elements to the project

Also, do as much research as we can right now before meeting with Dr. Green

Scheduling with Professor Brace:

He has Friday conflicts, so we need backup options

Goal before next week is to get a backup time for meeting with him when he's busy on Fridays

10 minute check-ins are fine

We meet every Friday in 3355 E Hall at 1:30pm with Prof Brace except for when he has conflicts

Conclusions/action items:

PDS due date coming up, should be specific and measurable

Before next week meeting:

Fill out When2Meet schedule (Milica will text the link) and let Prof Brace know when we're free

Read final reports or other documents from previous semesters

Do outside research

Come up with questions for meeting with Dr. Green

2021/10/08 - Advisor Meeting 2

Kendra Besser - Dec 09, 2021, 6:21 PM CST

Title: Advisor Meeting 2

Date: 10/8/21

Content by: Milica Lukic

Present: Alex Houle, Charlie Zhu, Darshigaa Gurumoorthy, Kendra Besser, and Milica Lukic

Goals: Discuss preliminary presentation status

Content:

How are things going?

Design matrix is done and we are currently working on the preliminary presentation

*Professor Brace has suggested that we ask Dr. Green for more specific feedback on the design matrix and design ideas in general.

Questions we asked about the preliminary presentation:

Are there specific slides we need to use?

No

Slide expectations:

What is the project, our names, client name, who is the client and what is relevant

Problem description in our own words

Include what is important for the other students to know

Background material that are relevant to the design not a lecture on pulmonary physiology

PDS - what are the important parts of the design

How we decided to score the design matrix

Bring the prototype for interactive aspect

Future work - fabrication, testing, what we will test against

Dress business casual

Transitions from person to person nice but not necessary

Step forward and don't be awkward

Ask ourselves if there is a clearer way to present the information that is not text, so the slides are not overwhelming.

Break up problem statement into a couple of bullet points

Give presentation verbally and highlight information with images on the screen

Think about how can we prompt Q&A from the group

Maybe include a summary slide so that audience is engaged

Cite with the figure instead of doing a bit reference slide

Just do the short citation

Add hyperlinks to figures

Give enough attention to the alternative designs so it is clear how we decided on the final design

Conclusions/action items:

Send Prof Brace draft of slides by Wednesday if we want some feedback (highlight any specific slides we are specifically wanting feedback for)

2021/10/22 - Advisor Meeting 3

Kendra Besser - Dec 09, 2021, 6:20 PM CST

Title: Advisor Meeting 3

Date: 10/22/2021

Content by: Kendra and Milica

Present: Kendra, Alex, Charlie, Milica, and Darshigaa

Goals: The goal of advisor meeting notes is to record questions/ answers and conversations between the group and the advisor.

Content:

- Think of creating a nice visual timeline for our project
- How to create a presentation
  - First get all basics info down
  - Then make it visual
  - Replace texts bits with visuals
  - Don't read from slides!
- Comments on presentation
  - good job at PDS (very practical)
  - Design alternatives
    - Explain why designs are actually feasible
    - For the concentration design, explain that it is actually a model used in books and stuff
  - Color contrast in doc camera really doesn't show up well
    - Frame rate misses some of the flow or blinking rates of lights
    - Incorporate document camera limitations into our design process to make up for them
      - Include parameters like what kind of colors would work on a doc cam, what kind of display, etc
  - Color of plastic for housing that last year used worked well bc blended into podium so the lights stood out more
  - A minute or two too long but it was good that we showed the prototype
- Testing plans
  - Test under doc camera
  - Test with the group of 5 med students
  - Test current prototype and our final design to show before and after (get feedback as soon as we can)
  - We should go in and test the current prototype in Dr. Greens lecture room this week??????? In HSLC
    - Yeah that would be good, i will email him
  - Maybe create a survey to be filled out by students before and after
- Will the device be used to show clinical conditions?
  - This is pretty much what our device does… different v/q ratios can represent different conditions
  - Ask dr. green if he would like some sort of pre-programing for specific conditions
    - "Patient with ___" button that automatically goes to those levels
    - Top three settings or something
    - Or just adjustable v/q ratios?
    - But conditions might differ between patients so this might not work well

Conclusions/action items: In this meeting with our advisor, we discussed how the preliminary design presentation went and how we could have done better, along with future testing plans and a few design critiques. Our immediate next steps are to test the current prototype in the HSLC and email Dr. Green to ask a design question about pre-programmed V/Q ratios.

2021/11/15 - Advisor Meeting 4

Kendra Besser - Dec 09, 2021, 6:22 PM CST

Title: Advisor Meeting 4

Date: 11/15/2021

Content by: Kendra, Alex, Milica

Present: Kendra, Alex, Milica, Charlie, Darshigaa

Goals: The goal of this advisor meeting was to discuss the feedback received on our preliminary report, ask clarification questions, and brainstorm how we can better prepare for the final report.

Content:

Topics to discuss:

- Working on a new design, showed Dr. Green and he gave us some feedback
- Preliminary Report
    - Double check grammar
    - Make the figures more clear
        - 3D rendering would be helpful bc without seeing the prototype, the figures don't make too much sense
            - Side view/top view?
        - Use standard font for labels
        - Captions should describe what the figure is AND what to take from the figure like how the teacher/student would use the design
    - More references (especially for technical stuff like electrical components)
        - Diversity of sourcing types
        - Technical sources (standards, codes)
    - Patents and competing designs
        - We did this type of search and couldn't find any conclusions
        - "we searched pubweb with these key words and found these sources"
        - ^ use this to show that we tried to find competing
    - Codes and standards
        - Electrical codes might be relevant but we probably won't find too much else
            - Look on the back of our electrical components for classifications and then search with that (CE codes)

    - How could we have better applied physics/engineering -- should say: "appropriate engineering principles"?
            - Math - calculation to display values
                    - Explain the physiology with the math (i think is what he's getting at?)
            - Physics and engineering- full engineering process (how is the solution processed)
            - Connect constraints to design and explain design process
            - How prof brace defined the engineering process: "Define problem, explain constraints, use what we know about electricity, mechanics, etc to come up with a solution to address the needs, then create it"

    - How could we have improved the constraints, alternatives, and final design categories?
            - Does it have to run on battery power? Other constraints/requirements from the PDS?
                    - Explain these much more clearly in the report

            - Explain how these constraints lead us to the design like which size lights we should, use what size the whole thing needs to be, how long the battery life is or how it is powered
        - Use SI units

    - Impact category feedback: “Does this project apply outside of this one classroom?”
        - Our project is to design a teaching model for classroom use, specifically for Dr. Greens classroom
        - Global connection, other classrooms, it can be used individually or under doc camera, only requires a USB port (versatile)
        - This device can be shared, it is portable, can be used in many different classrooms by different people
            - We could explain that this can be used under a doc camera but can also just be used by students hands on so even if a classroom doesn't have like a projector or doc cam it is still helpful
        - Could be good to explain that our model can help students understand conditions that they will need to help patients with in the future (explain that it is applicable to future health care workers careers)

Conclusions/action items: After the meeting with professor Brace, we have a better understanding of how to go about our final report with more detail and description which will hopefully result in a better grade and a better understanding of our work for our readers.

2021/11/22 - Advisor Meeting 5

Kendra Besser - Dec 09, 2021, 6:19 PM CST

Title: Advisor Meeting 5

Date: 11/22/2021

Content by: Kendra

Present: Kendra, Charlie, Darshigaa

Goals: The goal of this advisor meeting was to discuss future testing plans, the new design we remodeled, and the progress we have made with the electrical work and coding programs.

Content:

Talk about:

- New design
- Electrical work with other professor
- Upcoming plans

How is it powered?

- Through USB
- Will it always be accessible?

Electrical work

- Updated him on the meeting and upcoming meetings

3D printing baseboard

- Think about financing
- Probably best to get reimbursed, make sure that's ok

Testing plans

- Survey with 5 med students to test function and human parts of it
- Test hardware parts
    - Test power hook up and repeatability
    - Testing electrical components
    - Test by reusing multiple times (20 times)
    - If it works once, it doesn't mean it works every time
    - Repeatability testing number of trials
    - Try different types of power (laptop, wall plug in)
- Document final weight and dimensions
- ^ other stuff like that, look at PDS
- Change environments
    - Warmer room, colder room
- UBS age of unit, may provide different powers
    - Test older or new laptops
    - Find USB standards
    - Testing how much amperage the device draws

Next friday meeting (week before presentation) during regular class time

Conclusions/action items: During this meeting with professor Brace, we present to him our new design and the progress we have made in coding and producing a breadboard. He gave us some feedback on our design and helped brainstorm testing plans for our future work. To continue with our project we will finish fabricating the prototype and begin testing with our final product.

2021/12/3 - Advisor Meeting 6

Kendra Besser - Dec 09, 2021, 6:26 PM CST

Title: Advisor Meeting 6

Date: 12/3/2021

Content by: Milica

Present: Kendra, Charlie, Darshigaa, Alex, Milica

Goals: The goal of this advisor meeting was to discuss the poster presentation next week, the progress we have made so far, and the things we still have to accomplish before the presentation.

Content:

To Do:

- Testing!!!!!
  - Make sure electrical components work
  - Test under the display
  - Get some student feedback
    - Set this up right away
- Poster presentation
  - Not too many words but more than a presentation
  - Have a video of how device is used
  - Bring props
  - Make sure we have power available and everything is charged and ready to go
  - Templates for posters available
    - Go back to old projects posters and see what layouts we like
  - We give 10 minute plus questions presentation, which is only time we all need to be at the poster
    - Everyone needs to speak
    - Then some stay there while others walk around and look at others
  - Focus on what work we have put into our project
    - A little bit about background
    - Not so much about alternative designs
    - Most of the time about how we came up with final design, things we learned along the way, changes we had to make to our design, and how our design meets the objectives of our project
      - Have testing for PDS specifications and explain if we met them
  - Need to figure out where we print our posters
    - Prof brace will ask and tell us
  - Get him our poster by Wednesday night for feedback on Thursday
  - Business casual??

Conclusions/action items: During this meeting with professor Brace, we present to him our progress on our current prototype and what are plans are to complete it by the presentation. We received some advice to make the poster presentation go as smoothly as possible. We need to continue with our fabrication and testing plans and prepare for the poster presentation.

2021/09/24 - Initial Product Design Specification

Charlie ZHU - Oct 20, 2021, 1:35 AM CDT

Title: Product Design Specification

Date: 2021/09/24

Content by: the whole team

Present: the whole team

Goals: Determine the requirement of design and the client need

Content:

Teaching Model for Ventilation and Perfusion Mismatching

Alex Houle, Charlie Zhu, Darshigaa Gurumoorthy, Kendra Besser, and Milica Lukic

09/24/2021

Function:

Ventilation and perfusion mismatching is the most predominant cause of hypoxemia. However, medical students often have a very difficult time understanding this concept. Other than a textbook diagram by John West in his text *Respiratory Physiology* [1], there are no relevant representations of ventilation/perfusion mismatching. Our goal is to improve a prototype completed by previous UW Madison students to create an effective teaching model of ventilation/ perfusion mismatching to be studied by medical students for a deeper understanding of hypoxemia.

Client requirements:

- Sliding knobs for changing the V/Q ratio to represent different levels of mismatching
- Output that shows oxygenation (client will help with calculations)
- A digital display of some sort for the values (or displayed on computer screen)
- Able to be showed in lecture hall under document camera
- Not necessarily realistic, but good representation of what happens in the body at different V/Q levels leading to hypoxemia

Design requirements:

1. Physical and Operational Characteristics
    1. Performance requirements:
        1. A physical model to represent the concept of ventilation/perfusion mismatching and how it leads to hypoxemia
        2. Used in a classroom setting
        3. Ability to change ventilation/perfusion ratio

2. Safety:
    1. No danger of electrocution (no loose wires)
    2. Shell has no sharp corners

3. Accuracy and Reliability:
    1. All coding should be free of error and reproducible/stored where it can be retrieved easily
    2. This will be further analyzed after our testing phase

4. Life in Service:
    1. Arduino Uno may need to be replaced after approximately one year depending on the conditions under which it is stored
    2. Under good conditions for electrical components, expected life in service should be at least 5 years
    3. As a teaching model, device should last throughout lectures and hands on learning

5. Shelf Life:
    1. The product should be able to withstand storage for long periods of time. (At least five years under good condition of electronic components)
    2. The product needs to be reusable and could be set up easily
    3. The product will be placed in a sealed container in order to maintain a low moisture level
    4. Ideal storage temperature is in the range of 10-27℃ [2] (50-80 ℉)

6. Operating Environment:
    1. Classroom setting, not exposed to harsh elements
    2. Slight risk of damage due to mishandling between transition from classroom to storage

7. Ergonomics:
    1. Very light and portable
    2. Be able to be displayed in a lecture hall using a document camera, or seen in a small-group setting (within 3 meters of the device)

8. Size:
    1. Roughly 1 ft x 1 ft

9. Weight:
    1. Easily movable and carryable, no more than 15 lbs

10. Materials:
    1. 3D printed base because it is lightweight and cost effective
    2. LED lights to represent V/Q ratios because they are energy efficient

11. Aesthetics, Appearance, and Finish:
    1. No specific color
    2. Dinner-plate sized
    3. No loose wires or sharp corners
    4. Digital display of some kind for relevant values
    5. Computer program for inputting different V/Q ratios and visualizing effects on the human body if possible

2. Production Characteristics
    1. Quantity: number of units needed
        1. 4 units
            1. 3D printed base to hold all components together
            2. LED lights connected to create a string of illumination
            3. Arduino to connect the LEDs and program the model
            4. Sliders/ buttons to change the ventilation/perfusion mismatching ratios

2. Target Product Cost:
    1. To be determined once production phase begins
    2. Similar cost to previous semster's prototype (about $140)

3. Miscellaneous
    1. Standards and Specifications:
        1. No applicable at this time

2. Customer:
    1. Medical students and educators would be the customers
    2. Should be an effective teaching model, with interactive learning aspects for medical students to understand the complex topic

3. Patient-related concerns:
    1. Device will need to be carefully stored in order to prevent deterioration of electrical components

4. Competition:

1. Currently, there are no effective teaching models on the market

Citations

[1] West, J. B., & Luks, A. (2021). *West's respiratory physiology: The essentials*. Wolters Kluwer.

[2] *Storing electronics in a storage unit: Storing electronics in heat + cold*. EZ Storage. (2019, October 22). Retrieved September 24, 2021, from https://www.ezstoragenow.com/blog/delicate-balance-properly-storing-electronics-heat-cold/#:~:text=The%20trick%20to%20properly%20storing,between%2050%20and%2080%20degrees.

Conclusions/action items: The design needs to be a physical model which can be used during lecture. The adjustability of the product is important in order to represent the V/Q ratio at different levels. The product does not necessary be large since camara can be used to zoom in the model. Overall, our team already understand the requirement of the project. Next step is research more in order to get a better understanding of V/Q ratio mismatch and the ventilation perfusion process. After that, alternative design ideas need to be raised for further evaluation.

2021/10/01 - Design Matrix

Charlie ZHU - Oct 20, 2021, 1:15 AM CDT

Title: Design Matrix

Date: 10.01.2021

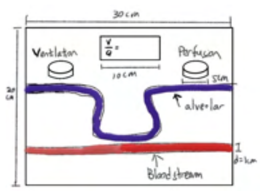
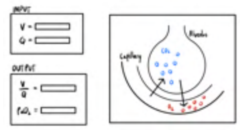
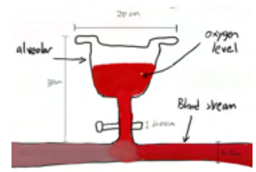
Content by: The whole team

Present: The whole team

Goals: Compare three alternative designs in order to decide the winning design

Content:

Design Matrix

Criteria (Weight)	Slider with LEDs and Screen*		Computer Animation*		Water/Dye Concentrations	
						
Intuitive use (30%)	5/5	30%	4/5	24%	2/5	12%
Learning Outcomes (30%)	4/5	24%	2/5	12%	4/5	24%
Adjustability (20%)	4/5	16%	5/5	20%	4/5	16%
Ease of fabrication (10%)	3/5	6%	2/5	4%	1/5	2%
Cost (5%)	2/5	2%	5/5	5%	2/5	2%
Safety (5%)	4/5	4%	5/5	5%	5/5	5%
Total		**82%**		**70%**		**61%**

*Larger diagrams included at the end of the document.

Descriptions of Models:

The slider with LEDs and screen model uses a 3D printed case that houses differently colored LEDs, slides for adjusting the V/Q ratio, and a digital display where the values the client would like to teach his students about can be displayed. The different colored LEDs represent different things, flowing in and out of the alveoli. Along with that, the speed at which the lights flashed could assist in demonstrating the changes that occur at higher or lower V/Q ratios.

The water and dye model uses a flexible tube that can expand and relax to show different blood flow volume measurements and a colorful dye that can be used to represent oxygenation of the blood. The water would run through the tube at different rates and depending on the avelious represented some amount of dye would be excreted into the tube to show a colorful oxygenated blood flow. The amount of dye excreted and velocity of water would be controlled by a computer program so that qualitative data can be displayed on a computer to show the V/Q ratios and oxygen levels of the portrayed blood flow.

The software animation model refers to use of a programming language to create a software where V and Q values could be input and the V/Q ratio, partial pressure of oxygen, and any other levels the client would like to calculate would be output. Along with these values, the program would provide an animation of one or multiple alveoli with flow rates depicted through use of arrows, number of molecules, and speed at which the molecules flow through the animation.

Descriptions of chosen criteria:

Intuitive use is the ability of the client to understand and use the product immediately after receiving it. The weight of this criteria is 30%, as the product will be used as a teaching model, and both the client and students must be able to use the model easily. The LEDs and Screen design receives 5/5 points for intuitive use since the only interactive part of the design is the slider which is used to control the V/Q ratio.

Learning outcomes refers to the design's effectiveness in leading students to understand the concept of ventilation and perfusion mismatching. Since the major purpose of the design is teaching, the weight of this criteria is given 30%. The LEDs and Screen design allows students to understand the concept without confusion because the slider in the design allows LED light to represent oxygen levels at different V/Q ratios. But since the exact V/Q ratio could not be shown in the design, 4 out of 5 points are given to this design.

In our design, adjustability refers to the ability to adjust the design in order to better accomplish the teaching purpose. The weight of adjustability is 20% because high adjustability will allow the client to better explain the concept of V/Q mismatching to different students. The adjustability of the LEDs and Screen design is considered high because the slider in the design allows the client to adjust the ratio of V/Q in order to show the effects that different ratios have on flow rates. However, factors other than the V/Q ratio (e.g. amount of hemoglobins) could not be changed in the design. Hence, 4 out of 5 points is given to The LEDs and Screen design

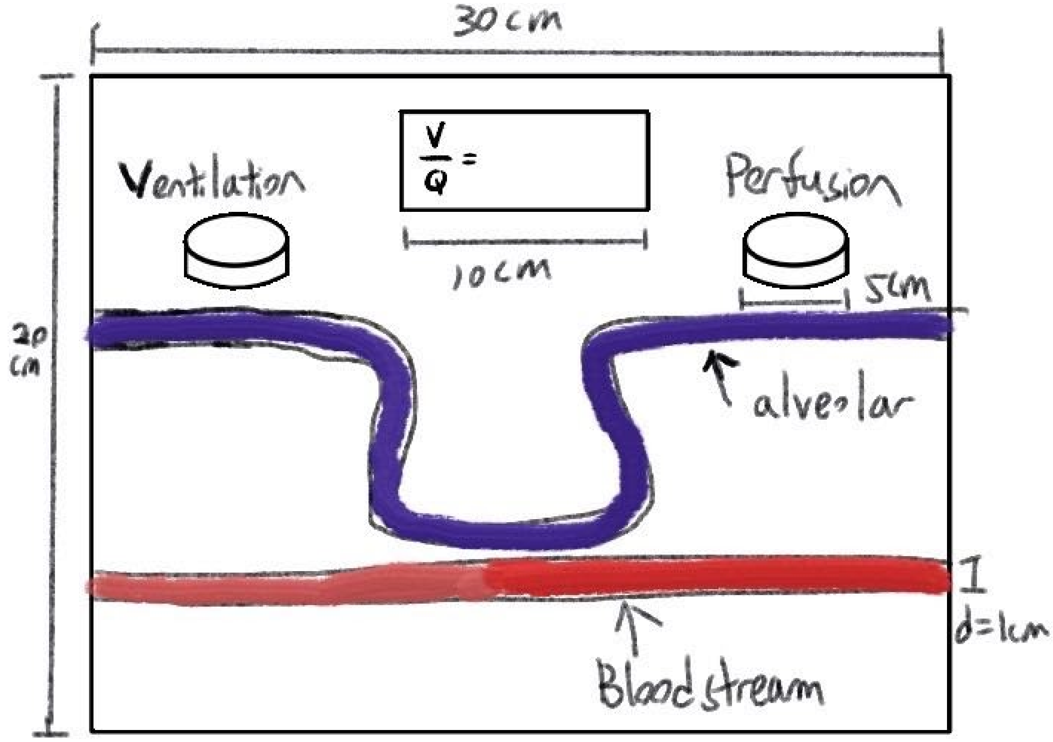
Ease of fabrication refers to the amount of time and effort needed in order to build the product. Since our team has the whole semester to complete the project, the weight of this criteria is only given 10%. The Slider with LEDs and Screen receives 3 out of 5 points because the model needs to be 3D printed, which may require a lot of time.

Cost refers to the cost needed to be spent on raw materials. Since the client's budget is high ($1000), the weight of this criteria is only given 5%. The slider with LEDs and Screen receives 2 out of 5 points because the cost of both 3D printing raw material and LED lights are relatively high, however well within the budget.

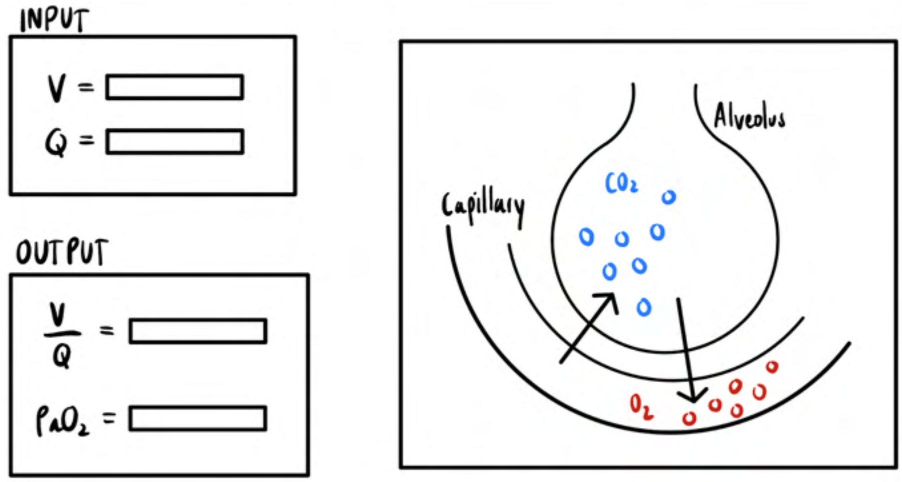
The criteria of safety refers to any risks associated with use of the device. The safety criteria is given a weight of 5% as there are little to no safety risks in any of the designs and in the way it will be used. The slider with LEDs and Screen is considered safe because the only risk of causing safety issues is the potential short-circuit of any electronic components in the design which is unlikely to happen. Based on this, 4 out of 5 points are given to this design.

Preliminary Diagrams:

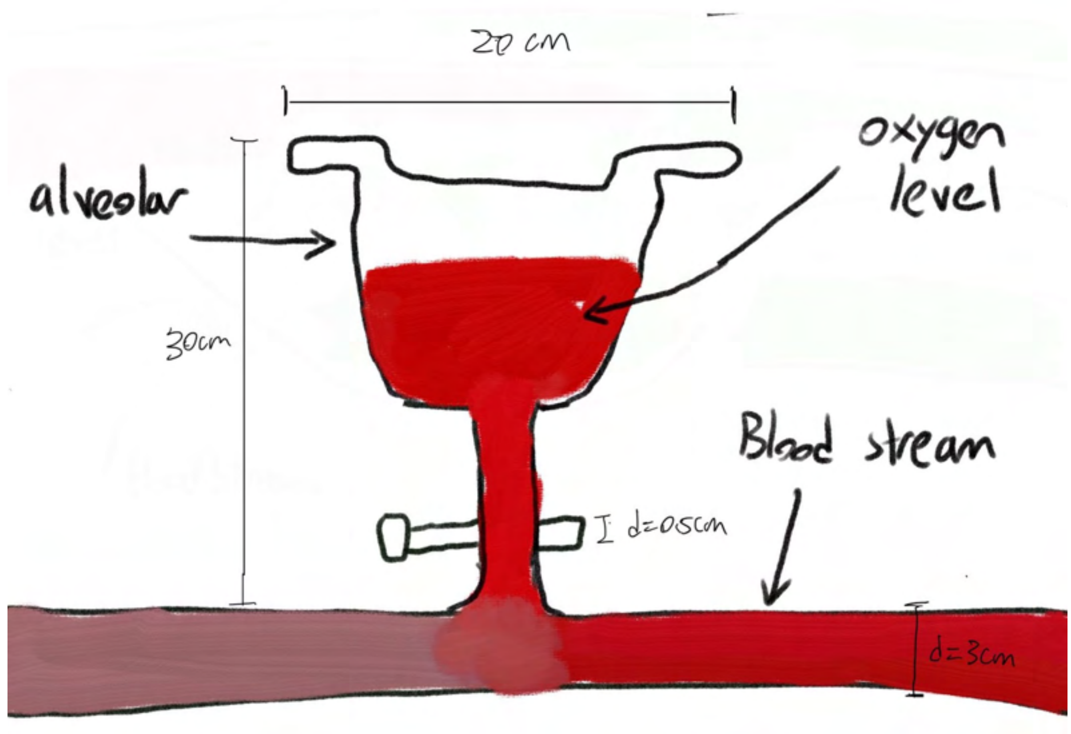
Slider with LEDs and Screen



Computer Animation



Water/Dye Concentrations



Conclusions/action items: The winning design is Sliders with LEDs and screen. After comparing three design, the design matrix determines the Sliders with LEDs and screen as the highest scores design due to great intuitive of use, excellent learning outcome, and the ease of fabrication. Our next step is finalize our final design and make slight modification. After that, fabrication plan will be discussed and start to fabricate the first prototype.

2021/12/05 - Coding Final Version

Charlie ZHU - Dec 15, 2021, 1:47 PM CST

Title: Coding Final Version

Date: 2021/12/05

Content by: Charlie Zhu and Alex Houle

Present: Charlie Zhu and Alex Houle

Goals: Coding for V/Q model

Content:

```
#include <NeoPixelBus.h>

#include <elapsedMillis.h>

#include <LiquidCrystal.h>

#include <Wire.h>

#include <dmtimer.h>

#define REDLITE 7

#define GREENLITE 8

#define BLUELITE 9

int brightness = 255;


const uint16_t PixelCount = 15; // this example assumes 4 pixels, making it smaller will cause a failure

const uint8_t PixelPin = 10;  // make sure to set this to the correct pin, ignored for Esp8266



const int rs = 12, en = 11, d4 = 5, d5 = 4, d6 = 3, d7 = 2;

LiquidCrystal lcd(rs, en, d4, d5, d6, d7);

#define colorSaturation 128

elapsedMillis valueTime = 0;

elapsedMillis lightTime = 0;

elapsedMillis lightDelay = 0;
```

```
elapsedMillis ledTime = 0;

DMTimer ledUpdateTimer(1000000); //Create a timer and specify its interval in microseconds

DMTimer ventiUpdateTimer(1000000);

// three element pixels, in different order and speeds

NeoPixelBus<NeoGrbFeature, Neo800KbpsMethod> strip(PixelCount, PixelPin);

//NeoPixelBus<NeoRgbFeature, Neo400KbpsMethod> strip(PixelCount, PixelPin);


RgbColor red(colorSaturation, 0, 0);

RgbColor green(0, colorSaturation, 0);

RgbColor blue(0, 0, colorSaturation);

RgbColor white(colorSaturation);

RgbColor black(0);

RgbColor grey(128,128,128);


RgbColor a(17,0,232);

RgbColor b(34,0,215);

RgbColor c(51,0,193);

RgbColor d(68,0,178);

RgbColor e(85,0,162);

RgbColor f(103,0,145);

RgbColor g(123,0,123);

RgbColor h(145,0,103);

RgbColor j(162,0,85);

RgbColor k(178,0,68);

RgbColor l(193,0,51);

RgbColor m(215,0,34);

RgbColor n(232,0,17);


int buttonPin = 23;
```

```
int LED1 = 35;

int LED2 = 37;

int LED3 = 39;

int LED4 = 41;

int LED5 = 43;

int LED6 = 45;

int LED7 = 47;

int LED8 = 49;

int LED9 = 51;

int LED10 = 53;



HslColor hslRed(red);

HslColor hslGreen(green);

HslColor hslBlue(blue);

HslColor hslWhite(white);

HslColor hslBlack(black);

int x = 500;

int sensorValue;

float PerfusionValue;

float VentiValue;

float sensorPerValue;

float sensorVenValue;

int buttonState = 0;



// the setup routine runs once when you press reset:

void setup() {

  Serial.begin(9600);
```

```
while (!Serial); // wait for serial attach// initialize serial communication at 9600 bits per second:

  Serial.println();
  Serial.println("Initializing...");
  Serial.flush();

    // this resets all the neopixels to an off state
  strip.Begin();
  for (int i=0; i<15; i++){
    strip.SetPixelColor(i,red);
  }
  strip.Show();

  Serial.println();
  Serial.println("Running...");
pinMode(LED1,OUTPUT);
pinMode(LED2,OUTPUT);
pinMode(LED3,OUTPUT);
pinMode(LED4,OUTPUT);
pinMode(LED5,OUTPUT);
pinMode(LED6,OUTPUT);
pinMode(LED7,OUTPUT);
pinMode(LED8,OUTPUT);
pinMode(LED9,OUTPUT);
pinMode(LED10,OUTPUT);

lcd.begin(20, 4);
```

```
  lcd.setCursor(0,0);

  lcd.print("V Value = ");

  lcd.setCursor(0,1);

  lcd.print("Q Value =");

  lcd.setCursor(0,2);

  lcd.print("V/Q ratio = ");

  lcd.setCursor(0,3);

  lcd.print("PaO2 = ");

  pinMode(REDLITE, OUTPUT);

  pinMode(GREENLITE, OUTPUT);

  pinMode(BLUELITE, OUTPUT);

  analogWrite(REDLITE, 0);

  analogWrite(GREENLITE, 0);

  analogWrite(BLUELITE, 0);

  }


void readDials(){

  float PerfusionValue = 0;

  float VentiValue = 0;

  float sensorPerValue = analogRead(A0);

    PerfusionValue = round((sensorPerValue/7.24));

  float sensorVenValue = analogRead(A3);

    VentiValue = round((sensorVenValue/7.06));

    ledUpdateTimer.setInterval((105-PerfusionValue)*8000);

  float VQratio = VentiValue / PerfusionValue;

  float PaO2=(485.596*( pow((VQratio),2))+VQratio*62.9359+21.4172)/(0.533853+1.60718*VQratio+3.26961*
(pow(VQratio,2)));

    if (valueTime> 150){ //150ms delay: Updates screen every 150ms
```

```
Serial.print ("Perfusion value is ");

Serial.println (PerfusionValue);

Serial.print ("Ventilation value is ");

Serial.println (VentiValue);

Serial.print ("V/Q ratio is ");

Serial.println (VQratio);

Serial.print ("PaO2 value is ");

Serial.println (PaO2);


lcd.setCursor(11,0);

lcd.print(VentiValue  ,2);

lcd.print("  ");

lcd.setCursor(11,1);

lcd.print(PerfusionValue  ,2);

lcd.print("  ");

lcd.setCursor(12,2);

lcd.print(VQratio  ,2);

lcd.print("  ");

lcd.setCursor(7,3);

lcd.print(PaO2 ,2);

lcd.print("   ");

valueTime = 0;}

if (PerfusionValue < 2){

   for (int i=0;i<15;i++){

     strip.SetPixelColor(i,grey);

     strip.Show();

   }

    readDials();

  VentilationLEDs();
```

```
    }

  }

  void VentilationLEDs (){

   float VentiValue = 0;

   float sensorVenValue = analogRead(A3);

   VentiValue = round((sensorVenValue/7.06));

   if ((VentiValue >0) && (VentiValue<= 10)){

     for (int i=35; i<54; i+=2){

       digitalWrite(i, LOW);

    }

    readDials();

   }

   if ((VentiValue >10) && (VentiValue<= 20)){

     digitalWrite(35,HIGH);

     for (int i=37; i<54; i+=2){

       digitalWrite(i, LOW);

     }   readDials();

    }

   if ((VentiValue >20) && (VentiValue<= 30)){

     digitalWrite(35,HIGH);

     digitalWrite(37,HIGH);

     for (int i=39; i<54; i+=2){

       digitalWrite(i, LOW);

     }  readDials();

      }

   if ((VentiValue >30) && (VentiValue<= 40)){

     for (int i=35; i<40; i+=2){

     digitalWrite(i,HIGH);

     }
```

```
  for (int i=41; i<54; i+=2){
    digitalWrite(i, LOW);
  }readDials(); }
if ((VentiValue >40) && (VentiValue<= 50)){
  for (int i=35; i<42; i+=2){
  digitalWrite(i,HIGH);
  }
  for (int i=43; i<54; i+=2){
    digitalWrite(i, LOW);

  }readDials();  }


if ((VentiValue >50) && (VentiValue<= 60)){
  for (int i=35; i<44; i+=2){
  digitalWrite(i,HIGH);
  }
  for (int i=45; i<54; i+=2){
    digitalWrite(i, LOW);
  }readDials();



  }
if ((VentiValue >60) && (VentiValue<= 70)){
  for (int i=35; i<46; i+=2){
  digitalWrite(i,HIGH);
  }
  for (int i=47; i<54; i+=2){
    digitalWrite(i, LOW);
```

```
  } readDials();




  }

 if ((VentiValue >70) && (VentiValue<= 80)){

  for (int i=35; i<48; i+=2){

  digitalWrite(i,HIGH);

  }

  for (int i=49; i<54; i+=2){

    digitalWrite(i, LOW);

  }readDials();




     }

 if ((VentiValue >80) && (VentiValue<= 90)){

  for (int i=35; i<50; i+=2){

  digitalWrite(i,HIGH);

  }

  for (int i=51; i<54; i+=2){

    digitalWrite(i, LOW);

  }   readDials();


  }

 if ((VentiValue) > 90){

  digitalWrite(35, HIGH);

  for (int i=35; i<54; i+=2){

  digitalWrite(i,HIGH);

  } readDials();

  }
```

```
    }

  void allLIGHTS(){

    float sensorPerValue = analogRead(A0);

    PerfusionValue = round((sensorPerValue/7.24));

  //   if (PerfusionValue < 6){

  //      for (int i=0;i<15;i++){

  //        strip.SetPixelColor(i,grey);

  //        strip.Show();

  //      }

  //       readDials();

  //    VentilationLEDs();

  //    }

    if(PerfusionValue >=6) {

      for (int i=0; i<15; i++){ //there is 15 LEDs so this goes over each one, one by one

        while (ledUpdateTimer.isTimeReached() == false){

          strip.SetPixelColor(i,hslBlack); // start by setting the pixel that you're working on to red (turn it on)

          strip.Show(); // this command is needed to update the LED

      }

      readDials();

      VentilationLEDs();

      Serial.println (PerfusionValue);

      strip.SetPixelColor(0,blue);

      strip.SetPixelColor(1,a);

      strip.SetPixelColor(2,b);

      strip.SetPixelColor(3,c);

      strip.SetPixelColor(4,d);

      strip.SetPixelColor(5,e);

      strip.SetPixelColor(6,f);

      strip.SetPixelColor(7,g);
```

```
    strip.SetPixelColor(8,h);

    strip.SetPixelColor(9,j);

    strip.SetPixelColor(10,k);

    strip.SetPixelColor(11,l);

    strip.SetPixelColor(12,m);

    strip.SetPixelColor(13,n);

    strip.SetPixelColor(14,red);

    }

}}



  void loop (){

    allLIGHTS();

  }
```

Conclusions/action items:

All coding work are done, the circuit works are expected. (Each version of codes could be found in Charlie's individual folder)

2021/12/07 - SolidWorks Board Design

Charlie ZHU - Dec 15, 2021, 1:59 PM CST

Title: Solidwork design of the board

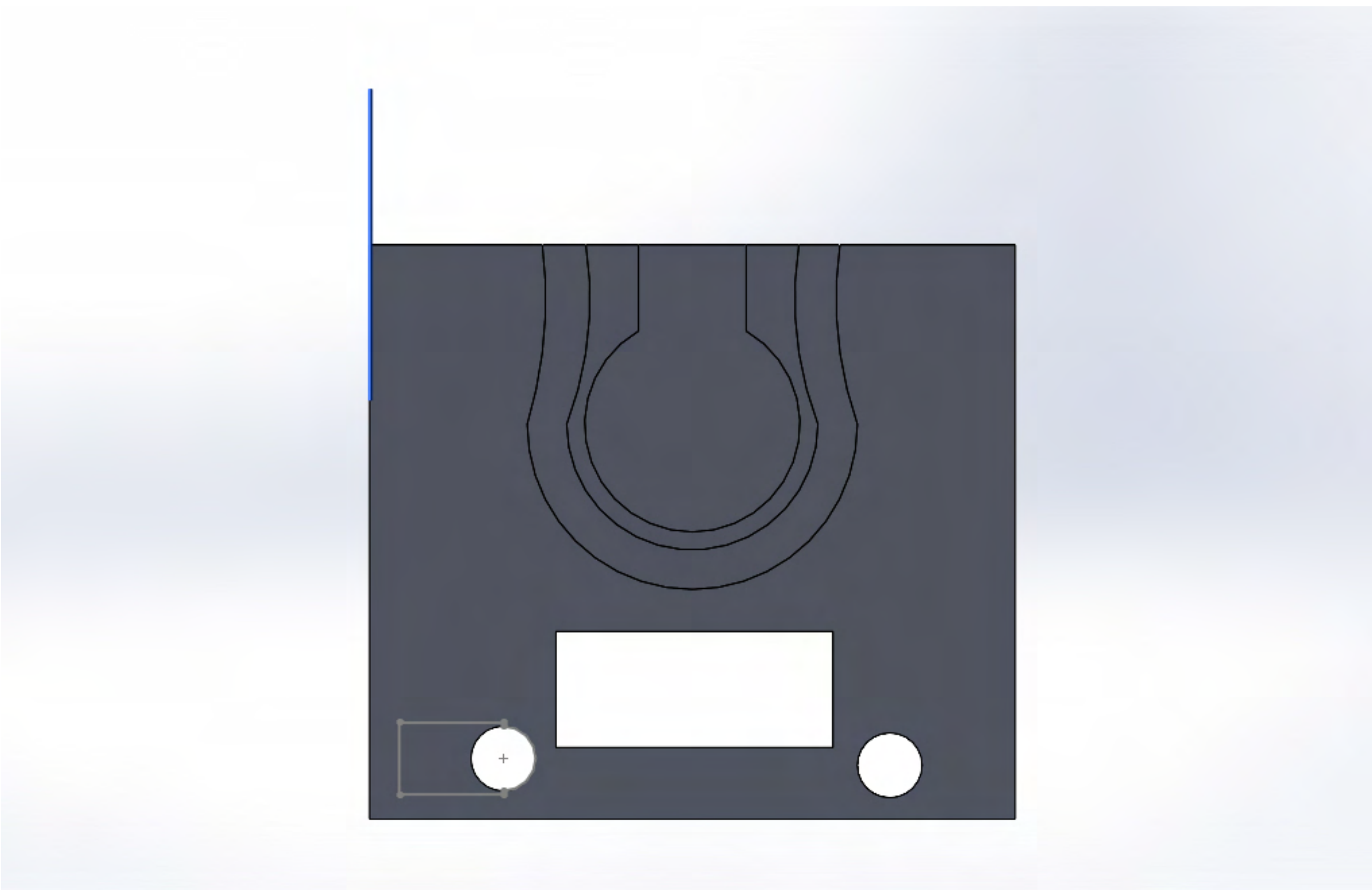
Date: 2021/12/07

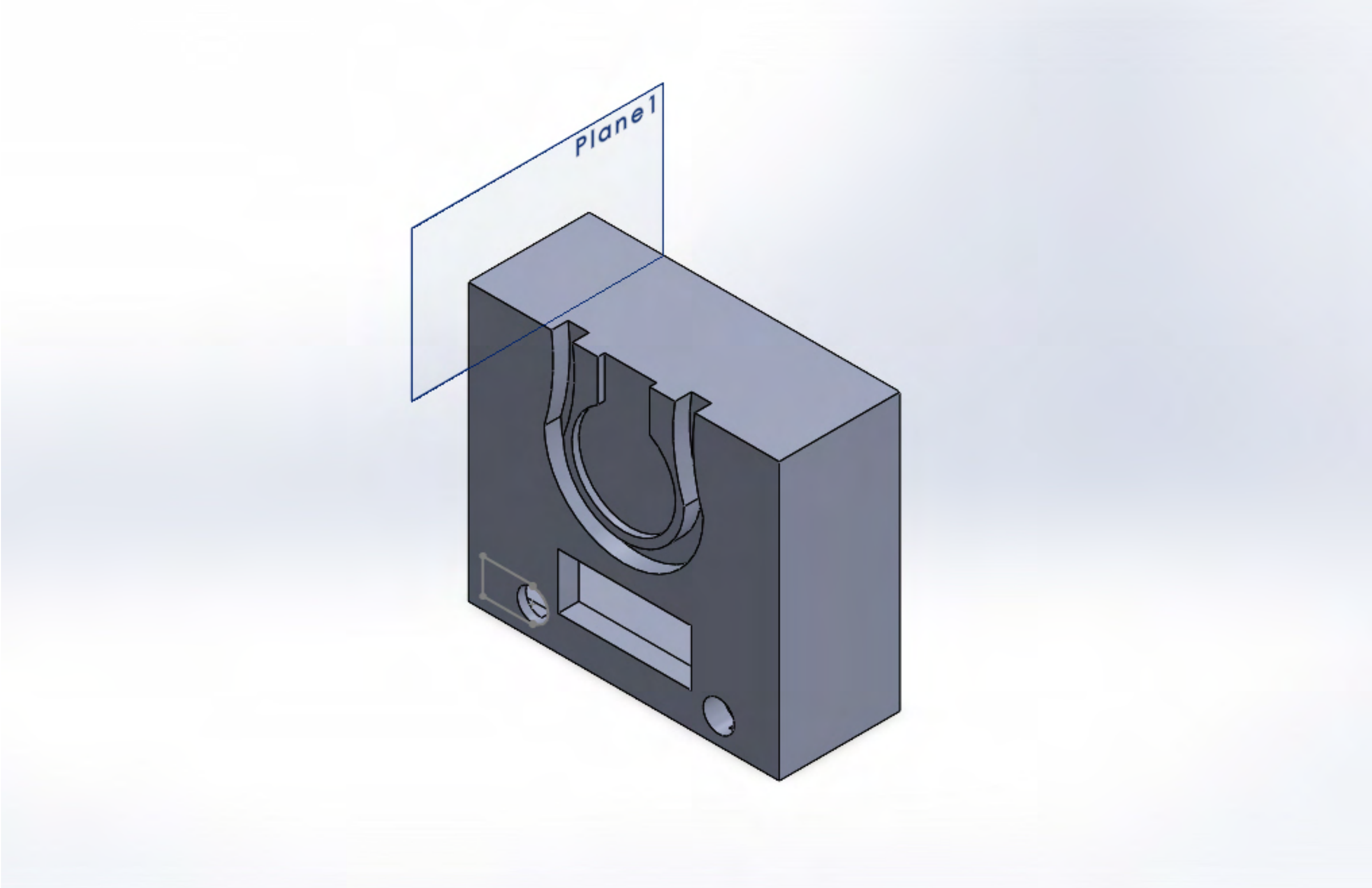
Content by: Charlie Zhu and Kendra Besser

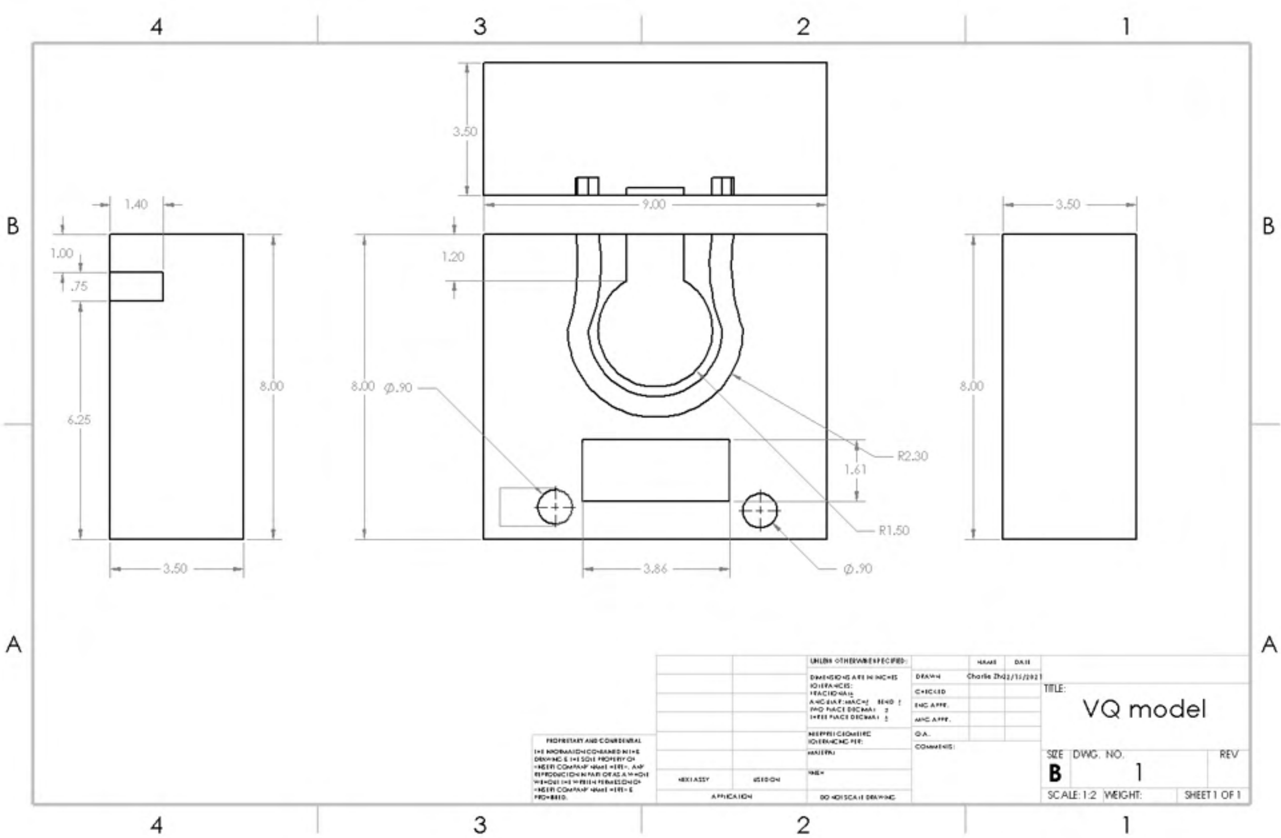
Present: Charlie Zhu and Kendra Besser

Goals: Finalize 3D Model of our project for 3D printing

Content:







Conclusions/action items:

3D model of V/Q model. Final design with all dimensions. Will be printed through 3D printing.

2021/12/07 - SolidWorks Back Design

Charlie ZHU - Dec 15, 2021, 2:02 PM CST

Title: Solidwork design of the back

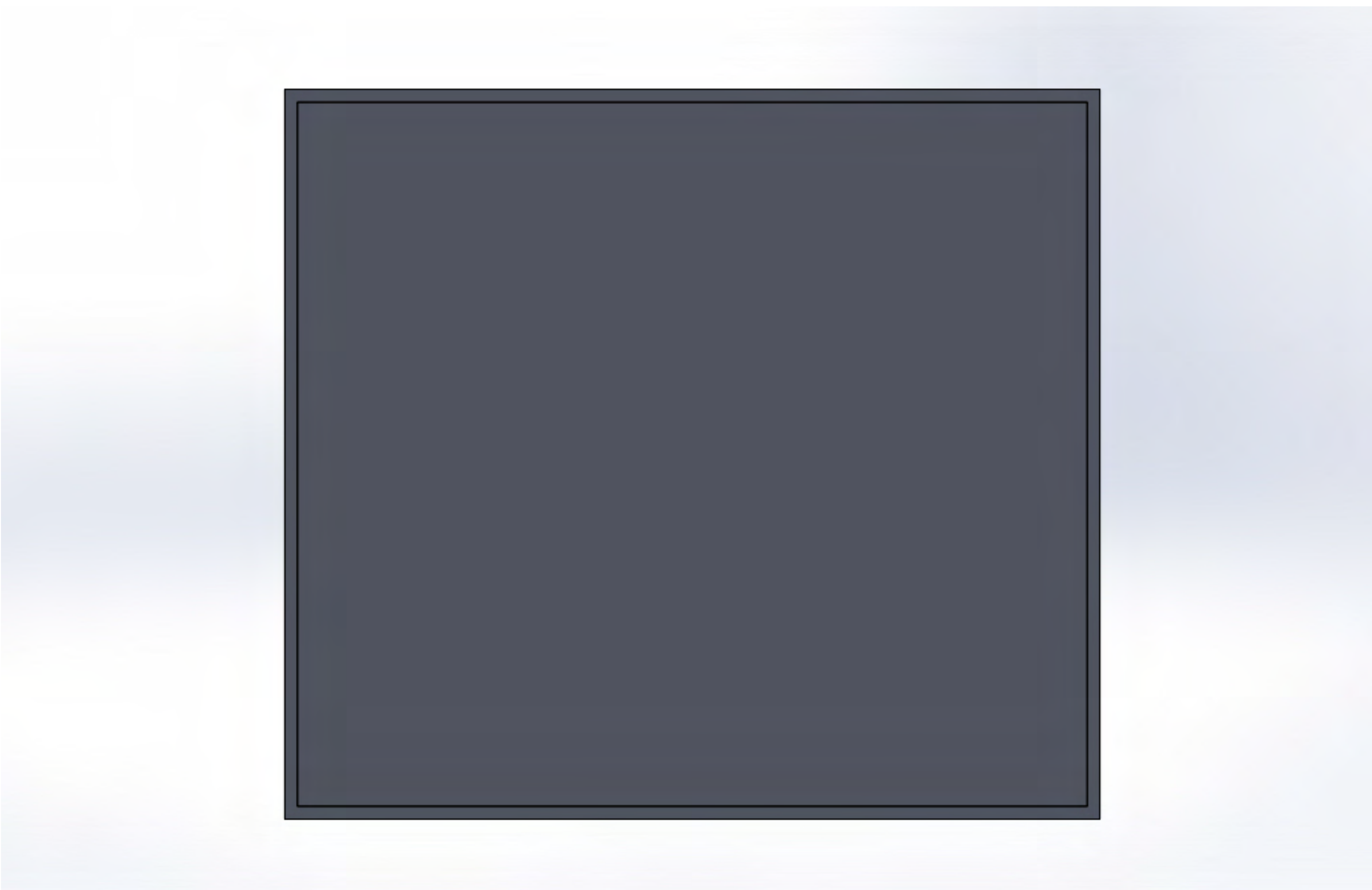
Date: 2021/12/07

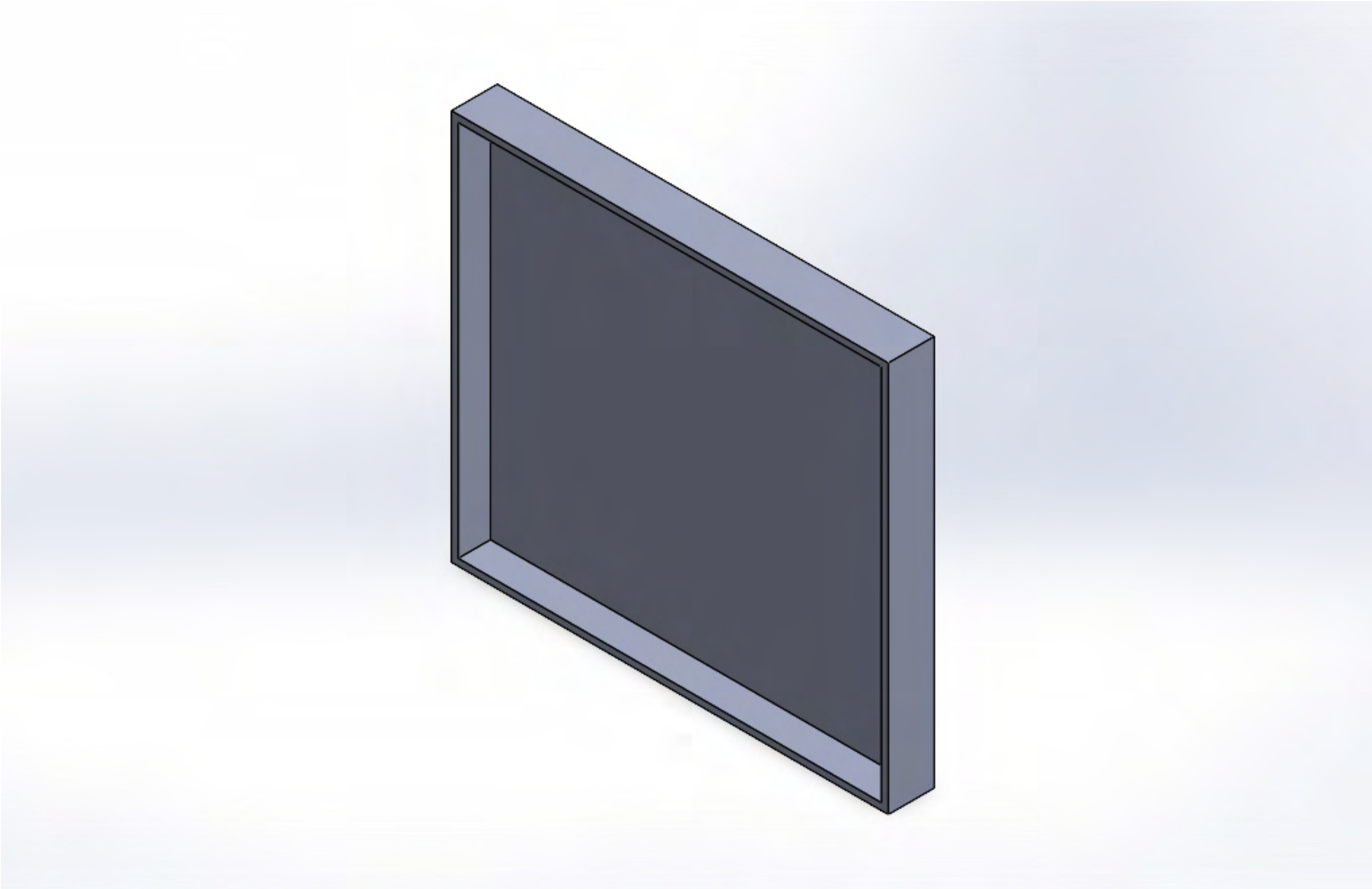
Content by: Charlie Zhu and Kendra Besser

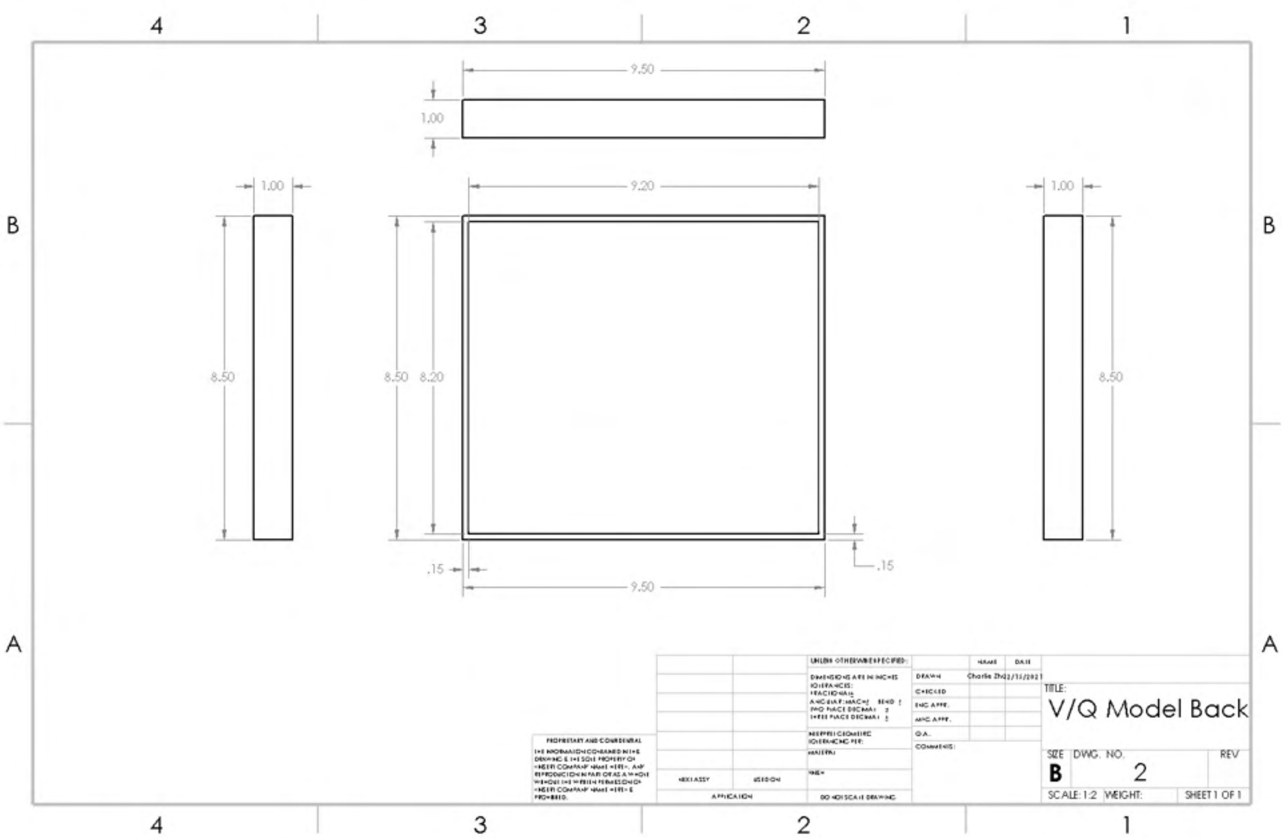
Present: Charlie Zhu and Kendra Besser

Goals: Finalize 3D Model of our project for 3D printing

Content:







Conclusions/action items:

3D model of V/Q model's back. Final design with all dimensions. Will be printed through 3D printing.

2021/12/05 - Updated Design Matrix

MILICA LUKIC - Dec 15, 2021, 2:27 PM CST

Title: Updated Design Matrix

Date: 12/05/21

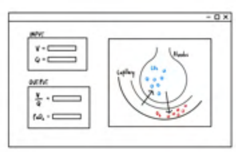
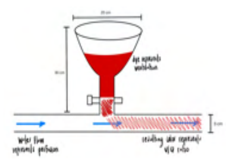
Content by: Milica Lukic

Present: N/A

Goals: Add new sketches to design matrix to make it clearer and more organized.

Content:

Design Matrix

Criteria (Weight)	Slider with LEDs and Screen 		Water/Dye Concentrations 			
Intuitive use (30%)	5/5	30%	4/5	24%	2/5	12%
Learning Outcomes (30%)	4/5	24%	2/5	12%	4/5	24%
Adjustability (20%)	4/5	16%	5/5	20%	4/5	16%
Ease of fabrication (10%)	3/5	6%	2/5	4%	1/5	2%
Cost (5%)	2/5	2%	5/5	5%	2/5	2%
Safety (5%)	4/5	4%	5/5	5%	5/5	5%
Total		**82%**		**70%**		**61%**

Descriptions of Models:

The slider with LEDs and screen model uses a 3D printed case that houses differently colored LEDs, slides for adjusting the V/Q ratio, and a digital display where the values the client would like to teach his students about can be displayed. The different colored LEDs represent different things, flowing in and out of the alveoli. Along with that, the speed at which the lights flashed could assist in demonstrating the changes that occur at higher or lower V/Q ratios.

The water and dye model uses a flexible tube that can expand and relax to show different blood flow volume measurements and a colorful dye that can be used to represent oxygenation of the blood. The water would run through the tube at different rates and depending on the avelious represented some amount of dye would be excreted into the tube to show a colorful oxygenated blood flow. The amount of dye excreted and velocity of water would be controlled by a computer program so that qualitative data can be displayed on a computer to show the V/Q ratios and oxygen levels of the portrayed blood flow.

The software animation model refers to use of a programming language to create a software where V and Q values could be input and the V/Q ratio, partial pressure of oxygen, and any other levels the client would like to calculate would be output. Along with these values, the program would provide an animation of one or multiple alveoli with flow rates depicted through use of arrows, number of molecules, and speed at which the molecules flow through the animation.

Descriptions of chosen criteria:

Intuitive use is the ability of the client to understand and use the product immediately after receiving it. The weight of this criteria is 30%, as the product will be used as a teaching model, and both the client and students must be able to use the model easily. The LEDs and Screen design receives 5/5 points for intuitive use since the only interactive part of the design is the slider which is used to control the V/Q ratio.

Learning outcomes refers to the design’s effectiveness in leading students to understand the concept of ventilation and perfusion mismatching. Since the major purpose of the design is teaching, the weight of this criteria is given 30%. The LEDs and Screen design allows students to understand the concept without confusion because the slider in the design allows LED light to represent oxygen levels at different V/Q ratios. But since the exact V/Q ratio could not be shown in the design, 4 out of 5 points are given to this design.

In our design, adjustability refers to the ability to adjust the design in order to better accomplish the teaching purpose. The weight of adjustability is 20% because high adjustability will allow the client to better explain the concept of V/Q mismatching to different students. The adjustability of the LEDs and Screen design is considered high because the slider in the design allows the client to adjust the ratio of V/Q in order to show the effects that different ratios have on flow rates. However, factors other than the V/Q ratio (e.g. amount of hemoglobins) could not be changed in the design. Hence, 4 out of 5 points is given to The LEDs and Screen design

Ease of fabrication refers to the amount of time and effort needed in order to build the product. Since our team has the whole semester to complete the project, the weight of this criteria is only given 10%. The Slider with LEDs and Screen receives 3 out of 5 points because the model needs to be 3D printed, which may require a lot of time.

Cost refers to the cost needed to be spent on raw materials. Since the client's budget is high ($1000), the weight of this criteria is only given 5%. The slider with LEDs and Screen receives 2 out of 5 points because the cost of both 3D printing raw material and LED lights are relatively high, however well within the budget.

The criteria of safety refers to any risks associated with use of the device. The safety criteria is given a weight of 5% as there are little to no safety risks in any of the designs and in the way it will be used. The slider with LEDs and Screen is considered safe because the only risk of causing safety issues is the potential short-circuit of any electronic components in the design which is unlikely to happen. Based on this, 4 out of 5 points are given to this design.

2021/12/15 - Updated Product Design Specification

Charlie ZHU - Dec 15, 2021, 3:25 PM CST

Title: Updated Product Design Specification

Date: 12/15/21

Content:

Teaching Model for Ventilation and Perfusion Mismatching
Alex Houle, Charlie Zhu, Darshigaa Gurumoorthy, Kendra Besser, and Milica Lukic
12/15/2021

Function:

Ventilation and perfusion mismatching is the most predominant cause of hypoxemia. However, medical students often have a very difficult time understanding this concept. Other than a textbook diagram by John West in his text *Respiratory Physiology* [1], there are no relevant representations of ventilation/perfusion mismatching. Our goal is to improve a prototype completed by previous UW Madison students to create an effective teaching model of ventilation/ perfusion mismatching to be studied by medical students for a deeper understanding of hypoxemia. The teaching model will represent an alveolus and a capillary with individual lights; the lights will blink at different speeds to demonstrate different perfusion and ventilation rates. Lastly, the ventilation and perfusion rates will be converted to a ratio and partial pressure of oxygen values that will be displayed on the model.

Client requirements:

- Sliding knobs for changing the V/Q ratio to represent different levels of mismatching
- Output that shows oxygenation (client will help with calculations)
- A digital display of some sort for the values (or displayed on computer screen)
- Able to be showed in lecture hall under document camera
- Not necessarily realistic, but good representation of what happens in the body at different V/Q levels leading to hypoxemia

Design requirements:

1. **Physical and Operational Characteristics**
    a. Performance requirements:
        i. An interactive model that has movable knobs that change V and Q values

ii. V and Q values vary from 0-100 L/min
iii. Used in a classroom setting under a document camera
iv. Clearly visibility of LEDs and LED display board under a document camera
v. Displayed V/Q ratio and P_aO_2 value on LED display board
vi. Accurate coding calculations of V/Q ratio and P_aO_2 in mmHg based on set V and Q values
vii. Power obtained via USB cord to computer

b. Safety:

i. No danger of electrocution (no loose wires)
ii. Shell has no sharp corners

c. Accuracy and Reliability:

i. Coding calculations of V/Q ratio and P_aO_2 should be accurate compared to manually calculations
ii. Electrical components should be durable and sturdilly connected to a breadboard
iii. Electrical work and coding should be able to produce accurate results for different V and Q values during at least 5 consecutive tests

d. Life in Service:

i. Under a safe temperature range (10°C to 40°C), expected life in service should be at least 10 years
ii. Electrical components should help conserve battery
iii. As a teaching model, device should last throughout lectures and hands on learning

e. Shelf Life:

i. The product should be able to withstand storage for long periods of time. (At least ten years under good condition of electronic components)
ii. The product needs to be reusable and set up easily
iii. The product will be placed in a sealed container in order to maintain a low moisture level
iv. Ideal storage temperature is in the range of 10°C to 40°C. [2]

f. Operating Environment:

i. Classroom setting, not exposed to harsh elements
ii. Used under a document camera during lectures
iii. Slight risk of damage due to mishandling between transition from classroom to storage

g. Ergonomics:

i. Less than 0.3m x 0.3m and made out of the lightest possible PLA in order to be easily portable
ii. Be able to be displayed in a lecture hall using a document camera, or seen in a small-group setting (within 3 meters of the device)

h. Size:
   i. Maximum display size of 22.86cm x 22.86cm in order to fit under the document camera

i. Weight:
   i. Easily movable and carryable, no more than 6.8 kg.

j. Materials:
   i. Baseboard material should be compatible with skin contact
   ii. All materials exposed from the outside should be able to withstand sanitation in between uses
   iii. Lights used to represent oxygen and blood flow should be within 80 lumens which is safe to human eyes [3]
   iv. Arduino Mega to allow for large amount of digital ports required

k. Aesthetics, Appearance, and Finish:
   i. Black baseboard
   ii. “Dinner-plate” sized
   iii. No loose wires or sharp corners
   iv. Digital display of some kind for relevant values
   v. Computer program for inputting different V/Q ratios and visualizing effects on the human body if possible

2. Production Characteristics

a. Quantity: number of units needed
   i. 5 units
      1. 3D printed base to hold all components together
      2. LED lights connected to create a string of illumination
      3. Arduino to connect the LEDs and program the model
      4. Knobs and potentiometers to change the ventilation/perfusion mismatching ratios
      5. Resistors, breadboards, and wires to connect electrical components to arduino
      6. LCD screen to display values

b. Target Product Cost:
   i. Similar cost to previous semster’s prototype (about $140)
   ii. Maximum budget of $1000

3. Miscellaneous

a. Standards and Specifications:

i. BS 9000 - Electronic Components Package (Assessed Quality System) [4]

ii. IEEE 1118.1-1990 - IEEE Standard for Microcontroller System Serial Control Bus [5]

iii. IEC/EN-62471Photobiological Safety of Lamps and Lamp Systems [6]

b. Customer:

i. Medical students and educators would be the customers
ii. Should be an effective teaching model, with interactive learning aspects for medical students to understand the complex topic

c. Patient-related concerns:

i. Device will need to be carefully stored in order to prevent deterioration of electrical components

d. Competition:

i. Petersson and Glenny's ventilation perfusion model [7]
ii. Herrmann's ventilation perfusion system [8]

Citations

[1] West, J. B., & Luks, A. (2021). *West's respiratory physiology: The essentials*. Wolters Kluwer.

[2] *Storing electronics in a storage unit: Storing electronics in heat + cold*. EZ Storage. (2019, October 22). Retrieved September 24, 2021, from https://www.ezstoragenow.com/blog/delicate-balance-properly-storing-electronics-heat-cold/#:~:text=The%20trick%20to%20properly%20storing,between%2050%20and%2080%20degrees.

[3] B. Davis, "Home," *MVOrganizing*, 26-Mar-2021. [Online]. Available: https://www.mvorganizing.org/can-you-go-blind-from-staring-at-a-flashlight/. [Accessed: 15-Dec-2021].

[4] "BS 9000 Electronic Components Package," *ANSI Webstore*. [Online]. Available: https://webstore.ansi.org/Standards/BSI/BS9000ElectronicComponents. [Accessed: 15-Dec-2021].

[5] "IEEE 1118.1-1990 - IEEE standard for Microcontroller System Serial Control Bus," *IEEE SA - The IEEE Standards Association - Home*. [Online]. Available: https://standards.ieee.org/standard/1118_1-1990.html. [Accessed: 15-Dec-2021].

[6]"IEC 62471 for LED lighting products," *Smart Vision Lights*, 22-Apr-2020. [Online]. Available: https://smartvisionlights.com/resources/lighting-basics-resources/iec-62471-for-led-lighting-products/. [Accessed: 15-Dec-2021].

[7]J. Petersson and R. W. Glenny, "Gas exchange and ventilation–perfusion relationships in the lung," *European Respiratory Society*, 01-Oct-2014. [Online]. Available: https://erj.ersjournals.com/content/44/4/1023. [Accessed: 15-Dec-2021].

[8] J. Herrmann, V. Mori, J. H. T. Bates, and B. Suki, “Modeling lung perfusion abnormalities to explain early COVID-19 hypoxemia,” *Nature News*, 28-Sep-2020. [Online]. Available: https://www.nature.com/articles/s41467-020-18672-6. [Accessed: 15-Dec-2021].

2021/12/13 - Fabrication and Material Cost

Charlie ZHU - Dec 15, 2021, 1:25 PM CST

Title: Fabrication and Material Cost

Date: 12/15/2021

Content by: Charlie Zhu

Present: N/A

Goals: N/A

Content:

Table 1. Cost and materials chart in order of purchase with the most recent at bottom.

Item	Manufacturer	Quantity	Cost/Unit	Link
Digital Display	Adafruit	1	$24.95	https://www.adafruit.com/product/498#technical-details
Panel Mount 10K potentiometer	Adafruit	2	$1.90	https://www.adafruit.com/product/562
Panel Mount Right Angle 10K Linear Potentiometer	Adafruit	2	$3.00	https://www.adafruit.com/product/3395
Solid Machines Metal Knob	Adafruit	2	$7.90	https://www.adafruit.com/product/2056#description
3D printing prototype (1) fabrication cost	Ultimaker	1	$25.92	https://making.engr.wisc.edu/mini-mart/
3D printing prototype_board (2) fabrication cost	Ultimaker	1	$23.28	https://making.engr.wisc.edu/mini-mart/
3D printing prototype_lid (2) fabrication cost	Ultimaker	1	$22.96	https://making.engr.wisc.edu/mini-mart/
3D printing prototype_board (3) fabrication cost	Ultimaker	1	$37.92	https://making.engr.wisc.edu/mini-mart/
3D printing prototype_lid (3) fabrication cost	Ultimaker	1	$16.00	https://making.engr.wisc.edu/mini-mart/

3D printing prototype_lid (4) fabrication cost	Ultimaker	1	$18.32	https://making.engr.wisc.edu/mini-mart/
Super Glue	Pacer	1	$1.15	https://making.engr.wisc.edu/mini-mart/
Arduino Mega	Elegoo	1	$22.00	https://making.engr.wisc.edu/mini-mart/
Large Breadboard	Adafruit	1	$3.00	https://making.engr.wisc.edu/mini-mart/
Led bulbs	Adafruit	16	$4.00	https://making.engr.wisc.edu/mini-mart/
Female to male Arduino wires	Adafruit	40	$2.00	https://making.engr.wisc.edu/mini-mart/
Heat Shrink	Eventronic	9	$0.90	https://making.engr.wisc.edu/mini-mart/
Epoxy	Hardman	5	$7.50	https://making.engr.wisc.edu/mini-mart/
LED Strip	Adafruit	2	$25.00	https://www.adafruit.com/product/3919?gclid=CjwKCAjww5r8BRB6EiwArcckCzEIg95MquQekbTMIV_LZ4VwndfflJ-GjxrnGvsVQTvlRloZGAF2jxoCVIoQAvD_BwE
Bright White 5mm LED (25 pack)	Adafruit	1	$6.95	https://www.adafruit.com/product/754
Total	$254.65			

Conclusions/action items: All fabrication and material cost are listed

2021/10/31 - Initial fabrication plans

Kendra Besser - Dec 15, 2021, 1:26 PM CST

Title: Initial fabrication plans

Date: 10/31/2021

Content by: Kendra

Present: Kendra, Milica, Alex, Charlie, Darshigaa

Goals: Establish who will be doing what during the fabrication time period.

Content:

	Task	Who	Deadline	Complete
Old prototype testing	test functionality by using it	Everyone	10/28	100%
	test under doc camera	Kendra and Charlie	10/29	100%
Fabricate prototype 1	Solidworks sketch and print	Kendra	11/1	100%
	Create code to run program (use resources if needed)	Charlie, Alex, Milica	11/2	100%
	Assemble bread board/ electrical work (order new sliders and use what we have)	Kendra and Darshiga	11/3	100%
	Assemble whole prototype	Everyone	11/3	100%
Test prototype 1	Test under doc camera	Darshigaa	11/4	100%
	Test functionality by using it	Everyone	11/4	100%
	Comapre new prototype to old one	Everyone	11/4	100%
Show and Tell		Everyone	11/5	100%

Conclusions/action items:

These were the initial fabrication plans, the actual plan varied slightly from the intended plans. For example, some dates were completed later and many team members worked on each task instead of just one or two members.

2021/12/05 - Updated Fabrication Plans

MILICA LUKIC - Dec 15, 2021, 3:14 PM CST

Title: Updated Fabrication Plans

Date: 12/5/21

Content:

Updated Fabrication Plans

Old Prototype Testing

- Test under document camera in lecture hall
- Get feedback from BME classmates during Show and Tell

Fabricate New Prototype

- Order Online or Purchase at Makerspace:
  - RGB LED strips x2
  - individual white LED 3 to 5mm bulbs x1 pack of 25
  - Potentiometers x2
  - Knobs x2
  - 20x4 RGB Digital Display
- Use 3D printer at the Makerspace to build front and back of model to house electrical components
- Assemble circuit, program lights with knobs and display, and build prototype
  - Meet with Professor Nimunkar and Brittany Glaeser for assistance with circuitry and programming

Test New Prototype

- Get feedback from BME classmates during Poster Presentation
- Get feedback from Dr. Green and his medical students during private meeting
- Test the code's ability to calculate the correct V/Q ration and partial pressure of oxygen repeatedly

2021/12/03 - Front 3D Print Version 1

Charlie ZHU - Dec 15, 2021, 2:14 PM CST

Title: 3D printing Version 1 V/Q Model

Date: 2021/12/03

Content by: Charlie Zhu

Present: Charlie Zhu

Goals: 3D print our V/Q model Version 1

Content:

uwmadmaker@gmail.com
Fri 12/3/2021 1:13 PM
To: Charlie ZHU

Hi Charlie Zhu:

The print job "Ventilation Perfusion Model" is printing on a Ultimaker printer. You'll receive another email when the print job is ready to be picked or if there is an issue.

Although the estimated print time is 21 hours, please do not come to the Makerspace to pick-up the print until you have received a pick-up email.

If 21 + 1 whole business day has passed. Email <maker-3dprint@engr.wisc.edu> and reference this job # 1978595702.

This is an automated message from the Makerspace 3D Print System (I'm a bot). Do not reply to this email.

Happy Making,
The 3D Printing Team

Reply | Forward

Conclusions/action items:

Dimension does not fit, second time reprint is needed

2021/12/07 - Front 3D Print Version 2

Charlie ZHU - Dec 15, 2021, 2:15 PM CST

Title: 3D printing Version 2 V/Q Model

Date: 2021/12/07

Content by: Charlie Zhu

Present: Charlie Zhu

Goals: 3D print our V/Q model Version 2

Content:

U

uwmadmaker@gmail.com
Tue 12/7/2021 1:24 PM
To: Charlie ZHU

Hi Charlie Zhu:

The print job "V/Q Model" is printing on a Ultimaker printer. You'll receive another email when the print job is ready to be picked or if there is an issue.

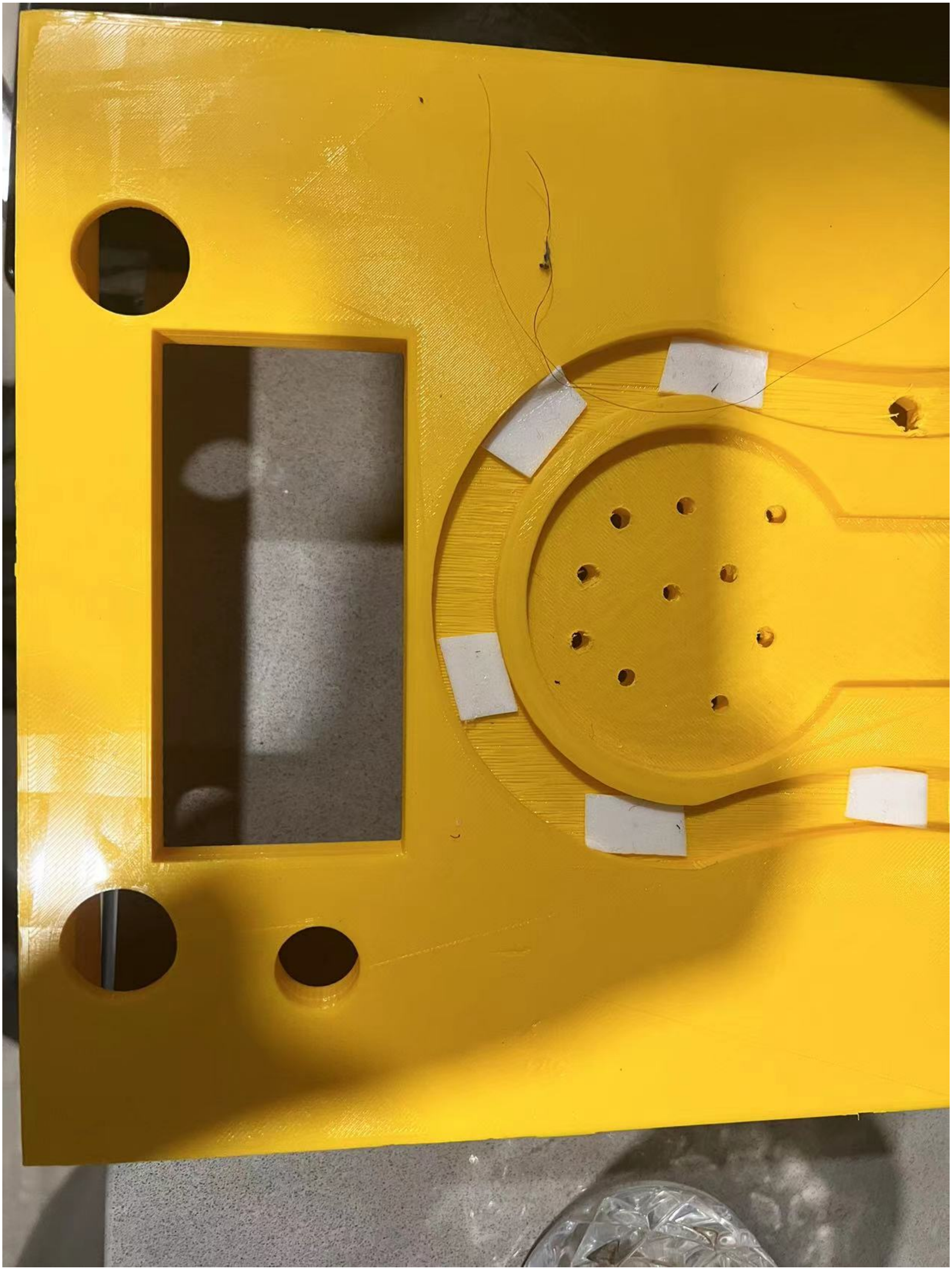
Although the estimated print time is 20 hours, please do not come to the Makerspace to pick-up the print until you have received a pick-up email.

If 20 + 1 whole business day has passed. Email <maker-3dprint@engr.wisc.edu> and reference this job # 1992092255.

This is an automated message from the Makerspace 3D Print System (I'm a bot). Do not reply to this email.

Happy Making,
The 3D Printing Team

Reply | Forward



Conclusions/action items:

Display board Dimension does not fit, Black color is more desired than yellow. Third time reprint is needed

2021/12/10 - Front 3D Print Version 3

Charlie ZHU - Dec 15, 2021, 2:17 PM CST

Title: 3D printing Version 3 V/Q Model

Date: 2021/12/10

Content by: Charlie Zhu

Present: Charlie Zhu

Goals: 3D print our V/Q model Version 3

Content:


Q
V
ALVEOLUS
CAPILLARY

uwmadmaker@gmail.com
Fri 12/10/2021 2:37 PM
To: Charlie ZHU

Hi Charlie Zhu:

The print job "VQ model" is printing on a Ultimaker printer. You'll receive another email when the print job is ready to be picked or if there is an issue.

Although the estimated print time is 53 hours, please do not come to the Makerspace to pick-up the print until you have received a pick-up email.

If 53 + 1 whole business day has passed. Email <maker-3dprint@engr.wisc.edu> and reference this job # 2009636839.

This is an automated message from the Makerspace 3D Print System (I'm a bot). Do not reply to this email.

Happy Making,
The 3D Printing Team

Reply | Forward

Conclusions/action items:

Final fabrication, and everything fits fine. No need to reprint.

2021/12/08 - Back 3D Print Version 1

Charlie ZHU - Dec 15, 2021, 2:18 PM CST

Title: 3D printing back Version 1 V/Q Model

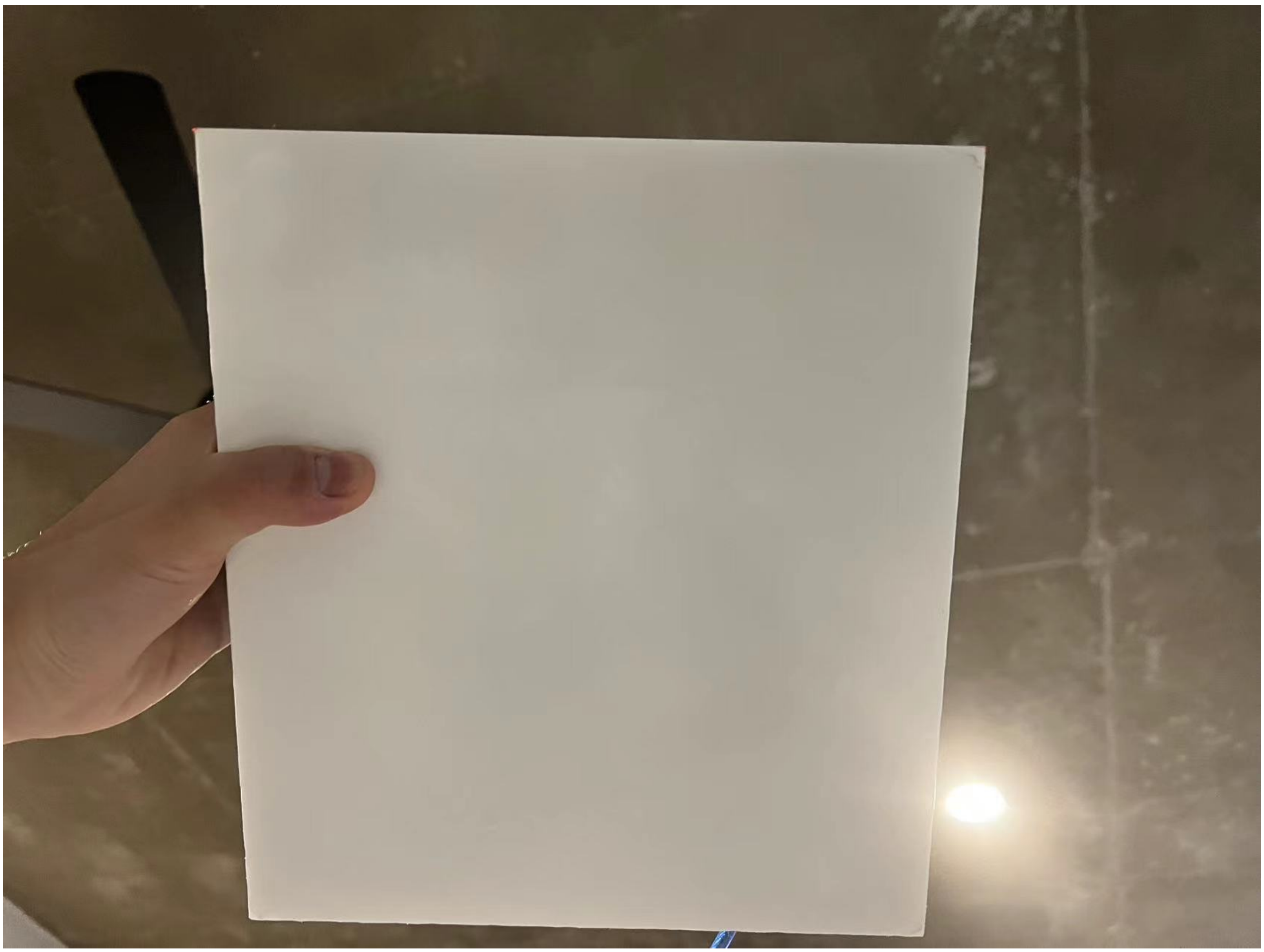
Date: 2021/12/08

Content by: Charlie Zhu

Present: Charlie Zhu

Goals: 3D print our V/Q model back Version 1

Content:



uwmadmaker@gmail.com
Wed 12/8/2021 9:18 AM
To: Charlie ZHU

Hi Charlie Zhu:

The print job "V/Q model lid" is printing on a Ultimaker printer. You'll receive another email when the print job is ready to be picked or if there is an issue.

Although the estimated print time is 30 hours, please do not come to the Makerspace to pick-up the print until you have received a pick-up email.

If 30 + 1 whole business day has passed. Email <maker-3dprint@engr.wisc.edu> and reference this job # 1997686115.

This is an automated message from the Makerspace 3D Print System (I'm a bot). Do not reply to this email.

Happy Making,
The 3D Printing Team

Reply | Forward

Conclusions/action items:

Dimension does not fit, second time reprint is needed

2021/12/14 - Back 3D Print Version 2

Charlie ZHU - Dec 15, 2021, 2:19 PM CST

Title: 3D printing back Version 2 V/Q Model

Date: 2021/12/14

Content by: Charlie Zhu

Present: Charlie Zhu

Goals: 3D print our V/Q model back Version 2

Content:

U

uwmadmaker@gmail.com
Tue 12/14/2021 2:23 PM
To: Charlie ZHU

Hi Charlie Zhu:

The print job "V/Q Model Lid" is printing on a Ultimaker printer. You'll receive another email when the print job is ready to be picked or if there is an issue.

Although the estimated print time is 16 hours, please do not come to the Makerspace to pick-up the print until you have received a pick-up email.

If 16 + 1 whole business day has passed. Email <maker-3dprint@engr.wisc.edu> and reference this job # 2025319984.

This is an automated message from the Makerspace 3D Print System (I'm a bot). Do not reply to this email.

Happy Making,
The 3D Printing Team

Reply | Forward

Conclusions/action items:

Dimension does not fit, third time reprint is needed

2021/12/15 - Back 3D Print Version 3

Charlie ZHU - Dec 15, 2021, 2:21 PM CST

Title: 3D printing back Version 3 V/Q Model

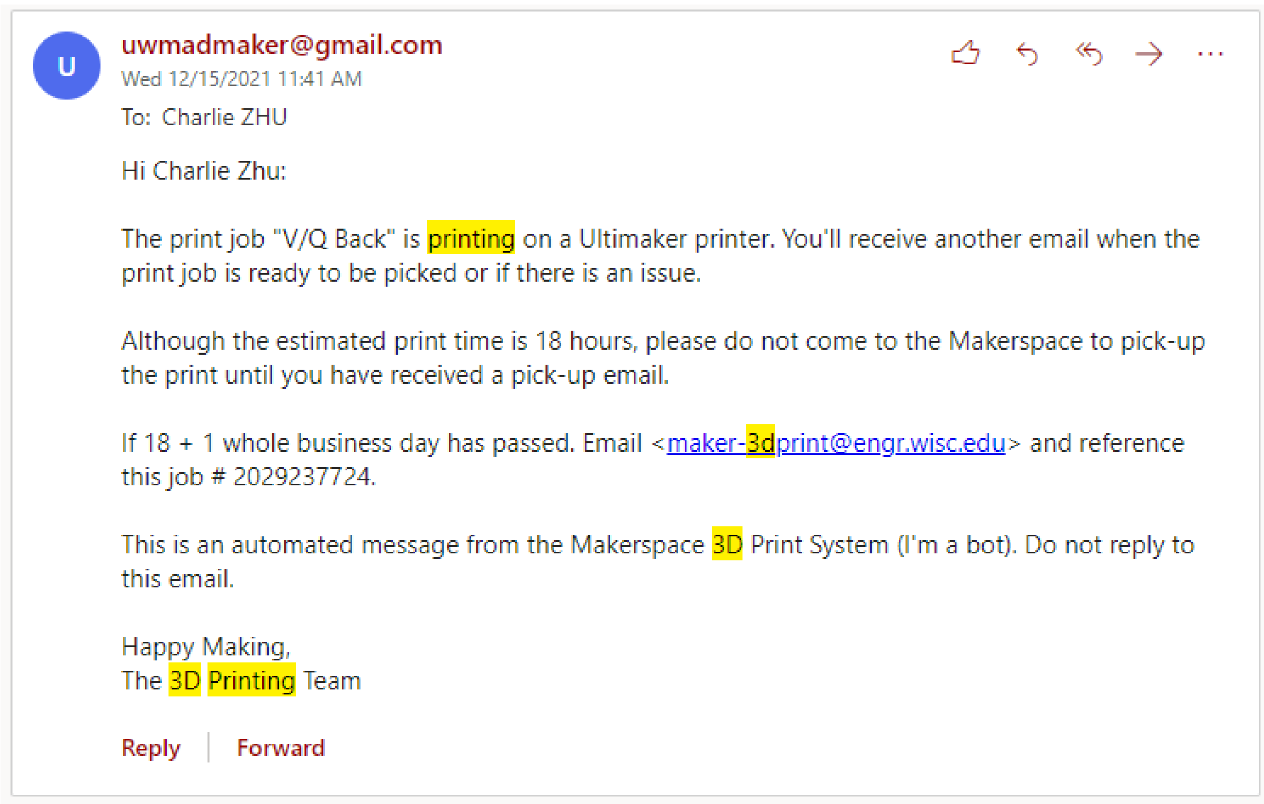
Date: 2021/12/15

Content by: Charlie Zhu

Present: Charlie Zhu

Goals: 3D print our V/Q model back Version 3

Content:



uwmadmaker@gmail.com
Wed 12/15/2021 11:41 AM
To: Charlie ZHU

Hi Charlie Zhu:

The print job "V/Q Back" is printing on a Ultimaker printer. You'll receive another email when the print job is ready to be picked or if there is an issue.

Although the estimated print time is 18 hours, please do not come to the Makerspace to pick-up the print until you have received a pick-up email.

If 18 + 1 whole business day has passed. Email <maker-3dprint@engr.wisc.edu> and reference this job # 2029237724.

This is an automated message from the Makerspace 3D Print System (I'm a bot). Do not reply to this email.

Happy Making,
The 3D Printing Team

Reply | Forward

Conclusions/action items:

Final fabrication of the lid. Dimension are verified correct. It will be printed out on 12/16.

2021/12/15 - Protocol for Initial and Final Qualitative Tests

Kendra Besser - Dec 15, 2021, 1:35 PM CST

Title: Protocol for initial and final qualitative test

Date: 12/15/2021

Content by: Kendra

Present: Kendra, Charlie, Alex

Goals: Record how both qualitative tests were conducted.

Content:

The first test that was completed on the perfusion/ ventilation model was an initial qualitative test under a lecture hall document camera. Two team members visited a lecture hall in the health science learning center where the client, Chris Green, teaches. There, the original prototype from spring 2021 was tested underneath the document camera and on the projector. The test was completed on the original prototype to confirm the design specifications the new model was going to represent. To test visibility, intuitiveness, and potential improvements the prototype was placed on the document camera stage, and then the image projected was evaluated from the back of the classroom. This test was designed to point out the visual flaws and failures of the existing model. The expected outcomes will describe aesthetic characteristics that can be improved in the next model.

Similar to the initial qualitative test, the final prototype was tested under a document camera in a lecture hall. A document camera in a lecture hall, similar to the clients, was used. During the test, the same aspects as before (visibility, intuitiveness, and potential improvements) were evaluated. The expected results were improvements in component dimensions, projection visibility, and intuitiveness/ understanding of the model. However, the test still allowed for growth by evaluating and defining areas of physical improvement.

Conclusions/action items:

The tests were conducted under a document camera in a lecture hall and qualitative data was collected based on the model's appearance and functionality on the projected screen. See data under experimentation folder.

2021/12/15 - Protocol for Quantitative Repeatability Test

Kendra Besser - Dec 15, 2021, 1:38 PM CST

Title: Protocol for initial and final qualitative test

Date: 12/15/2021

Content by: Kendra and Milica

Present: Milica, Alex, Charlie, Darshigaa, Kendra

Goals: Record how the repeatability/quantitative test was conducted.

Content:

The last test was a repeatability/ quantitative test. This test was used to determine the durability of the electrical components and accuracy of the code. The test consists of changing the perfusion value and the ventilation value by turning the Q and V knobs respectively. Then based on the Q and V values, the V/Q ratio and partial pressure of oxygen were calculated by hand and compared to the displayed values from the code. This process was repeated five times to ensure the results were reliable. The test results will evaluate the ability of electrical components to work in harmony with each other and produce accurate displayed values every time. Additionally, the code is evaluated based on its accuracy and speed. The results will conclude if there are errors or variances in the displayed values when compared to the hand calculated values. The expected outcomes are the displayed values match the calculated values and the program runs smoothly and similarly every time.

Conclusions/action items:

The test was conducted by changing the V and Q values then calculating partial pressure of oxygen and V/Q ratio by hand then comparing those values to those displayed on the prototype. See data under the experimentation folder.

2021/12/15 - Protocol for Medical Student Survey

Kendra Besser - Dec 15, 2021, 2:21 PM CST

Title: Protocol for Medical Student Survey

Date: 12/15/2021

Content by: Alex and Charlie

Present: Everyone

Goals: create a survey to give to medical students to evaluate the ease of use and intuitiveness of our design.

Content:

The plan would be to have the students fill our the first few questions just by looking at the model, then we would explain the model and how it works, and they would fill out the second half of questions.

The survey is linked below.

https://docs.google.com/forms/d/1ICSQg12EW9IKuKWxBAnaA5ZNBT0VxaA9D1PtI7He5d0/edit?usp=sharing

Conclusions/action items:

we did not have a chance to carry out this testing but it is something that can be done as our project is carried on into next semester. The goal would be to show it to a few medical students then eventually increase the population to get more and more feedback.

2021/10/29 - Old Prototype Under Doc Cam

Kendra Besser - Nov 04, 2021, 4:25 PM CDT

Title: Old Prototype Under Doc Cam

Date: 10/29/2021

Content by: Kendra and Charlie

Present: Kendra and Charlie

Goals: Charlie and Kendra went to HSLC to test the old prototype under the doc camera to address what specifically need to change and what works. We did this before fabricating our new prototype so that we wouldn't repeat any mistakes from last year and improve fabrication efficiency.

Content:

Testing last semester's prototype under doc camera results:

- The maximum dimensions our prototype should be is 9x9in
- Prototype has to be connected to personal laptop
- Black 3D printing would be better than gray
- Display needs to be much bigger! No red colored words or any dark color (green and white are okay)
- Green LEDs for alveolus don't display well on big screen
- Scratches on 3D printed plastic are very apparent
- We should simplify alveolus
- Label parts of the display (which sliders are for wha

Conclusions/action items: There were numerous design aspects that Kendra and Charlie found did not work on last year's prototype. They suggested solution to numerous problems. Our next steps as a group is to make these design changes and fabricate a prototype that we can test again.

2021/11/5 - Show and tell feedback

Kendra Besser - Dec 15, 2021, 2:13 PM CST

Title: show and tell feedback

Date: 11/5/2021

Content by: Kendra, Milica

Present: Everyone

Goals: record some of the feedback and suggestions we got during the show and tell to help guide us in our fabrication plans.

Content:

During the show and tell we presented the original prototype and the changes we plan to make.

- Larger display
- Labels done with laser cutting or engraving
- Explanation of the colors
- Purple lights for the capillary
  - Brighter when capillary is more open
  - Dimmer when capillary is less open
- Arrow direction or 0, 50, 100 ticks for the knobs
- Is this in the lungs?
- Color of the alveolus?
  - Maybe just white light to show ventilation
  - Or is it too many lights
- O_2/CO_2 in same channel?

Conclusions/action items:

After the show and tell we got many outside perspective ideas on how to better represent an alveolus and capillary during ventilation and perfusion mismatching. We will take into consideration some of the suggestions as we work through the fabrication plans.

2021/12/9 - Final Qualitative Testing Results

Kendra Besser - Dec 15, 2021, 1:44 PM CST

Title: final qualitative test results

Date: 12/9/2021

Content by: Alex and Charlie

Present: Alex, Charlie, Kendra

initialGoals: Record the results of the final qualitative test with the model presented in the poster presentation and compare the initial and final qualitative test results.

Content:

Initial Test	Final Test
Model has to be connected to personal laptop through USB to obtain power	Model has to be connected to personal laptop through USB to obtain power
Grey PLA produces a shine that distracts the viewers eyes from the LED lights, Black PLA would increase visibility of the LEDs	Black PLA contrasted well with the LEDs and made the front face of the model easier to see on the projected screen
Electronic display needs to be roughly 4 times larger than the previous model because display was very hard to read on the projected screen	Display screen was large enough to produce clear and easy to read values
Red and dark colored text was difficult to view on a black display screen	The text on the display was very visible and easy to read against the contrasting background
Green LEDs do not display well under the document camera and make the alveoli difficult to understand	LED lights and LED flex strip are easy to see on the projection
Scratches on the PLA baseboard are very apparent under the document camera	Baseboard has a clean finish and is not distracting to the viewer
Previous model alveolus is too complex and difficult to understand	Labels made the alveolus and capillary representation intuitive and easy to understand
Overall prototype dimensions (17.24cm x 17.24cm) are too small to have model well spaced out	Overall prototype dimensions (22.86cm x 21.59cm) fit well on the projection screen
The V and Q buttons only had values 1-5	The V and Q knobs ranged from values 0.00-100.00

Conclusions/action items:

The initial and final qualitative tests varied significantly. Other than the source of power, every other description was different or completely opposite. The final model was significantly improved from the first and had many more positive results.

2021/12/9 - Quantitative Repeatability Test Results

Kendra Besser - Dec 15, 2021, 1:48 PM CST

Title: Repeatability test results

Date: 12/9/2021

Content by: Milica

Present: Alex, Charlie, Kendra, Darshigaa, Milica

Goals: Record the results of the repeatability test with the model presented in the poster presentation.

Content:

V Value (L/min)	Q Value (L/min)	V/Q Ratio Displayed	P_aO_2 Displayed (mmHg)	V/Q Ratio Calculated	P_aO_2 Calculated (mmHg)
90.00	100.00	0.90	101.84	0.9000	101.8412
6.00	37.00	0.16	50.42	0.1622	50.4199
29.00	56.00	0.52	82.14	0.5179	82.1384
59.00	100.00	0.59	86.86	0.5900	86.8567
6.00	74.00	0.08	43.33	0.0811	43.3342

Conclusions/action items:

The repeatability test concluded accurate coding calculations of the partial pressure of oxygen and V/Q ratios. It also confirmed durability of electrical components and their connections by repeating the test multiple times.

2021/09/23 - Progress Report 2

MILICA LUKIC - Oct 20, 2021, 2:02 AM CDT

Title: Progress Report 2

Content:

Teaching Model for Ventilation and Perfusion Mismatching (Hypoxemia Model)

Client: Dr. Chris Green
Advisor: Professor Chris Brace
Team: Kendra Besser kbesser@wisc.edu (Leader)
Milica Lukic mlukic@wisc.edu (Communicator)
Alex Houle arhoule@wisc.edu (BWIG)
Darshigaa Gurumoorthy dgurumoorthy@wisc.edu (BSAC)
Charlie Zhu xzhu333@wisc.edu (BPAG)
Date: September 17 to September 23, 2021

Problem Statement

Ventilation/ perfusion mismatching is the most predominant cause of hypoxemia; however, medical students often have a very difficult time understanding this concept. Other than a textbook diagram by John West in his text Respiratory Physiology there are no relevant representations of ventilation/ perfusion mismatching causing hypoxemia. Our goal is to continue work done by previous UW Madison students to create an accurate model of the lungs and blood flow where ventilation/ perfusion mismatching may occur with the intent to be studied by medical students for a deeper understanding of hypoxemia.

Brief Status Update

This week we had our first client meeting on zoom to introduce ourselves and learn about what our client expects from us. We had a slight scheduling conflict and only four members of our team were able to attend. Additionally, we had our first in person meeting with our advisor to ask course questions and get a better understanding of what we will be accomplishing this semester.

Summary of Weekly Team Member Design Accomplishments

- Team:
  - o All team members continued to research information on our project.
  - o Kendra, Milica, Alex, and Charlie met with client, Dr. Green online.
- Kendra Besser
  - o Completed research on hypoxemia, perfusion/ventilation ratios, and the physics behind pressure in the lungs and bloodstream.
  - o Completed readings and research on previous semesters' final reports and prototypes, except for physically seeing and handling the prototype.
  - o Recorded notes during and asked a few questions regarding materials for the prototype and whether the LEDs worked well to represent the ventilation/perfusion ratios.
- Milica Lukic
  - o Via email, connected with Dr. Green to set up our first meeting.
  - o Sent a when2meet.com link to the group so we could overlap and organize our schedules and find a time that works best for us to meet with each other, with our client, and with our advisor.
  - o Meet with Dr. Green after our meeting to obtain the previous semesters' physical work and prototype.
  - o Asked Dr. Green about a project budget and is currently setting up an organization of financial details for the team to view.
- Alex Houle
  - o Recorded all notes during the meeting with Dr. Green. Notes included future scheduled meeting times, project details, what has been done on this project before, expected design improvements for us to make, next steps, and questions and answers asked at the end.
- Darshigaa Gurumoorthy

  - o Caught up with meeting notes from the client meeting.
  - o Continued research on previous semesters' work and ventilation/perfusion mismatching.
- · Charlie Zhu
  - o Researched background information on the project and concepts to understand the designs and improvements that can be made. Specifically, he researched related previous projects, problem statement, materials, previous PDS, and previous client requirements.
  - o Completed research on P/V ratio
  - o Completed research on previous semester's final report
  - O Start working on Product Design Specification document

Weekly/Ongoing Difficulties

The only notable challenge this week was a slight scheduling conflict. When we meet with Dr. Green, Darshigaa could not attend because the meeting was set up with little advance. We recorded our notes and shared them with her so this problem should have no impact on our future work.

Upcoming Team and Individual Goals

- · Team:
  - o All team members will continue to research information on our project.
    - § Research other models or products of similar manner that may be out on the market or in a classroom setting
    - § Research design specifications such as best materials for use and coding techniques for the LED light display to improve the previous prototype
  - o Work on together and complete the PDS by 9/24.
  - o Begin brainstorming design improvements from the last semester's prototype or brainstorming new designs and compare effectiveness, skill, and cost to the previous design. Preferably this will be done in collaboration during one of our team meetings.
  - o Update lab archives notebooks with everything we have completed so far.
  - o Handle, use, and critique the previous prototype.

Project Timeline

Project Goal	Deadline	Team Assigned	Progress	Completed
Completed research on previous semester's work	9/24	All	100%	9/24
Completed research on hypoxemia	9/24	All	100%	9/24
Finalize design improvements	9/30	All		
Preliminary Presentations	10/08	All		
Preliminary Deliverables	10/13	All		
Show and Tell	11/05	All		
Poster Presentations	12/10	All		
Final Deliverables	12/15	All		

Arrows indicated dependencies

Expenses

Item	Description	Manufacturer	Part Number	Date	QTY	Cost Each	Total	Link
Component 1								
Component 2								
Component 3								
TOTAL:								**$0.00**

2021/09/30 - Progress Report 3

MILICA LUKIC - Oct 20, 2021, 2:03 AM CDT

Title: Progress Report 3

Content:

Teaching Model for Ventilation and Perfusion Mismatching (Hypoxemia Model)

Client: Dr. Chris Green
Advisor: Professor Chris Brace
Team: Kendra Besser kbesser@wisc.edu (Leader)
Milica Lukic mlukic@wisc.edu (Communicator)
Alex Houle arhoule@wisc.edu (BWIG)
Darshigaa Gurumoorthy dgurumoorthy@wisc.edu (BSAC)
Charlie Zhu xzhu333@wisc.edu (BPAG)
Date: September 24 to September 30, 2021

Problem Statement

Ventilation/ perfusion mismatching is the most predominant cause of hypoxemia; however, medical students often have a very difficult time understanding this concept. Other than a textbook diagram by John West in his text Respiratory Physiology there are no relevant representations of ventilation/ perfusion mismatching causing hypoxemia. Our goal is to continue work done by previous UW Madison students to create an accurate model of the lungs and blood flow where ventilation/ perfusion mismatching may occur with the intent to be studied by medical students for a deeper understanding of hypoxemia.

Brief Status Update

This week we meet with our client again to touch base on our progress and ask questions. Only a few members were able to make the meeting, but the other members read meeting notes to stay informed. Lastly, we completed and shared our first draft of the project design statement.

Summary of Weekly Team Member Design Accomplishments

· Team:

o All team members continued to research project designs and specifications.

o Milica, Alex, and Charlie attended a meeting with a client, Dr. Green.

o All team members worked in collaboration to complete and review the Project Design Specification draft.

o Met with the advisor to update him on our progress, ask questions about the Project design specifications, and talk about how to best prepare and what to expect of the preliminary oral presentation.

· Kendra Besser

o Read over meeting notes for the team meeting with the client and ask clarification questions to the group to stay up to date.

o Updated Client meeting notes on lab archives.

o Brainstormed design improvements and researched possibilities to create the outcome.

· Milica Lukic

o Via email, connected with Dr. Green to set up the second meeting.

o Maintained communication with Dr. Green to obtain resources from him and ask any midweek questions. Milica will compile and share this information with the rest of the team soon.

o Attended the meeting with Dr. Green to ask questions and stay informed of his expectations for our project.

· Alex Houle

o Recorded all notes during the meeting with Dr. Green. Notes included meeting layout, budget details, explanation to last year's project, how to work with Tammy Greko for software implantation, and expected next steps.

o Started creating design matrix criteria, and continued to read through last year's final report to brainstorm improvements

· Darshigaa Gurumoorthy

- o Read over meeting notes for the team meeting with the client and ask clarification questions to the group to stay up to date.

· Charlie Zhu
- o Attended the meeting with Dr. Green to ask questions and stay informed of his expectations for our project.
- o Doing research regarding Hemoglobin dissociation curve
- o Attend BPAG meeting on Friday

Weekly/Ongoing Difficulties

Only Charlie, Alex, and Milica were able to attend the meeting with Dr. Green; however, Alex recorded notes and Kendra and Darshigaa read over them and asked questions to stay informed.

Upcoming Team and Individual Goals

· Team:
- o Prepare and practice for our preliminary presentation in two weeks. Complete all work that needs to be done and reported on during the presentation. Practice what we will and who will present what.
- o Continue brainstorming design improvements from the last semester's prototype or brainstorming new designs and compare effectiveness, skill, and cost to the previous design. Preferably this will be done in collaboration during one of our team meetings.
- o Update lab archives notebooks with everything we have completed so far.
- o Handle, use, and critique the previous prototype.

Project Timeline

Project Goal	Deadline	Team Assigned	Progress	Completed
Completed research on previous semester's work	9/24	All	100%	9/24
Completed research on hypoxemia	9/24	All	100%	9/24
Finalize design improvements	9/31	All	50%	
Preliminary Presentations	10/15	All		
Preliminary Deliverables	10/20	All		
Show and Tell	11/05	All		
Poster Presentations	12/10	All		
Final Deliverables	12/15	All		

Arrows indicated dependencies

Expenses

Item	Description	Manufacturer	Part Number	Date	QTY	Cost Each	Total	Link
Component 1								
Component 2								
Component 3								
TOTAL:								**$0.00**

budget: $1000

2021/10/07 - Progress Report 4

MILICA LUKIC - Oct 20, 2021, 2:04 AM CDT

Title: Progress Report 4

Content:

Teaching Model for Ventilation and Perfusion Mismatching (Hypoxemia Model)

Client: Dr. Chris Green
Advisor: Professor Chris Brace
Team: Kendra Besser kbesser@wisc.edu (Leader)
Milica Lukic mlukic@wisc.edu (Communicator)
Alex Houle arhoule@wisc.edu (BWIG)
Darshigaa Gurumoorthy dgurumoorthy@wisc.edu (BSAC)
Charlie Zhu xzhu333@wisc.edu (BPAG)
Date: October 1 to October 7, 2021

Problem Statement

Ventilation/ perfusion mismatching is the most predominant cause of hypoxemia; however, medical students often have a very difficult time understanding this concept. Other than a textbook diagram by John West in his text Respiratory Physiology there are no relevant representations of ventilation/ perfusion mismatching causing hypoxemia. Our goal is to continue work done by previous UW Madison students to create an accurate model of the lungs and blood flow where ventilation/ perfusion mismatching may occur with the intent to be studied by medical students for a deeper understanding of hypoxemia.

Brief Status Update

This week we decided to skip the meeting with Dr. Green so that we could focus on finalizing the content necessary in the preliminary design presentation next week and working on our design ideas. We met with Professor Brace last Friday online to inform him of our progress and ask questions about the preliminary design presentation. We completed and communicated our design matrix with explanations.

Summary of Weekly Team Member Design Accomplishments

· Team:
  o All team members continued to research project designs and specifications.
  o All team members attended the meeting with professor brace to inform him of our progress and ask questions about the preliminary design presentation.
  o All team members collaborated before the advisor meeting to brainstorm 3 final designs for our presentation
    - We began by listing all creative designs then narrowed our list down one by one by keeping in mind the customer’s needs, cost, time, and design specifications.
    - Eventually we narrowed it down to the three different designs that we compared in a design matrix.
  o All team members collaborated or looked over the design matrix to accurately compare our three final designs.
    - After comparison, we choose the final design that we will create by looking for the design with the best ratings.
    - Kendra, Alex, and Charlie completed the quantitative section of the design matrix.

· Kendra Besser
  o Brainstormed and communicated all design ideas during the group collaboration to find 3 final designs.
  o Created original list of criteria to be judged and weighed in the design matrix
  o Created an explanation of the water/dye concentration model at the bottom of the design matrix for some more contents for the advisor and client.
  o Worked with Alex and Charlie to complete the quantitate work in the design matrix table.

· Milica Lukic
  o Brainstormed and communicated all design ideas during the group collaboration to find 3 final designs.

- o Compiled all information shared with her by Dr. Green and sent to the rest of the team.
- o Finalized and distributed the design matrix to the client and advisor.
- o Wrote the descriptions of the remaining models at the bottom of the design matrix to give the client and advisor a clearer understanding of the designs we are comparing.

· Alex Houle
- o Brainstormed and communicated all design ideas during the group collaboration to find 3 final designs.
- o Worked with Kendra and Charlie to complete the quantitate work in the design matrix table.
- o Suggested changes to the criteria that will be judged and weighted to make the design matrix more intuitive and less broad.

· Darshigaa Gurumoorthy
- o Brainstormed and communicated all design ideas during the group collaboration to find 3 final designs.
- o Looked over the design matrix to agree or comment about anything of concern.

· Charlie Zhu
- o Worked with Alex and Kendra to complete the quantitate work in the design matrix table.
- o Completed all descriptions of chosen criteria so that the advisor and client could have a very clear expectation of what we will judge our designs off of and how we will test our design in a specific and measurable way.

Weekly/Ongoing Difficulties

As a team we had no significant weekly difficulties.

Upcoming Team and Individual Goals

· Team:
- o Prepare and practice for our preliminary presentation in one week. Complete all work that needs to be done and reported on during the presentation. Practice what we will and who will present what.
- o Update lab archives notebooks with everything we have completed so far.
- o Handle, use, and critique the previous prototype.
- o Update design matrix or any other design specification document as we see fit.

Project Timeline

Project Goal	Deadline	Team Assigned	Progress	Completed
Completed research on previous semester's work	9/24	All	100%	9/24
Completed research on hypoxemia	9/24	All	100%	9/24
Finalize design improvements	9/31	All	100%	9/24
Preliminary Presentations	10/15	All	10%	
Preliminary Deliverables	10/20	All		
Show and Tell	11/05	All		
Poster Presentations	12/10	All		
Final Deliverables	12/15	All		

Arrows indicated dependencies

Expenses

Item	Description	Manufacturer	Part Number	Date	QTY	Cost Each	Total	Link
Component 1								
Component 2								
Component 3								
TOTAL:								**$0.00**

2021/10/14 - Progress Report 5

MILICA LUKIC - Oct 20, 2021, 2:05 AM CDT

Title: Progress Report 5

Content:

Teaching Model for Ventilation and Perfusion Mismatching (Hypoxemia Model)

Client: Dr. Chris Green
Advisor: Professor Chris Brace
Team: Kendra Besser kbesser@wisc.edu (Leader)
Milica Lukic mlukic@wisc.edu (Communicator)
Alex Houle arhoule@wisc.edu (BWIG)
Darshigaa Gurumoorthy dgurumoorthy@wisc.edu (BSAC)
Charlie Zhu xzhu333@wisc.edu (BPAG)
Date: October 8 to October 14, 2021

Problem Statement

Ventilation/ perfusion mismatching is the most predominant cause of hypoxemia; however, medical students often have a very difficult time understanding this concept. Other than a textbook diagram by John West in his text Respiratory Physiology there are no relevant representations of ventilation/ perfusion mismatching causing hypoxemia. Our goal is to continue work done by previous UW Madison students to create an accurate model of the lungs and blood flow where ventilation/ perfusion mismatching may occur with the intent to be studied by medical students for a deeper understanding of hypoxemia.

Brief Status Update

Due to midterm exams, the team could not find a time to meet with Dr. Green. We will all attend a meeting next week instead to fill Dr. Green in on our design ideas, fabrication plans, and how the presentation went. We met with Professor Brace last Friday to go over questions on the preliminary design presentation. The rest of the week was spent preparing for the presentation.

Summary of Weekly Team Member Design Accomplishments

- Team:
  - All team members attended the meeting with professor brace to inform him of our progress and ask questions about the preliminary design presentation.
  - All team members worked on the preliminary design presentation slideshow outline.
    - Created slides and topic headers appropriately for our project.
    - Created a speech for their section to hit the most important topics.
    - Agreed on who will present on each topic on Friday and complete each section of the slides.
    - Everyone read over the rubric and presentation guidelines to feel most prepared for this presentation and in an attempt to achieve the highest score we can.
- Kendra Besser
  - Continued working on the design matrix section of the preliminary design presentation.
  - Inserted design matrix into the slideshow.
  - Created a speech discussing the criteria we used, why we used those criteria, how we weighed the criteria, the scores each design got, and how we will effectively test each criterion in our testing phase.
- Milica Lukic
  - Continued working on the PDS summary section of the preliminary design presentation.
  - Kept in contact with Dr. Green to cancel and reschedule this week's meeting to next week.
  - Inserted bullet points of the PDS into the slideshow for the presentation.

    - Created a speech to capture the most important aspects of our design and what design specifications we are focusing on the most.
- Alex Houle
    - Continued working on the problem statement and background information sections of the preliminary design presentation.
    - Inserted main points of our problem statement and a diagram of the lungs and circulation to them to help explain VQ ratios.
    - Created a speech to educate the audience on VQ ratios and why the topic is difficult for med students to understand.
- Darshigaa Gurumoorthy
    - Continued working on the overview and future work section of the preliminary design presentation.
    - Created a speech to introduce the team, the client, and the clients background along with a project description and future work that includes testing plans, fabrication plans, and something the prompt the audience with to get them engaged.
- Charlie Zhu
    - Continued working on the design alternatives section of the preliminary design presentation.
    - Insert bullet point and picture into the slideshow
    - Created a speech to fully describe the design alternatives. He will describe all three designs in detail so that the audience can understand what designs we are comparing in our design matrix.

Weekly/Ongoing Difficulties

Due to midterms this week, no team members were able to meet with Dr. Green, so we have rescheduled our meeting to next week.

Upcoming Team and Individual Goals

- Team:
    - Meet later Thursday (10/14) to run through the presentation and make sure we have smooth transitions.
    - Prepare and practice for our preliminary presentation on Friday. Create any presenting notecards or pointers to help the presentation go smoothly.
    - Update LabArchives to reflect everything we have completed so far.
    - Handle, use, and critique the previous prototype.
    - Work on and complete preliminary deliverables by 10/20.

Project Timeline

Project Goal	Deadline	Team Assigned	Progress	Completed
Completed research on previous semester's work	9/24	All	100%	9/24
Completed research on hypoxemia	9/24	All	100%	9/24
Finalize design improvements	9/31	All	100%	9/24
Preliminary Presentations	10/15	All	100%	10/13
Preliminary Deliverables	10/20	All		
Show and Tell	11/05	All		

Poster Presentations	12/10	All		
Final Deliverables	12/15	All		

Arrows indicated dependencies

Expenses

Item	Description	Manufacturer	Part Number	Date	QTY	Cost Each	Total	Link
Component 1								
Component 2								
Component 3								
TOTAL:								**$0.00**

2021/10/21 - Progress Report 6

MILICA LUKIC - Dec 15, 2021, 2:20 PM CST

Title: Progress Report 6

Content:

Teaching Model for Ventilation and Perfusion Mismatching (Hypoxemia Model)

Client: Dr. Chris Green

Advisor: Professor Chris Brace

Team: Kendra Besser kbesser@wisc.edu (Leader)

Milica Lukic mlukic@wisc.edu (Communicator)

Alex Houle arhoule@wisc.edu (BWIG)

Darshigaa Gurumoorthy dgurumoorthy@wisc.edu (BSAC)

Charlie Zhu xzhu333@wisc.edu (BPAG)

Date: October 15 to October 21, 2021

Problem Statement

Ventilation/ perfusion mismatching is the most predominant cause of hypoxemia; however, medical students often have a very difficult time understanding this concept. Other than a textbook diagram by John West in his text Respiratory Physiology there are no relevant representations of ventilation/ perfusion mismatching causing hypoxemia. Our goal is to continue work done by previous UW Madison students to create an accurate model of the lungs and blood flow where ventilation/ perfusion mismatching may occur with the intent to be studied by medical students for a deeper understanding of hypoxemia.

Brief Status Update

This week was a major turning point for the semester. Our team presented our preliminary presentation to our advisor and other BME 200/300 classmates on Friday. On Wednesday, we finalized and submitted our preliminary deliverables, such as the report, notebook, and evaluations.

Summary of Weekly Team Member Design Accomplishments

- Team:
  - o All team members worked on and completed the preliminary design presentation slideshow.
  - o All team members participated in the presentation and practiced their sections beforehand.
- All team members met up before the presentation to do a full practice of our speeches and give feedback to one another.
  - o All team members worked on the preliminary report.
- We divided and conquered different sections of the report; everyone worked on something.
- We cited and referenced our own sources.
- We all reviewed all sections, added more information, or made suggestions for the creator to change.
- We submitted the report on time and shared it with the client.

- All team members updated the lab archives notebook.

- Each person filled in their own research and many team members helped fill in the group work such as meeting notes.
- All our notes and research were shared in a shared google drive so the work mostly consisted of transferring our work.

· Kendra Besser

- Presented the design matrix section of the preliminary design presentation.

· Milica Lukic

- Presented the PDS summary section of the preliminary design presentation.
- Sent our preliminary report to Dr. Green and professor Brace.

· Alex Houle

- Presented the problem statement and background information sections of the preliminary design presentation.
- Uploaded the preliminary report to our team website.
- Submitted the preliminary report and lab archives notebook to canvas.

· Darshigaa Gurumoorthy

- Presented the overview and future work section of the preliminary design presentation.

· Charlie Zhu

- Presented the design alternatives section of the preliminary design presentation.

Weekly/Ongoing Difficulties

N/A

Upcoming Team and Individual Goals

· Team:

- Reflect on our submitted peer evaluations and make suggestions to the group to help us work more effectively and better together.
- Begin fabrication of our design to make a functioning prototype.

- Use CAD to create a drawing of our electrical housing.
- 3D print this housing at the UW-Madison Makerspace.
- Use Arduino Uno to program the LEDs as well as calculations that must be done for the desired outputs.
- Assemble and connect all different aspects of the device, such as sliders, electrical components, and 3D printed housing.

- After building, we will finalize our testing plan and begin testing.

Project Timeline

Project Goal	Deadline	Team Assigned	Progress	Completed
Completed research on previous semester’s work	9/24	All	100%	9/24
Completed research on hypoxemia	9/24	All	100%	9/24

Finalize design improvements	9/31	All	100%	9/24
Preliminary Presentations	10/15	All	100%	10/13
Preliminary Deliverables	10/20	All	100%	10/19
Build first prototype	10/30			
Test first prototype				
Revise prototype (draft 2)				
Test prototype 2				
Show and Tell	11/05	All		
Poster Presentations	12/10	All		
Final Deliverables	12/15	All		

Arrows indicated dependencies

Expenses

[redacted]

Component 1	
Component 2	
Component 3	
TOTAL:	**$0.00**

Max Budget: $1000

2021/10/28 - Progress Report 7

MILICA LUKIC - Dec 15, 2021, 2:31 PM CST

Title: Progress Report 7

Content:

Teaching Model for Ventilation and Perfusion Mismatching (Hypoxemia Model)

Client: Dr. Chris Green

Advisor: Professor Chris Brace

Team: Kendra Besser kbesser@wisc.edu (Leader)

Milica Lukic mlukic@wisc.edu (Communicator)

Alex Houle arhoule@wisc.edu (BWIG)

Darshigaa Gurumoorthy dgurumoorthy@wisc.edu (BSAC)

Charlie Zhu xzhu333@wisc.edu (BPAG)

Date: October 22 to October 28, 2021

Problem Statement

Ventilation/ perfusion mismatching is the most predominant cause of hypoxemia; however, medical students often have a very difficult time understanding this concept. Other than a textbook diagram by John West in his text Respiratory Physiology there are no relevant representations of ventilation/ perfusion mismatching causing hypoxemia. Our goal is to continue work done by previous UW Madison students to create an accurate model of the lungs and blood flow where ventilation/ perfusion mismatching may occur with the intent to be studied by medical students for a deeper understanding of hypoxemia.

Brief Status Update

This week was a planning week; we laid out everything we have left to accomplish this semester and organized a strategy to get it done. There were no significant difficulties this week, but we predict many in the next couple weeks as we begin fabrication and simultaneously testing our new prototype. We are prepared for setbacks in the plan and have flexible solutions to get everything done. Additionally, this week we had two successful meetings with our client and advisor to update them on what we have accomplished, answer their questions, and notify them of our plans.

Summary of Weekly Team Member Design Accomplishments

· Team:

o All team members attended a meeting with Dr. Green.

- Received advice about specific material to use.
- Answered questions from Dr. Green.
- Asked about design details such as shape, display, and alveolus location.
- Received advice for future testing plans.

o All team members attended a meeting with Professor Brace.

- Received feedback from preliminary design presentation.

- Discussed future testing plans.
- Received advice about specific design detail questions to ask Dr. Green.
  - Kendra Besser
    - Created a fabrication plan for all team members to self-assign work.
    - Self-assigned solidworks and breadboard tasks for fabrication of prototype 1 plans.
    - Will test old prototype at HSLC on 10/29 under doc camera.
    - Contacted HSLC for room availability for 10/29 (the new testing date).
    - Recorded advisor and client meeting notes on 10/22.
  - Milica Lukic
    - Communicated with Dr. Green to obtain HSLC number.
    - Contacted HSLC for room availability for 10/27 (the original testing date).
    - Recorded advisor and client meeting notes on 10/22.
    - Assigned coding task for fabrication of prototype 1 plans.
  - Alex Houle
    - Recorded client meeting notes on 10/22.
    - Assigned coding task for fabrication of prototype 1 plans.
  - Darshigaa Gurumoorthy
    - Assigned testing prototype 1 under a HSLC doc camera.
  - Charlie Zhu
    - Will test old prototype at HSLC on 10/29 under doc camera.
    - Assigned bread board task for fabrication of prototype 1 plans.

Weekly/Ongoing Difficulties

NA

Upcoming Team and Individual Goals

  - Team:
    - Update lab archives notebook.
- Individually fill out our own folders with new information.
- Together update group folders.
    - Prepare for show and tell.
    - Follow and complete fabrication and testing plans. (Specifics below)
- Everyone:
      - Assemble the whole prototype.
      - Test functionality of the new prototype by using it individually.
      - Compare the new prototype to the old prototype.
- Continue testing after show and tell and revise the prototype as needed.

- Kendra Besser
  - Create a well dimensioned solidworks sketch for the new prototype baseboard.
  - Send sketches to makerspace to be printed and pick up prints.
  - Help assemble electrical work to create a functioning bread board.
- Milica Lukic
  - Create a code to run a program for the new prototype.
  - Use online and university resources as needed.
- Alex Houle
  - Help create a code to run a program for the new prototype.
  - Use online and university resources as needed.
- Darshigaa Gurumoorthy
  - Test new prototype under doc camera at HSLC.
  - Record testing plans and outcomes.
- Charlie Zhu
  - Assemble electrical work to create a functioning bread board in the new prototype.
  - Order new components such as V/Q sliders and use components from previous prototype/ extras from last semester/ components that team members already have.

Project Timeline

Project Goal	Deadline	Team Assigned	Progress	Completed
Completed research on previous semester's work	9/24	All	100%	9/24
Completed research on hypoxemia	9/24	All	100%	9/24
Finalize design improvements	9/31	All	100%	9/24
Preliminary Presentations	10/15	All	100%	10/13
Preliminary Deliverables	10/20	All	100%	10/19
Test last semesters prototype	10/29	Kendra and Charlie	10%	
1st prototype baseboard printed	11/1	Kendra		
1st prototype code program	11/2	Milica and Alex		
1st prototype breadboard	11/3	Kendra and Charlie		

1st prototype full assembly	11/3	Everyone
1st prototype testing	11/4	Darshigaa
Show and Tell	11/05	All
Poster Presentations	12/10	All
Final Deliverables	12/15	All

Arrows indicated dependencies

Expenses

[redacted]

Component 1			
3D printed Baseboard	Maker's space	1	
Component 2			
Sliding electrical components		2	
Component 3			
TOTAL:			**$0.00**

2021/11/04 - Progress Report 8

MILICA LUKIC - Dec 15, 2021, 2:32 PM CST

Title: Progress Report 8

Content:

Teaching Model for Ventilation and Perfusion Mismatching (Hypoxemia Model)

Client: Dr. Chris Green

Advisor: Professor Chris Brace

Team: Kendra Besser kbesser@wisc.edu (Leader)

Milica Lukic mlukic@wisc.edu (Communicator)

Alex Houle arhoule@wisc.edu (BWIG)

Darshigaa Gurumoorthy dgurumoorthy@wisc.edu (BSAC)

Charlie Zhu xzhu333@wisc.edu (BPAG)

Date: October 29 to November 4, 2021

Problem Statement

Ventilation/ perfusion mismatching is the most predominant cause of hypoxemia; however, medical students often have a very difficult time understanding this concept. Other than a textbook diagram by John West in his text Respiratory Physiology there are no relevant representations of ventilation/ perfusion mismatching causing hypoxemia. Our goal is to continue work done by previous UW Madison students to create an accurate model of the lungs and blood flow where ventilation/ perfusion mismatching may occur with the intent to be studied by medical students for a deeper understanding of hypoxemia.

Brief Status Update

The team spent this week preparing for the show and tell on November 5th. We continued with our fabrication plans that we assigned last week; however, we were unable to finish fabricating a fully functional prototype by show and tell so we plan to use last semester's prototype along with a poster of all the changes we plan to make soon.

Summary of Weekly Team Member Design Accomplishments

· Team:

o All team members prepared for “show and tell” (11/5).

o Will meet up later 11/4 to discuss changes in fabrication plans and preparations for “show and tell”.

· Kendra Besser

o Tested old prototype at HSLC on 10/29 under doc camera and recorded findings.

o Meet with Charlie to hand off the prototype and discuss changes in our fabrication plans.

o Researched last semester's materials and created a list of what parts to keep and what to buy. Listed a few options for purchasing the new parts. Recorded findings in Lab Archives.

o Created a sketch of the PLA 3D printed base board that will be printed once dimensions are finalized (depends on parts ordered).

    - o Began brainstorming electrical parts and how to connect the breadboard.

- · Milica Lukic
    - o Began brainstorming code to create a functioning device
    - o Drew up different design ideas for the 3D printed housing and placement of LEDs
- · Alex Houle
    - o Created a shared document with the group to brainstorm key details to keep in mind during fabrication and for the rest of the semester. Notes included:

- Testing plans
- Material questions
- Code analysis questions
- Reminder to keep in mind an overall goal of 2 alveoli

    - o Began brainstorming code to create a functioning device.

- · Darshigaa Gurumoorthy
    - o Began brainstorming electrical parts and how to connect the breadboard.
- · Charlie Zhu
    - o Tested old prototype at HSLC on 10/29 under doc camera and recorded findings.
    - o Met with Kendra to receive the prototype and discuss changes in our fabrication plans.
    - o Worked with last year's prototype and coding descriptions in an attempt to create a new code for our new prototype. Ran into coding challenges and organized a team meeting to resolve those challenges (the team will work together to complete the code).

Weekly/Ongoing Difficulties

Unfortunately, the group was not able to successfully fabricate a functional prototype by show and tell (November 5th). However, we plan to use last year's prototype for show and tell and present on how we will change the design in the next few days and how the finished design will compare to the current one.

Upcoming Team and Individual Goals

- · Team:
    - o Update lab archives notebook.

- Individually fill out our own folders with new information.
- Together update group folders.

    - o Present at "show and tell" and reflect on peer feedback that we will receive.
    - o Continue with fabrication plans then test and revise the new prototype.

- Everyone:
    - Assemble the whole prototype.
    - Test functionality of the new prototype by using it individually.
    - Compare the new prototype to the old prototype.
- · Kendra Besser
    - o Send sketches to makerspace to be printed and pick up prints.

  - Help assemble electrical work to create a functioning bread board.
- Milica Lukic
  - Create a code to run a program for the new prototype.
  - Use online and university resources as needed.
- Alex Houle
  - Help create a code to run a program for the new prototype.
  - Use online and university resources as needed.
- Darshigaa Gurumoorthy
  - Test new prototype under doc camera at HSLC.
  - Record testing plans and outcomes.
  - Help assemble electrical work to create a functioning bread board.
- Charlie Zhu
  - Help create a code to run a program for the new prototype.
  - Use online and university resources as needed.

Project Timeline

Project Goal	Deadline	Team Assigned	Progress	Completed
Completed research on previous semester's work	9/24	All	100%	9/24
Completed research on hypoxemia	9/24	All	100%	9/24
Finalize design improvements	9/31	All	100%	9/24
Preliminary Presentations	10/15	All	100%	10/13
Preliminary Deliverables	10/20	All	100%	10/19
Test last semesters prototype	10/29	Kendra and Charlie	100%	10/29
1st prototype baseboard printed	11/1	Kendra	90%	
1st prototype code program	11/2	Milica, Alex, and Charlie	10%	
1st prototype breadboard	11/3	Kendra and Darshigaa		
1st prototype full assembly	11/3	Everyone		
1st prototype testing	11/4	Darshigaa		
Show and Tell	11/05	All		

Poster Presentations	12/10	All
Final Deliverables	12/15	All

Arrows indicated dependencies

Expenses

[redacted]				
Component 1				
	3D printed Baseboard	Maker’s space	1	
Component 2				
	Sliding electrical components		1	
Component 3				
	Display Window		1	
Component 4				
Component 5				
TOTAL:				**$0.00**

Max budget: $1000

2021/11/11 - Progress Report 9

MILICA LUKIC - Dec 15, 2021, 2:33 PM CST

Title: Progress Report 9

Content:

Teaching Model for Ventilation and Perfusion Mismatching (Hypoxemia Model)

Client: Dr. Chris Green

Advisor: Professor Chris Brace

Team: Kendra Besser kbesser@wisc.edu (Leader)

Milica Lukic mlukic@wisc.edu (Communicator)

Alex Houle arhoule@wisc.edu (BWIG)

Darshigaa Gurumoorthy dgurumoorthy@wisc.edu (BSAC)

Charlie Zhu xzhu333@wisc.edu (BPAG)

Date: November 5 to November 11, 2021

Problem Statement

Ventilation/ perfusion mismatching is the most predominant cause of hypoxemia; however, medical students often have a very difficult time understanding this concept. Other than a textbook diagram by John West in his text Respiratory Physiology there are no relevant representations of ventilation/ perfusion mismatching causing hypoxemia. Our goal is to continue work done by previous UW Madison students to create an accurate model of the lungs and blood flow where ventilation/ perfusion mismatching may occur with the intent to be studied by medical students for a deeper understanding of hypoxemia.

Brief Status Update

The team presented and received feedback from the show and tell on 11/5. We redesigned our prototype based on the feedback to better demonstrate V/Q ratios. We waited for parts to arrive this week and continued working on the code and electrical connections to create a functioning prototype.

Summary of Weekly Team Member Design Accomplishments

· Team:

o Meet up later on 11/4 to discuss changes in fabrication plans and preparations for “show and tell”.

o Presented at show and tell and collected feedback from peers.

- Brainstormed design revisions based on the feedback received.
- Recorded verbal feedback given in a shared doc “show and tell feedback”
- Engaged with other groups to understand their projects and give them feedback.

o Brainstormed Code to create a functioning prototype.

· Kendra Besser

o Brainstormed electrical parts and how to connect the breadboard.

  - o Worked with Milica to find all the new electrical components needed to fabricate the new prototype.

· Milica Lukic

  - o Emailed Erin to order Components 2 through 5.
  - o Worked with Kendra to find all the new electrical components needed to fabricate the new prototype.
  - o Sketched new design according to feedback.

· Alex Houle

  - o Worked with Charlie to create a google survey for coinvent feedback during the show and tell; this will also be used as our first testing results.

· Darshigaa Gurumoorthy

  - o Created an elevator pitch draft for everyone to use at the show and tell.

· Charlie Zhu

  - o Worked with Alex to create a google survey for coinvent feedback during the show and tell; this will also be used as our first testing results.

Weekly/Ongoing Difficulties

As a team, we decided to redesign our prototype with channels flowing to and from the alveolus and capillaries; this helps demonstrate oxygenation of the blood separately from ventilation rates and perfusion rates. Our progress has been slowed down while we wait for the components to be shipped.

Upcoming Team and Individual Goals

· Team:

  - o Update lab archives notebook.

- Individually fill out our own folders with new information.
- Together update group folders.
  - o Continue with fabrication plans then test and revise the new prototype.
- Everyone:
  - Assemble the whole prototype.
  - Test functionality of the new prototype by using it individually.
  - Compare the new prototype to the old prototype.
  - o Update final report with progress we have made so far.

· Kendra Besser

  - o Send sketches to makerspace to be printed and pick up prints.
  - o Help assemble electrical work to create a functioning bread board.

· Milica Lukic

  - o Create a code to run a program for a new prototype.
  - o Use online and university resources as needed.

· Alex Houle

  - o Help create a code to run a program for a new prototype.

- Use online and university resources as needed.

- Darshigaa Gurumoorthy
  - Test new prototype under doc camera at HSLC.
  - Record testing plans and outcomes.
  - Help assemble electrical work to create a functioning bread board.
- Charlie Zhu
  - Help create a code to run a program for a new prototype.
  - Use online and university resources as needed.

Project Timeline

Project Goal	Deadline	Team Assigned	Progress	Completed
Completed research on previous semester's work	9/24	All	100%	9/24
Completed research on hypoxemia	9/24	All	100%	9/24
Finalize design improvements	9/31	All	100%	9/24
Preliminary Presentations	10/15	All	100%	10/13
Preliminary Deliverables	10/20	All	100%	10/19
Test last semesters prototype	10/29	Kendra and Charlie	100%	10/29
1st prototype baseboard printed	11/1	Kendra	90%	
1st prototype code program	11/2	Milica, Alex, and Charlie	10%	
1st prototype breadboard	11/3	Kendra and Darshigaa		
1st prototype full assembly	11/3	Everyone		
1st prototype testing	11/4	Darshigaa		
Show and Tell	11/05	All		
Poster Presentations	12/10	All		
Final Deliverables	12/15	All		

Arrows indicated dependencies

Expenses

[redacted]

Component 1- Baseboard								
	3D printed Baseboard	Maker’s space			1			
Component 2- Solid machined metal knob – 1” diameter								
	Potentiometer cap	Adafruit	2056	11/9	2	3.95	7.90	https://www.adafruit.com/product/2056#description
Component 3- RGB blacklight negative LCD 20x4 +extras – RGB on black								
	Display Window	Adafruit	498	11/9	1	20.95	20.95	https://www.adafruit.com/product/498
Component 4- Panel Mount Right Angle 10K Linear Potentiometer w/On-Off Switch - 10K Linear w/ Switch								
	Vertical potentiometer	Adafruit	3395	11/9	2	1.50	3.00	https://www.adafruit.com/product/3395
Component 5- Panel Mount 10K Potentiometer (Breadboard Friendly) - 10K Linear								
	Horizontal potentiometer	Adafruit	652	11/9	2	0.95	1.90	https://www.adafruit.com/product/562
TOTAL:								**$33.75**

Max budget: $1000

2021/11/18 - Progress Report 10

MILICA LUKIC - Dec 15, 2021, 2:34 PM CST

Title: Progress Report 10

Content:

Teaching Model for Ventilation and Perfusion Mismatching (Hypoxemia Model)

Client: Dr. Chris Green

Advisor: Professor Chris Brace

Team: Kendra Besser kbesser@wisc.edu (Leader)

Milica Lukic mlukic@wisc.edu (Communicator)

Alex Houle arhoule@wisc.edu (BWIG)

Darshigaa Gurumoorthy dgurumoorthy@wisc.edu (BSAC)

Charlie Zhu xzhu333@wisc.edu (BPAG)

Date: November 12 to November 18, 2021

Problem Statement

Ventilation/ perfusion mismatching is the most predominant cause of hypoxemia; however, medical students often have a very difficult time understanding this concept. Other than a textbook diagram by John West in his text Respiratory Physiology there are no relevant representations of ventilation/ perfusion mismatching causing hypoxemia. Our goal is to continue work done by previous UW Madison students to create an accurate model of the lungs and blood flow where ventilation/ perfusion mismatching may occur with the intent to be studied by medical students for a deeper understanding of hypoxemia.

Brief Status Update

This week the group attended a client meeting and advisor meeting to inform them of our progress and ask questions about our new design. Our fabrication process has been slowed down due to redesigning our prototype multiple times, but we are working hard to stay on track.

Summary of Weekly Team Member Design Accomplishments

· Team:

o Attended client meeting (11/12)

- Recorded notes
- Asked a few designs questions including dial settings and displayed values
- Discussed the new design and received feedback
- Brainstormed design changes to account for Dr. Greens feedback

o Attended advisor meeting (11/15)

- Recorded notes

- Asked questions about the preliminary report grading comments and specified how we can improve the report for the final submission
- received advice and additional feedback for the report
    - o meet as a group (11/12) to schedule meetings and discuss new design criteria

· Kendra Besser

o Created a sketch for a new design of the teaching model after the client meeting

o Recorded notes during both meetings

o Communicated with professor Brace to schedule regular advisor meetings for the next few weeks

· Milica Lukic

o Created multiple sketches for a new design of the teaching model after the client meeting

o Continued communication with Dr. Green to send our new designs and schedule meetings

o Recorded notes during both meetings

· Alex Houle

o Brainstormed coding language to program the new teaching model

o Recorded notes during both meetings

· Darshigaa Gurumoorthy

o Followed along during the meetings

· Charlie Zhu

o Recorded notes during client meeting, due to scheduling conflict couldn't attend advisor meeting

o Received new components and inspected them to begin things about the electrical work that will go into the new design

o Read advisor meeting notes to stay up to date with the rest of the group

Weekly/Ongoing Difficulties

Last week we redesigned our prototype based on the comments we received during the show and tell. This week we presented our new design to Dr. Green and received some critical feedback from him. Thus, we redesigned our prototype again. All the redesigns have slowed our fabrication plans down; however, we are working efficiently to catch back up to our original schedule.

Upcoming Team and Individual Goals

· Team:

o Update lab archives notebook.

- Individually fill out our own folders with new information.
- Together update group folders.
    - o Continue with fabrication plans then test and revise the new prototype.
- Everyone:

· Assemble the whole prototype.

· Test functionality of the new prototype by using it individually.

· Compare the new prototype to the old prototype.

- Update final report with progress we have made so far and comments on the rule brick.

- Kendra Besser
  - Send sketches to makerspace to be printed and pick up prints.
  - Help assemble electrical work to create a functioning bread board.
- Milica Lukic
  - Create a code to run a program for a new prototype.
  - Use online and university resources as needed.
- Alex Houle
  - Help create a code to run a program for a new prototype.
  - Use online and university resources as needed.
- Darshigaa Gurumoorthy
  - Test new prototype under doc camera at HSLC.
  - Record testing plans and outcomes.
  - Help assemble electrical work to create a functioning bread board.
- Charlie Zhu
  - Help create a code to run a program for a new prototype.
  - Use online and university resources as needed.

Project Timeline

Project Goal	**Deadline**	**Team Assigned**	**Progress**	**Completed**
Completed research on previous semester's work	9/24	All	100%	9/24
Completed research on hypoxemia	9/24	All	100%	9/24
Finalize design improvements	9/31	All	100%	9/24
Preliminary Presentations	10/15	All	100%	10/13
Preliminary Deliverables	10/20	All	100%	10/19
Test last semesters prototype	10/29	Kendra and Charlie	100%	10/29
1st prototype baseboard printed	11/1	Kendra	90%	
1st prototype code program	11/2	Milica, Alex, and Charlie	20%	
1st prototype breadboard	11/3	Kendra and Darshigaa		
1st prototype full assembly	11/3	Everyone		

1st prototype testing	11/4	Darshigaa
Show and Tell	11/05	All
Poster Presentations	12/10	All
Final Deliverables	12/15	All

Arrows indicated dependencies

Expenses

[redacted]

Component 1- Baseboard							
3D printed Baseboard	Maker's space			1			
Component 2- Solid machined metal knob – 1" diameter							
Potentiometer cap	Adafruit	2056	11/9	2	3.95	7.90	https://www.adafruit.com/product/2056#description
Component 3- RGB blacklight negative LCD 20x4 +extras – RGB on black							
Display Window	Adafruit	498	11/9	1	20.95	20.95	https://www.adafruit.com/product/498
Component 4- Panel Mount Right Angle 10K Linear Potentiometer w/On-Off Switch - 10K Linear w/ Switch							
Vertical potentiometer	Adafruit	3395	11/9	2	1.50	3.00	https://www.adafruit.com/product/3395
Component 5- Panel Mount 10K Potentiometer (Breadboard Friendly) - 10K Linear							
Horizontal potentiometer	Adafruit	652	11/9	2	0.95	1.90	https://www.adafruit.com/product/562
TOTAL:							**$33.75**

Max budget: $1000

2021/12/02 - Progress Report 11

MILICA LUKIC - Dec 15, 2021, 2:34 PM CST

Title: Progress Report 11

Content:

Teaching Model for Ventilation and Perfusion Mismatching (Hypoxemia Model)

Client: Dr. Chris Green

Advisor: Professor Chris Brace

Team: Kendra Besser kbesser@wisc.edu (Leader)

Milica Lukic mlukic@wisc.edu (Communicator)

Alex Houle arhoule@wisc.edu (BWIG)

Darshigaa Gurumoorthy dgurumoorthy@wisc.edu (BSAC)

Charlie Zhu xzhu333@wisc.edu (BPAG)

Date: November 19, 2021 to December 2, 2021

Problem Statement

Ventilation/ perfusion mismatching is the most predominant cause of hypoxemia; however, medical students often have a very difficult time understanding this concept. Other than a textbook diagram by John West in his text Respiratory Physiology there are no relevant representations of ventilation/ perfusion mismatching causing hypoxemia. Our goal is to continue work done by previous UW Madison students to create an accurate model of the lungs and blood flow where ventilation/ perfusion mismatching may occur with the intent to be studied by medical students for a deeper understanding of hypoxemia.

Brief Status Update

In the past two weeks, the team continued to work through the fabrication plans and overcome design challenges. With Thanksgiving break it was hard to collaborate, but we communicated as best as possible and planned to meet as a team on 12/3 to discuss what needs to be completed next week. Before break, the half of the team attended a quick advisor meeting where we discussed design details, fabrication plans, and test plans.

Summary of Weekly Team Member Design Accomplishments

- Team:
  - o Continued working on completing the prototype.
  - o Kendra, Darshigaa, Charlie attended the meeting with our advisor to discuss design details, fabrication plans, and received a lot of advice on future testing plans.
- Kendra Besser
  - o Transfers a paper sketch of the baseboard into solid works with proper dimensions to be 3D printed in the makerspace.
  - o Sent sketches to the team for critiques and modified the sketch to their suggestions.
  - o Recorded notes during the advisor meeting.

· Milica Lukic

o Communicated with Dr. Green and coworkers to figure out how to pay for the 3D printed materials in the makerspace.

o Reviewed the baseboard sketch and gave suggestions before it was printed.

o Worked with Alex to get the parts to him before break.

o Set up a meeting with Brittany Glaeser, who worked on this project last year, to discuss how she wrote her code.

· Alex Houle

o Worked on the prototype electrical components over break to generate a code in Arduino that will program our prototype.

o Brainstormed how the electrical components will physically fit together but due to the lack of materials at home, couldn't complete the breadboard.

o Informed the team on the strides he made over the break and what questions need to be answered so that we can complete the breadboard.

· Darshigaa Gurumoorthy

o Attended advisor meeting.

· Charlie Zhu

o Attended the advisor meeting and talked about the progress made in the professor meeting a week earlier while working on the breadboard and electrical components.

o Communicated a lot over break to help solve design issues with other individuals.

o Gave Kendra suggestions on how to improve the baseboard sketch.

Weekly/Ongoing Difficulties

With Thanksgiving break interrupting our plans, our progress was a bit broken up and it was difficult to collaborate simultaneously. However, as individuals we got work done and shared our findings with each other to stay informed.

Upcoming Team and Individual Goals

· Team:

o Update lab archives notebook.

§ Individually fill out our own folders with new information.

§ Together update group folders.

o Continue with fabrication plans then test and revise the new prototype.

o Update final report with progress we have made so far and comments on the rule brick.

o Meet as a team on 12/3 to discuss next steps for the following week and what we can do to complete a functioning prototype before the poster presentation.

o Work on preparations for the poster presentation.

· Kendra Besser

o Send sketches to makerspace to be 3D printed and pick up prints.

· Milica Lukic

o Help Alex complete the breadboard.

o Meet with Brittany to discuss the previous code.

- Alex Houle
  - Finishes the electrical components of the prototype using makerspace resources.
- Darshigaa Gurumoorthy
  - Test new prototype under doc camera at HSLC.
  - Record testing plans and outcomes.
  - Help Alex complete the breadboard.
- Charlie Zhu
  - Help Alex complete the breadboard.
  - Meet with Brittany to discuss the previous code.
  - Revise the prototype.

Project Timeline

Project Goal	Deadline	Team Assigned	Progress	Completed
Completed research on previous semester's work	9/24	All	100%	9/24
Completed research on hypoxemia	9/24	All	100%	9/24
Finalize design improvements	9/31	All	100%	9/24
Preliminary Presentations	10/15	All	100%	10/13
Preliminary Deliverables	10/20	All	100%	10/19
Test last semesters prototype	10/29	Kendra and Charlie	100%	10/29
1st prototype baseboard printed	11/1	Kendra	90%	
1st prototype code program	11/2	Milica, Alex, and Charlie	20%	
1st prototype breadboard	11/3	Kendra and Darshigaa		
1st prototype full assembly	11/3	Everyone		
1st prototype testing	11/4	Darshigaa		
Show and Tell	11/05	All	100%	11/05
Poster Presentations	12/10	All		

Final Deliverables	12/15	All

Arrows indicated dependencies

Expenses

[redacted]

Component 1- Baseboard							
3D printed Baseboard	Maker’s space			1			
Component 2- Solid machined metal knob – 1” diameter							
Potentiometer cap	Adafruit	2056	11/9	2	3.95	7.90	https://www.adafruit.com/product/2056#description
Component 3- RGB blacklight negative LCD 20x4 +extras – RGB on black							
Display Window	Adafruit	498	11/9	1	20.95	20.95	https://www.adafruit.com/product/498
Component 4- Panel Mount Right Angle 10K Linear Potentiometer w/On-Off Switch - 10K Linear w/ Switch							
Vertical potentiometer	Adafruit	3395	11/9	2	1.50	3.00	https://www.adafruit.com/product/3395
Component 5- Panel Mount 10K Potentiometer (Breadboard Friendly) - 10K Linear							
Horizontal potentiometer	Adafruit	652	11/9	2	0.95	1.90	https://www.adafruit.com/product/562
TOTAL:							**$33.75**

Max budget: $1000

2021/12/09 - Progress Report 12

MILICA LUKIC - Dec 15, 2021, 2:35 PM CST

Title: Progress Report 12

Content:

Teaching Model for Ventilation and Perfusion Mismatching (Hypoxemia Model)

Client: Dr. Chris Green

Advisor: Professor Chris Brace

Team: Kendra Besser kbesser@wisc.edu (Leader)

Milica Lukic mlukic@wisc.edu (Communicator)

Alex Houle arhoule@wisc.edu (BWIG)

Darshigaa Gurumoorthy dgurumoorthy@wisc.edu (BSAC)

Charlie Zhu xzhu333@wisc.edu (BPAG)

Date: December 3 to December 9, 2021

Problem Statement

Ventilation/ perfusion mismatching is the most predominant cause of hypoxemia; however, medical students often have a very difficult time understanding this concept. Other than a textbook diagram by John West in his text Respiratory Physiology there are no relevant representations of ventilation/ perfusion mismatching causing hypoxemia. Our goal is to continue work done by previous UW Madison students to create an accurate model of the lungs and blood flow where ventilation/ perfusion mismatching may occur with the intent to be studied by medical students for a deeper understanding of hypoxemia.

Brief Status Update

Our final week consisted of a lot of hard work; as a team we completed fabrication, coding, and testing to present a final product at the poster presentations. We ran into more problems than we accounted for while 3D printing and making the code, but we worked together to get everything done on time.

Summary of Weekly Team Member Design Accomplishments

· Team:

o Continued working on completing the prototype.

o Attended advisor meeting on 12/3 to discuss testing plans and poster presentation details.

o Attended a group meeting on 12/3 to discuss what needs to be done and when it needs to be done to have a final product for the poster presentation.

· Kendra Besser

o Printed the original 3D baseboard at the makerspace with Charlie.

o Reshaped the solid works sketch multiple times to better fit the electrical components and to change dimensions so it can fit in the printer.

o Helped complete the poster for the final poster presentation.

- Milica Lukic
    - o Completed the poster organization and content for the poster presentation.
    - o Maintained communication with Dr. Green and invited him to the poster presentation.
    - o Communicated with Professor Brace to ask for poster feedback.
    - o Recorded notes during advisor and group meetings.
    - o Soldered electrical components to fit to the breadboard.
    - o Workd with Brittany to help on the coding and electrical connections.
    - o Met with Alex and Charlie to calibrate potentiometers and determine display values.
- Alex Houle
    - o Worked on the coding and electrical connections to construct a final product that works the way we intended it to.
    - o Met with Milica and Charlie to calibrate potentiometers and determine display values.
- Darshigaa Gurumoorthy
    - o Helped complete the poster for the final poster presentation.
- Charlie Zhu
    - o Printed all 3D sketches for the baseboard.
    - o Worked on the coding and electrical connections to construct a final product that works the way we intended it to.
    - o Met with Alex and Milica to calibrate potentiometers and determine display values.

Weekly/Ongoing Difficulties

This week we ran into many fabrication difficulties. Despite planning for obstacles and a 3D print wait time, we still had to redesign many times which resulted in multiple different prints. This ultimately set us back on completing our testing plans. However, with strong communication and many long nights, as a team we worked hard to stay on track and have everything ready for the poster presentation.

Upcoming Team and Individual Goals

- Team:
    - o Update lab archives notebook.

- Individually fill out our own folders with new information.
- Together update group folders.
    - o Update final report and all other deliverables.
    - o Work on preparations for the poster presentation.

Project Timeline

Project Goal	Deadline	Team Assigned	Progress	Completed
Completed research on previous semester's work	9/24	All	100%	9/24
Completed research on hypoxemia	9/24	All	100%	9/24

Finalize design improvements	9/31	All	100%	9/24
Preliminary Presentations	10/15	All	100%	10/13
Preliminary Deliverables	10/20	All	100%	10/19
Test last semesters prototype	10/29	Kendra and Charlie	100%	10/29
prototype baseboard printed	11/1	Kendra	100%	12/3
prototype code program	11/2	Milica, Alex, and Charlie	100%	12/7
prototype breadboard	11/3	Alex and Charlie	100%	12/8
Show and Tell	11/05	All	100%	11/05
Prototype full assembly		Everyone	100%	12/8
prototype testing		Everyone	100%	12/9
Poster Presentations	12/10	All	100%	12/9
Final Deliverables	12/15	All	20%	

Arrows indicated dependencies

Expenses

[redacted]

Component 1- Baseboard

3D printed Baseboard	Maker’s space			1			

Component 2- Solid machined metal knob – 1” diameter

Potentiometer cap	Adafruit	2056	11/9	2	3.95	7.90	https://www.adafruit.com/product/2056#description

Component 3- RGB blacklight negative LCD 20x4 +extras – RGB on black

Display Window	Adafruit	498	11/9	1	20.95	20.95	https://www.adafruit.com/product/498

Component 4- Panel Mount Right Angle 10K Linear Potentiometer w/On-Off Switch - 10K Linear w/ Switch

Vertical potentiometer	Adafruit	3395	11/9	2	1.50	3.00	https://www.adafruit.com/product/3395

Component 5- Panel Mount 10K Potentiometer (Breadboard Friendly) - 10K Linear

Horizontal potentiometer	Adafruit	652	11/9	2	0.95	1.90	https://www.adafruit.com/product/562
TOTAL:							**$33.75**

Max budget: $1000

2021/10/15 - Preliminary Presentation

Charlie ZHU - Dec 15, 2021, 2:42 PM CST

Title: 2021/10/15 Preliminary Presentation

Date: 2021/10/15

Content by: The whole team

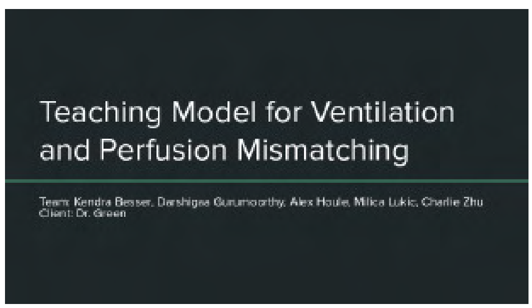
Present: The whole team

Goals: N/A

Content:

Conclusions/action items:N/A

Charlie ZHU - Dec 15, 2021, 2:42 PM CST



Preliminary_Presentation_.pdf(946.1 KB) - download

2021/10/20 - Preliminary Report

MILICA LUKIC - Oct 20, 2021, 3:06 PM CDT

Title: Preliminary Report

Date: 10/21

Content by: Whole team

Present: Whole team

Content:

BME Design

Teaching Model for Ventilation and Perfusion Mismatching

Team Members:
Kendra Besser (Leader)
Milica Lukic (Communicator)
Darshigaa Gurumoorthy (BSAC)
Alex Houle (BWIG)
Charlie Zhu (BPAG)

Client: Dr. Chris Green UW-Health
Advisor: Prof. Chris Brace UW-Madison

BME 200/300: Fall 2021
10.19.2021

Abstract

Understanding the concept of Ventilation(V) and Perfusion(Q) in the Lungs and how the ratio between them affects the body is of great clinical significance, considering the fact that any mismatch in the ratio leads to a variety of problems such as hypoxia, hypoxia and hypercapnia. However, it is a difficult concept and there is virtually no representation of this concept available in the market and the medical faculty and students have to rely on a textbook diagram in 'Respiratory Physiology' by John West, which is not an effective way to learn for the students. This is why our Client, Dr. Christopher Green commissioned us to create an effective teaching model. While previous BME 2/300 students did work on the project, the design still needed significant improvements to be made to make it effective. After much deliberation on our three top design ideas, we decided to build upon the previous model and change it to include sliders and LED screens as well as change the housing of the components to fit the needs of the clients and make the model more effective. We are currently working on the fabrication of this improved model and will begin our testing process in the near future.

Table of Contents

I. Introduction

Chronic obstructive pulmonary disease, asthma, chronic bronchitis, pulmonary congestion, airway obstruction, pulmonary embolism, and many other common conditions lead to ventilation perfusion mismatching [1]. Ventilation perfusion mismatching is the main cause of hypoxemia; hypoxemia is a state of low oxygenated blood flow that leads to poorly oxygenated tissues. Although ventilation perfusion mismatching is very common, it is a very difficult concept for medical students to learn. The only demonstration of how ventilation perfusion mismatching occurs in the capillaries of the lungs is a textbook diagram by John West in his text Respiratory Physiology [2]. However, this textbook diagram is confusing and does not allow students the opportunity to physically observe different ventilation perfusion ratios and its effects on the oxygenation of the blood flow. It is necessary for medical students to have a physical, interactive model so they can unlock a deeper understanding of ventilation perfusion mismatching; according to the Harvard Gazette, active learning can subconsciously help students learn [3]. The main focus of this design process is to create a working prototype of an intuitive and interactive teaching model for medical students to learn the effects of ventilation perfusion mismatching.

II. Background

Lungs are a sponge-like organ housed within the rib cage in the human body and form a major part of the respiratory system. The lungs contain alveoli, which are the main site of gaseous exchange. An alveolus is a cluster of tiny air sacs that are surrounded by a mesh of tiny blood vessels called capillaries. The alveolus provides a moist site that helps in gaseous exchange. Gaseous exchange occurs mostly by diffusion[4].

When the air flows into the lungs and reaches the alveoli, Oxygen diffuses from the alveoli into the blood that flows into the pulmonary capillaries because there is a high concentration of oxygen in the lungs and a low concentration in the blood while the Carbon dioxide diffuses from the pulmonary capillaries to the alveoli due to the high concentration of Carbon dioxide in deoxygenated blood and the subsequent low concentration in the lungs [5].

This entire process of airflow into the lungs is known as Ventilation (V) and the flow of blood into the pulmonary capillaries is known as Perfusion (Q). Due to the increase in gravity as blood moves down towards the base of the lung, the weight of the fluid in the pleural cavity increases, thus increasing ventilation rates[6]. However, gravity also has a major effect on the perfusion rates. Since it pulls the blood towards the base, perfusion rates are much higher at the base than the apex. This leads to a lower V/Q ratio at the base.

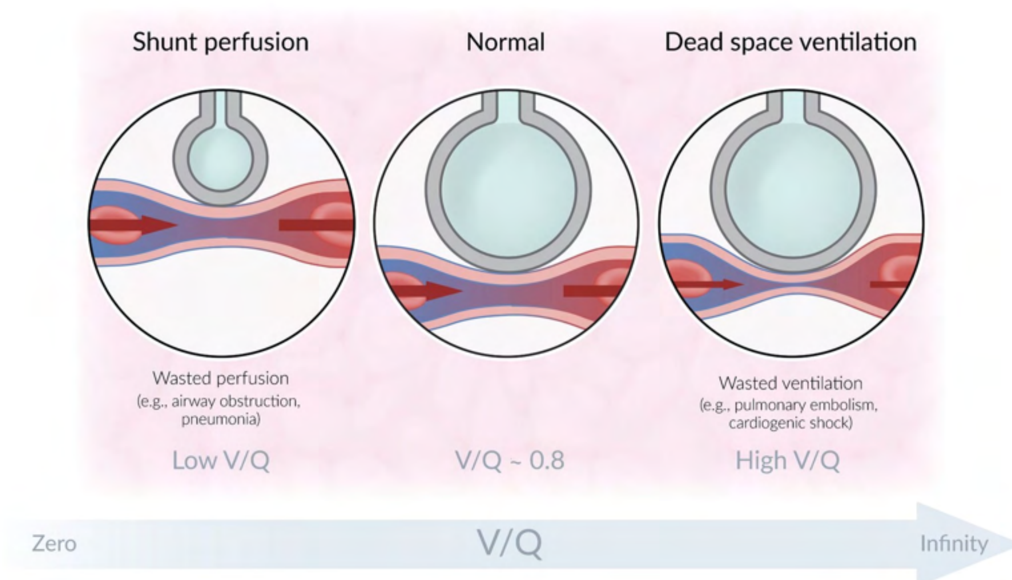


Figure1. Depictions and defining factors of different V/Q ratios[6]

It is known that in a healthy individual, the V/Q ratio is around 1 in the middle of the lung and varies between 0.3 and 2.1 across the lung while the average value lies around 0.8 [6]. Any mismatch in this ratio would be detrimental to the human body. A too-high ratio would be the result of decreased perfusion, and the most common cause of this are pulmonary embolisms (blood clot that travels to a lung artery). This leads to hypoxemia, which is low levels of oxygen in the blood.

A high ratio can also be associated with dead-space ventilation, which involves more ventilation than necessary. A too-low ratio refers to a decreased ventilation, which is typically the result of COPD, asthma, or an airway obstruction. It can lead to Hypoxia, which is the condition wherein less oxygen is available to the bodily tissues and in some cases can lead to hypercapnia, wherein there are high levels of Carbon Dioxide in the blood[6].

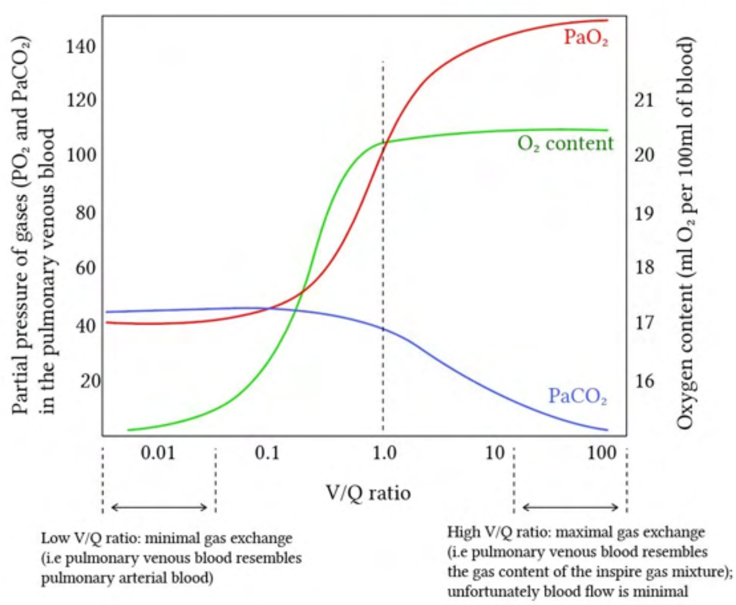


Figure2. Relationship between V/Q ratio and partial pressure of gases[7]

Our client, Dr. Chris Green, a medical educator and a pediatric pulmonologist with UW-Health. observed that this is a concept that students often struggle with which inspired him to create a teaching model for ventilation and perfusion mismatching to help students understand the concept better.

To design and build our prototype, lots of foundational research must be done to understand what is happening in each alveoli. Having a complete understanding of the ventilation and perfusion process is absolutely essential so that the teaching model can be adequate enough to teach it to another person. Understanding the causes and consequences of the V/Q mismatch is also essential, as the end goal of the teaching model is to understand the concept and be able to apply it into practice as a medical professional. Researching previous work done on teaching models and analyzing the benefits and drawbacks also shapes the prototype, as being able to improve from what is already out there is key to designing a product. Given the technical nature of this project, knowledge and experience working with the mechanical pieces, such as LEDs, Arduino products, and wires makes the manufacturing process easier, and also allows for more advanced features on the prototype. Dr. Green has offered his assistance in the mathematical process of computing the ratio, but a baseline understanding at minimum of how the equation works is required in order to effectively teach the concept.

One of the most important design specifications is that Dr. Green is looking for sliders that can adjust the V/Q ratio to represent different levels of mismatching. Along with this, a digital display that shows output of the partial pressure of oxygen and the partial pressure of carbon dioxide is very important. The client needs to be able to show the device in a lecture hall, under a document camera for example, so the model must be less than about 10 in or 25 cm on any side. Another specification given by the client is that the model does not necessarily need to be realistic, but must be a good representation and visualization of what happens in the body at different V/Q levels leading to hypoxemia

III. Preliminary Designs

Design 1: Slider with LEDs and Screen

The slider with LEDs and screen model uses a 3D printed case that houses differently colored LEDs, slides for adjusting the V/Q ratio, and a digital display where the values the client would like to teach his students about can be displayed. The different colored LEDs represent different things, flowing in and out of the alveoli. Along with that, the speed at which the lights flashed could assist in demonstrating the changes that occur at higher or lower V/Q ratios.

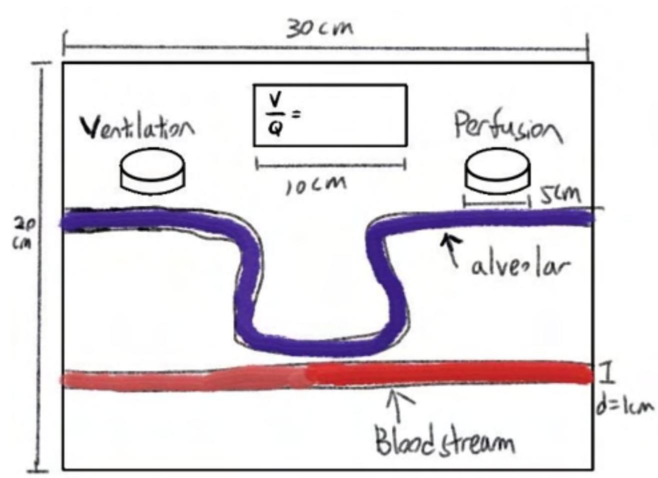


Figure3. Design drawing for slider with LEDs and screen design

Design 2: Computer Animation

The software animation model refers to use of a programming language to create a software where V and Q values could be input and the V/Q ratio, partial pressure of oxygen, and any other levels the client would like to calculate would be output. Along with these values, the program would provide an animation of one or multiple alveoli with flow rates depicted through use of arrows, number of molecules, and speed at which the molecules flow through the animation.

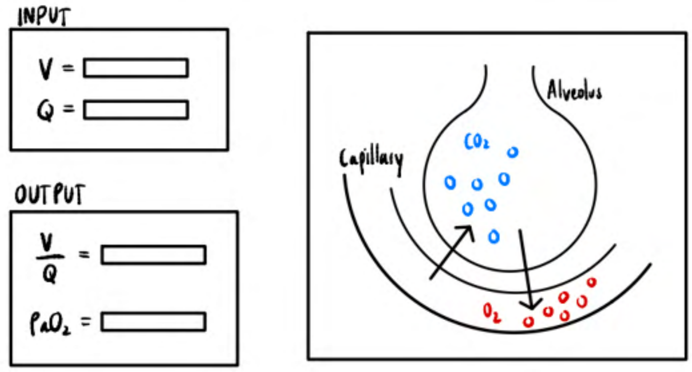


Figure4. Design drawing for computer animation design

Design 3: Water/Dye Concentrations

The water and dye model uses a flexible tube that can expand and relax to show different blood flow volume measurements and a colorful dye that can be used to represent oxygenation of the blood. The water would run through the tube at different rates and depending on the avelious represented some amount of dye would be excreted into the tube to show a colorful oxygenated blood flow. The amount of dye excreted and velocity of water would be controlled by a computer program so that qualitative data can be displayed on a computer to show the V/Q ratios and oxygen levels of the portrayed blood flow.

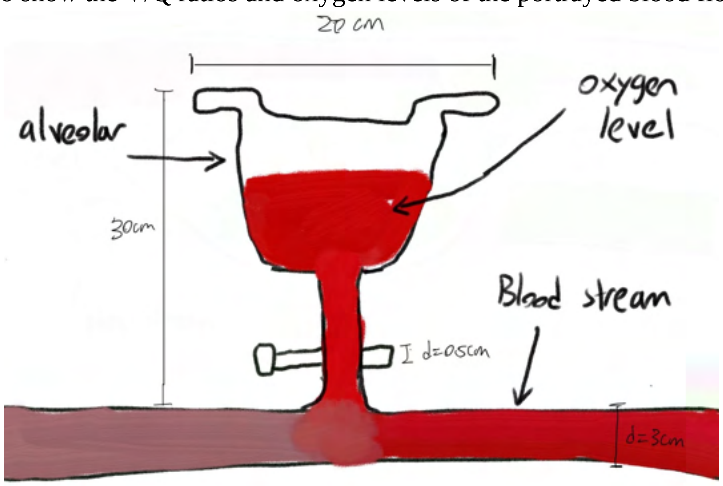


Figure5. Design drawing for water/dye concentration design

IV. Preliminary Design Evaluation

Design Matrix

To determine necessary criteria for the design matrix, the primary purpose of this device was prioritized. Scores were given largely based on effectiveness of the potential designs as teaching models.

Intuitive use is the ability of the client to understand and use the product immediately after receiving it. The weight of this criteria is 30%, as the product will be used as a teaching model, and both the client and students must be able to use the model easily. The LEDs and screen design received full points as the interactive component of the sliders is easy to understand.

The learning outcomes criteria refers to the design's effectiveness in leading students to understand the concept of ventilation and perfusion mismatching. Since the major purpose of the design is teaching, the weight of this criteria is given 30%. The LEDs and screen design allows students to understand the concept without confusion because oxygen levels at different V/Q ratios can be seen by adjusting the V/Q sliders.

The adjustability criteria refers to the ability to adjust V/Q input in order to be more precise and variable. The weight of adjustability is 20% because high adjustability will allow the client to better explain the concept of V/Q mismatching to different students. The adjustability of the LEDs and screen design is considered high because the slider in the design allows the client to adjust the ratio of V/Q in order to show the effects that different ratios have on flow rates.

Ease of fabrication was given a weight of 10% as there are many great resources available to us through the engineering department that will make the fabrication process much easier, especially for 3D printing.

The cost criteria was given a weight of 5% as the budget given by the client should be more than enough for the materials involved.

The safety criteria was given a weight of 5% as there are little to no safety risks involved.

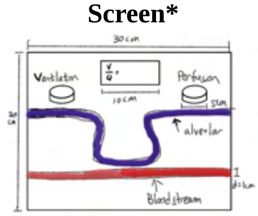
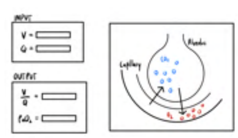
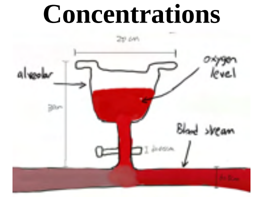
Criteria (Weight)	**Slider with LEDs and Screen*** 		**Computer Animation*** 		**Water/Dye Concentrations** 	
Intuitive use (30%)	5/5	30%	4/5	24%	2/5	12%
Learning Outcomes (30%)	4/5	24%	2/5	12%	4/5	24%
Adjustability (20%)	4/5	16%	5/5	20%	4/5	16%
Ease of fabrication (10%)	3/5	6%	2/5	4%	1/5	2%
Cost (5%)	2/5	2%	5/5	5%	2/5	2%
Safety (5%)	4/5	4%	5/5	5%	5/5	5%
Total	**82%**		**70%**		**61%**	

Figure6. Preliminary design matrix

Proposed Final Design

After much discussion as a team with both the client and advisor, the proposed final design is the slider with LEDs and screen design. This design would offer the best learning outcomes for medical students, allow for hands-on teaching and learning experiences, and be an intuitive tool for the classroom.

V. Fabrication/Development Process

Materials

Although fabrication has not yet begun, the team plans to create the device with sliders, a digital display, LEDs of different colors, Arduino Uno for programming, and 3D printed housing for all electrical components.

The sliders were chosen because they offer the user the ability to easily adjust the V and Q values. Two will be used so that the V/Q ratio can be manipulated by changing V, Q, or both. The digital display was selected so that the user can see the V/Q ratio as well as partial pressure of oxygen and carbon dioxide results from the V and Q values inputted. LEDs of different colors will allow the user to visualize the flow of oxygen and blood through the alveolus. The Arduino Uno will conduct the calculations as well as allow for the programming of the LEDs, potentially to flash at different speeds for different V/Q ratios levels. 3D printed housing for all of these components was chosen as it is not expensive to create, readily available at the UW-Madison Makerspace

Methods

The exact methods for creating the prototype are still to be determined. However, the fabrication plan includes 3D printing the housing for the LEDs, purchasing the digital display, sliders, and other electrical components, and assembling and printing using the tools at the UW-Madison Makerspace. Printing will be achieved by using SolidWorks to create a computer generated image of the electrical housing with its exact dimensions and precise shape. Along with this, assembling the circuitry will be a large component of the creation of the device.

Final Prototype

Final prototype has not yet been fabricated.

Testing

Testing has not yet been conducted. However, testing with the client and potentially the client's students would allow for better understanding of the effectiveness of the teaching model, whether or not it is intuitive, and how well the LED configuration can represent the flow rates.

VI. Results

Data and results will be collected after testing is conducted.

VII. Discussion

Discussion will be completed after fabrication and testing.

VIII. Conclusions

The team has been tasked with creating a teaching model for ventilation and perfusion mismatching. This issue is the most common cause of hypoxemia, however students have a difficult time grasping the complex topic. The client, Dr. Chris Green, is seeking an effective teaching model that offers a good visualization of the V/Q ratio in an alveolus of the lung. Findings and additional conclusions will be explained as fabrication and testing occurs.

For future work, the team plans to finalize the slider with LEDs and screen design. After the configuration and other specifics of the LEDs, such as color and flashing speed, are decided, fabrication can begin. Fabrication will include creating housing for the electrical components, purchasing the desired LEDs and a digital display, and assembling the circuitry. After fabrication is completed, testing will begin. This will consist of inputting different V and Q values and ensuring that the output oxygen and carbon dioxide levels are correct based on calculations that the client has provided. Along with this, the LEDs will be tested by inputting different V and Q values and ensuring that the correct colors and flashing speeds are observed. Moreover, the design will be tested by the client and potentially by students, to determine whether or not it is intuitive and helpful.

IX. References

[1] Adrienne Santos-Longhurst. (2018, October 26). What you need to know about V/Q mismatching. [Peer reviewed publication]. Available: https://www.healthline.com/health/v-q-mismatch#causes.

[2] West, J. B., & Luks, A. (2021). *West's respiratory physiology: The essentials*. Wolters Kluwer.

[3] Juan Siliezar. (2021, October 1). Finding a hands-on approach to remote learning. [Online Journal]. Available: https://news.harvard.edu/gazette/story/2021/10/study-finds-students-learn-better-through-physical-participation/.

[4] M. D. Lynne Eldridge, “What are the alveoli and how do they work?,” *Verywell Health*, 01-Sep-2021. [Online]. Available: https://www.verywellhealth.com/what-are-alveoli-2249043. [Accessed: 20-Oct-2021].

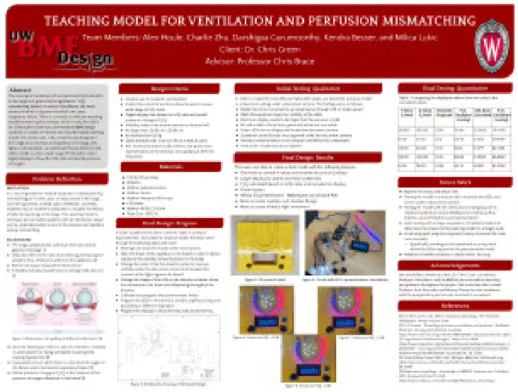
[5] Deborah Leader, R. N. (n.d.). What people with copd should know about v/q mismatch. *Verywell Health*. Retrieved September 24, 2021, from https://www.verywellhealth.com/what-is-vq-mismatch-in-the-lungs-914928.

[6] Respiratory physiology - Knowledge @ AMBOSS. Amboss.com. Published 2021. Accessed October 15, 2021. https://www.amboss.com/us/knowledge/Respiratory_physiology/

[7] A. Yartsev, “Effects of ventilation-perfusion mismatch on gas exchange: Deranged physiology,” *Effects of ventilation-perfusion mismatch on gas exchange | Deranged Physiology*, 07-Dec-2019. [Online]. Available: https://derangedphysiology.com/main/cicm-primary-exam/required-reading/respiratory-system/Chapter%200732/effects-ventilation-perfusion-mismatch-gas-exchange. [Accessed: 20-Oct-2021].

2021/12/10 - Poster Presentation

MILICA LUKIC - Dec 15, 2021, 2:38 PM CST



V_Q_Mismatch_Poster_Presentation_1_.pdf(1.9 MB) - download

2021/12/15 - Final Report

Charlie ZHU - Dec 15, 2021, 2:27 PM CST

Title: Final Report

Date: 12021/2/15

Content by: Whole team

Present: Whole team

Content:

Teaching Model for Ventilation and Perfusion Mismatching

Team Members:
Kendra Besser (Leader)
Milica Lukic (Communicator)
Darshigaa Gurumoorthy (BSAC)
Alex Houle (BWIG)
Charlie Zhu (BPAG)

Client: Dr. Chris Green UW-Health
Advisor: Prof. Chris Brace UW-Madison

BME 200/300: Fall 2021
12.15.2021

Abstract

The concept of ventilation (V, air flow) and perfusion (Q, blood flow) in the lungs and the effect of ventilation and perfusion mismatch on the body is of great clinical significance. The typical V/Q ratio is around 0.8, and any mismatching of the ratio can lead to a variety of problems such as hypoxemia or dead space ventilation, which can lead to respiratory failure. There is currently no effective teaching model for learning this concept available outside of textbook diagrams such as those in *Respiratory Physiology* by John West. The models found in literature lack helpful visual aids and interactive aspects. This is why the client, Dr. Christopher Green, has commissioned BME Design students to create an effective and interactive teaching model for ventilation and perfusion mismatching. Previous BME Design students began this project, but alterations to the design were necessary in order to create a more effective, intuitive, and visually helpful teaching model. This semester, the group has created a prototype which uses a 3D printed board designed in the image of an alveolus and capillary in the lungs, with LED lights to demonstrate movement of air and blood at different V/Q ratios. Knobs allow the users to visualize a wide range of V/Q ratios, and a digital display shows the V/Q ratio and partial pressure of oxygen.

Table of Contents

I. Introduction

Chronic obstructive pulmonary disease, asthma, chronic bronchitis, pulmonary congestion, airway obstruction, pulmonary embolism, and many other common conditions lead to ventilation perfusion mismatching [1]. Ventilation and perfusion mismatching is the main cause of hypoxemia. Hypoxemia is a state of low oxygenated blood flow that leads to poorly oxygenated tissues, which can ultimately lead to respiratory failure. Although ventilation perfusion mismatching is very common, it is a very difficult concept for medical students to learn. The only demonstration of ventilation and perfusion mismatching in the capillaries of the lungs are found in literature, such as *Respiratory Physiology*, a commonly used textbook by John West [2]. The diagrams found in literature are very confusing and do not allow the students to physically observe different V/Q ratios and their effects on blood and air flow in the lungs. It is necessary for medical students to have a physical, interactive model so they can unlock a deeper understanding of ventilation and perfusion mismatching. According to the Harvard Gazette, active learning assists students with their understanding, and it is imperative that medical professionals have a good grasp on this concept [3]. The main focus of this design process is to create a working prototype of an intuitive and interactive teaching model for medical students to learn the effects of ventilation and perfusion mismatching.

II. Background

The lungs are a sponge-like organ housed within the rib cage in the human body and form a major part of the respiratory system. The lungs contain alveoli, which are the main site of gaseous exchange. An alveolus is the tiny air sac in the lungs that is surrounded by a mesh of blood vessels called capillaries. The alveolus provides a moist site that helps in gaseous exchange. Gaseous exchange occurs mostly by diffusion [4].

When the air flows into the lungs and reaches the alveoli, oxygen diffuses from the alveoli into the blood that flows into the pulmonary capillaries because there is a high concentration of oxygen in the lungs and a low concentration in the blood while the carbon dioxide diffuses from the pulmonary capillaries to the alveoli due to the high concentration of Carbon dioxide in deoxygenated blood and the subsequent low concentration in the lungs [5].

This entire process of airflow into the lungs is known as ventilation (V) and the flow of blood into the pulmonary capillaries is known as perfusion (Q). Due to the increase in gravity as blood moves down towards the base of the lung, the weight of the fluid in the pleural cavity increases, thus increasing ventilation rates[6]. However, gravity also has a major effect on the perfusion rates. Since it pulls the blood towards the base, perfusion rates are much higher at the base than the apex. This leads to a lower V/Q ratio at the base.

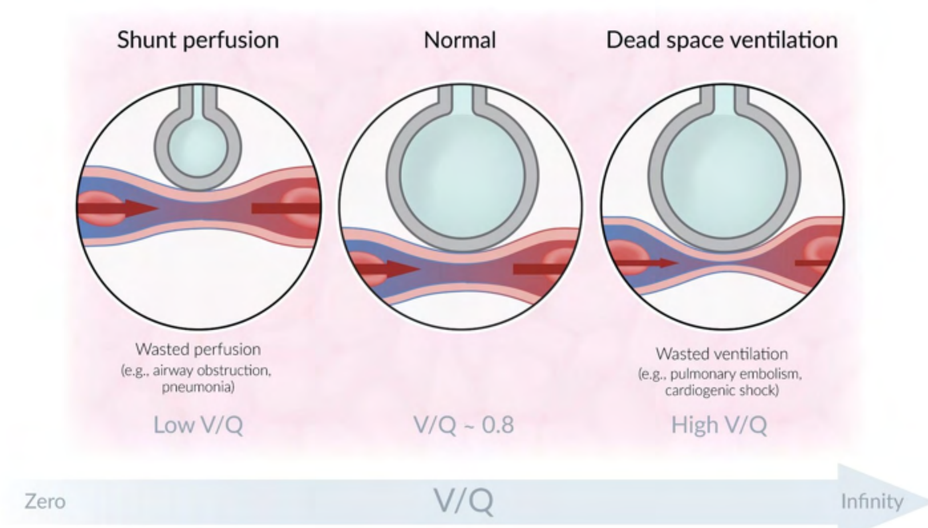


Figure 1. Depictions and defining factors of different V/Q ratios[6]

It is known that in a healthy individual, the V/Q ratio is around 1 in the middle of the lung and varies between 0.3 and 2.1 across the lung while the average value lies around 0.8 [6]. Any mismatch in this ratio would be detrimental to the human body. A too-high ratio would be the result of decreased perfusion, and the most common cause of this are pulmonary embolisms (blood clot that travels to a lung artery). This leads to hypoxemia, which is low levels of oxygen in the blood.

A high ratio can also be associated with dead-space ventilation, which involves more ventilation than necessary. A too-low ratio refers to a decreased ventilation, which is typically the result of COPD, asthma, or an airway obstruction. It can lead to hypoxia, which is the condition wherein less oxygen is available to the bodily tissues and in some cases can lead to hypercapnia, wherein there are high levels of carbon dioxide in the blood[6].

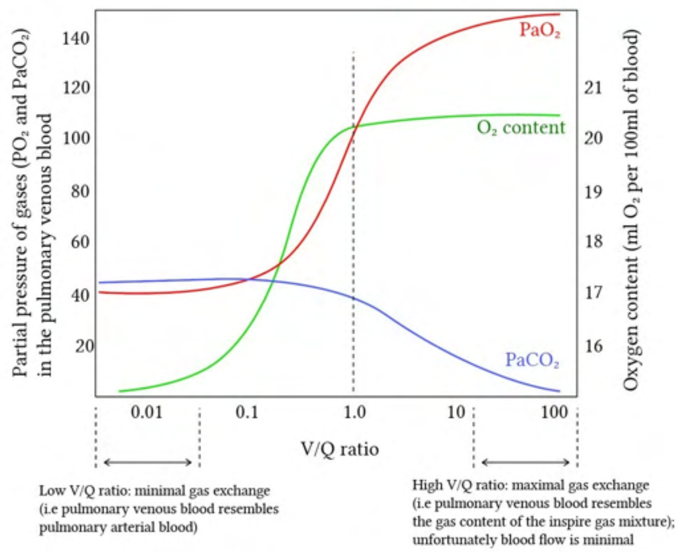


Figure 2. Relationship between V/Q ratio and partial pressure of gases [7]

Our client, Dr. Chris Green, a medical educator and a pediatric pulmonologist with UW-Health. observed that this is a concept that students often struggle with which inspired him to create a teaching model for ventilation and perfusion mismatching to help students understand the concept better.

To design and build our prototype, lots of foundational research must be done to understand what is happening in each alveoli. Having a complete understanding of the ventilation and perfusion process is absolutely essential so that the teaching model can be adequate enough to teach it to another person. Understanding the causes and consequences of the V/Q mismatch is also essential, as the end goal of the teaching model is to understand the concept and be able to apply it into practice as a medical professional. Researching previous work done on teaching models and analyzing the benefits and drawbacks also shapes the prototype, as being able to improve from what is already out there is key to designing a product. Given the technical nature of this project, knowledge and experience working with the mechanical pieces, such as LEDs, Arduino products, and wires makes the manufacturing process easier, and also allows for more advanced features on the prototype. Dr. Green has offered his assistance in the mathematical process of computing the ratio, but a baseline understanding at minimum of how the equation works is required in order to effectively teach the concept.

One of the most important design specifications is that Dr. Green is looking for sliders that can adjust the V/Q ratio to represent different levels of mismatching. Along with this, a digital display that shows output of the partial pressure of oxygen and the partial pressure of carbon dioxide is very important. The client needs to be able to show the device in a lecture hall, under a document camera for example, so the model must be less than about 10 in or 25 cm on any side. Another specification given by the client is that the model does not necessarily need to be realistic, but must be a good representation and visualization of what happens in the body at different V/Q levels leading to hypoxemia

III. Preliminary Designs

Design 1: Slider with LEDs and Screen

The slider with LEDs and screen model uses a 3D printed case that houses differently colored LEDs, potentiometer knobs for adjusting the V and Q values, and a digital display that shows the V/Q ratio and partial pressure of oxygen value according to the V/Q ratio. White LEDs represent the air flowing into the alveolus, and the blue-purple-red gradient LEDs represent the blood flowing through the capillaries. Along with that, the speed at which the lights flash assist in demonstrating the changes in air and blood flows that occur at different V/Q ratios.

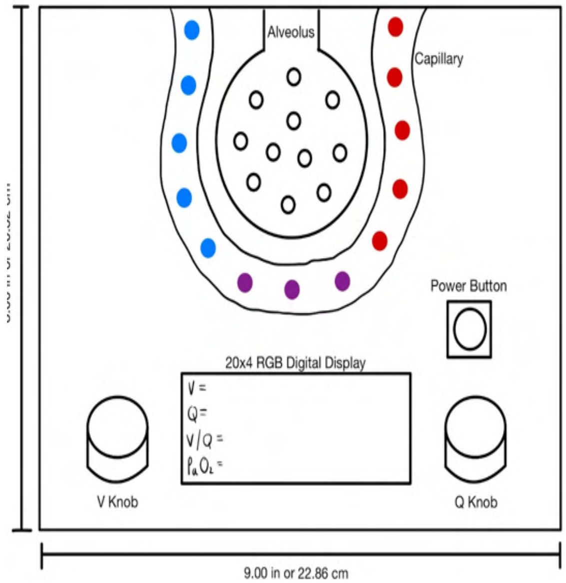


Figure 3. Design drawing for slider with LEDs and screen design

Design 2: Computer Animation

The software animation model refers to use of a programming language to create a software where ventilation and perfusion values can be input and the V/Q ratio, partial pressure of oxygen, and any other values the client would like to calculate would be output. Along with these values, the program could provide an animation of one or multiple alveoli with flow rates depicted through use of arrows, number of oxygen and carbon dioxide molecules, and speed at which the molecules flow through the animation.

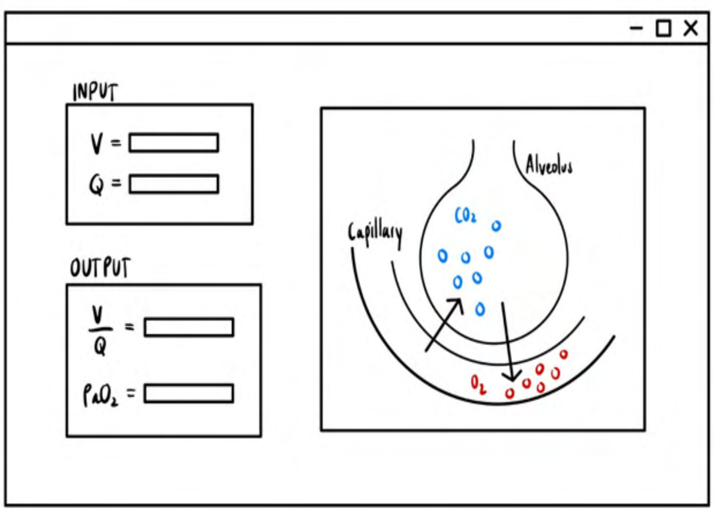


Figure 4. Design drawing for computer animation design

Design 3: Water/Dye Concentrations

The water and dye model uses a flexible tube that can expand and relax to show different blood flow levels. A colorful dye can be used to represent oxygenation of the blood. The water would run through the tube at different rates and depending on the ventilation value, a certain amount of dye would be excreted into the tube to show a colorful oxygenated blood flow. The amount of dye excreted and speed of water would be controlled by a computer program. The program could display the qualitative data on the computer such as V/Q ratio and partial pressure of oxygen in the blood.

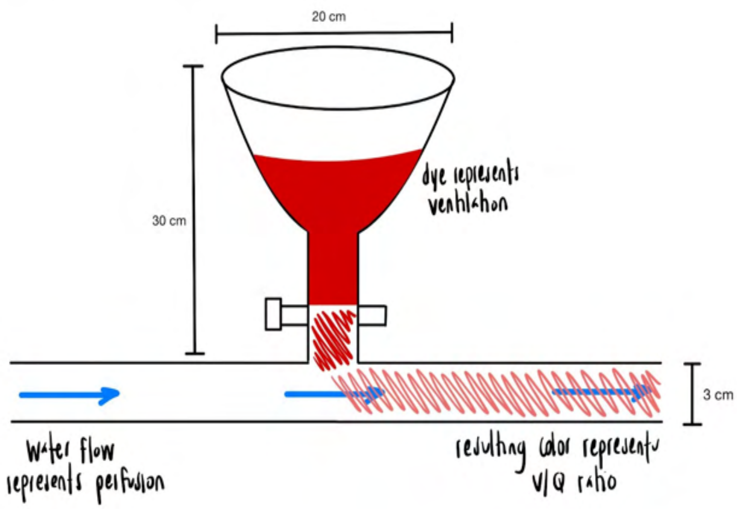


Figure 5. Design drawing for water/dye concentration design

IV. Preliminary Design Evaluation

Design Matrix

To determine necessary criteria for the design matrix, the primary purpose of this device was prioritized. Scores were given largely based on effectiveness of the potential designs as teaching models.

Intuitive use is the ability of the client to understand and use the product immediately after receiving it. The weight of this criteria is 30%, as the product will be used as a teaching model, and both the client and students must be able to use the model easily. The LEDs and screen design received full points as the interactive component of the sliders is easy to understand.

The learning outcomes criteria refers to the design’s effectiveness in leading students to understand the concept of ventilation and perfusion mismatching. Since the major purpose of the design is teaching, the weight of this criteria is given 30%. The LEDs and screen design allows students to understand the concept without confusion because oxygen levels at different V/Q ratios can be seen by adjusting the V/Q sliders.

The adjustability criteria refers to the ability to adjust V/Q input in order to be more precise and variable. The weight of adjustability is 20% because high adjustability will allow the client to better explain the concept of V/Q mismatching to different students. The adjustability of the LEDs and screen design is considered high because the slider in the design allows the client to adjust the ratio of V/Q in order to show the effects that different ratios have on flow rates.

Ease of fabrication was given a weight of 10% as there are many great resources available to us through the engineering department that will make the fabrication process much easier, especially for 3D printing.

The cost criteria was given a weight of 5% as the budget given by the client should be more than enough for the materials involved.

The safety criteria was given a weight of 5% as there are little to no safety risks involved.

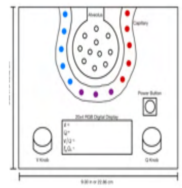
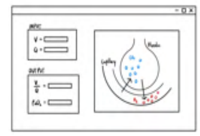
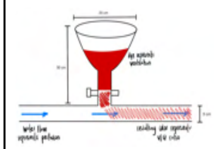
Criteria (Weight)	**Slider with LEDs and Screen*** 		**Computer Animation*** 		**Water/Dye Concentrations** 	
Intuitive use (30%)	5/5	30%	4/5	24%	2/5	12%
Learning Outcomes (30%)	4/5	24%	2/5	12%	4/5	24%
Adjustability (20%)	4/5	16%	5/5	20%	4/5	16%
Ease of fabrication (10%)	3/5	6%	2/5	4%	1/5	2%
Cost (5%)	2/5	2%	5/5	5%	2/5	2%
Safety (5%)	4/5	4%	5/5	5%	5/5	5%
Total		**82%**		**70%**		**61%**

Figure 6. Preliminary design matrix

Proposed Final Design

After much discussion as a team with both the client and advisor, the proposed final design is the slider with LEDs and screen design. This design would offer the best learning outcomes for medical students, allow for hands-on teaching and learning experiences, and be an intuitive tool for the classroom.

V. Fabrication/Development Process

Materials and Methods

The model runs through an Arduino Mega 2560, which was chosen because of the large number of digital ports. The capillary is represented by a NeoPixel LED flex strip, which contains 15 pixels that are individually controlled in the code. The gradient from blue to red represents the deoxygenated (blue) and oxygenated (red) blood moving through the capillary. Gas exchange would actually happen anywhere in this capillary if this was completely anatomically correct, but this was the best way it could be represented with a simple LED strip [7]. The speed of the LEDs turning on and off represents the perfusion rate, and at max speed, the perfusion value is 100. There is also a condition in the code testing if the perfusion value is less than 2, and if it passes, the capillary goes off, representing virtually no perfusion. An example of this code can be seen in Figure 7. To represent the ventilation in the alveolus, 10 individual LED bulbs were used. When all 10 of them are on the ventilation value is between 90 and 100, and when they are all off the ventilation rate is between 0 and 10. Ten holes with 3.175 mm diameter were drilled in the alveolus to be able to fit the terminals of the LED bulbs so the wires could be plugged into the Arduino. Another hole with 9.525 mm diameter was drilled at the inner surface of the LED strip channel which allows the terminal of the LED strip to be able to get through and connect to the breadboard. Controlling this ventilation and perfusion rate is facilitated through 2 potentiometers, which are attached to black knobs that are very easy to turn and adjust. Two 22.9 mm diameter holes were designed into the housing so the potentiometers could fit smoothly. They are calibrated so when fully turned, the value is 100, and when fully turned the other way, the value is 0. To visualize values (along with V/Q ratio and P_aO_2), a 20x4 LCD screen is utilized which allows for 4 lines of text, which is plenty of room for everything that needs to be displayed.

To house all of the components, A 3D-printed PLA box was created that has all the holes and divots needed to be able to fit all the potentiometers, lights, and LCD screens in it (see Figure 9). This PLA material was chosen because it has a 50 MPA tensile strength and 80 MPA flexural strength [10]. High strength of the outer shell secures enough mechanical strength of the model for daily storage and accidental impact due to fall down or hit by other objects. The model is 8.89cm tall, allowing for enough room to fit the Arduino Mega, 3 small breadboards, and a large amount of wires connecting all the components. A bottom for this model was also printed out of PLA, measuring slightly bigger (23.368 cm) than the top of the model to ensure a snug fit (see Figure 10). A hole cut in the side leaves enough room to connect the USB cord from the Arduino Mega to power through a computer. All the electronic components are glued inside the box with EPOXY glue and electronic tape in order to fit the components tightly in the box. Black plastic allows for the lights to stand out for clear viewing, and the 22.86 cm by 21.59 cm size allows for it to fit underneath a document camera without any difficulty.

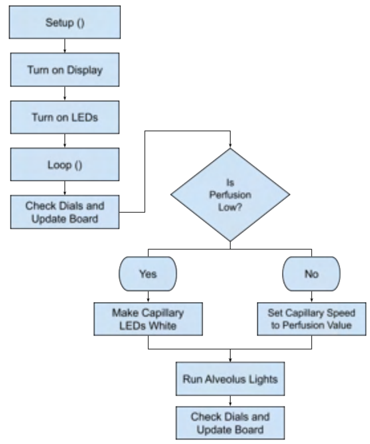


Figure 7: Code diagram

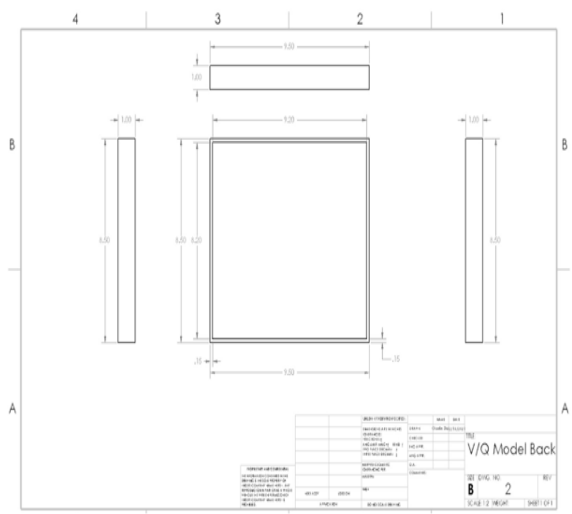


Figure 10: Bottom CAD model of print

Figure 11: Model display when Q=0, V≠0 (left), when V=1,Q≠0 (middle), and when Q≠0,V≠0 (right

Testing

The first test that was completed on the model was an initial qualitative test under a lecture hall document camera. Two team members visited a lecture hall in the health science learning center where the client, Chris Green, teaches. There, the original prototype from spring 2021 was tested underneath the document camera and on the projector. The test was completed on the original prototype to confirm the design specifications the new model was going to represent. To test visibility, intuitiveness, and potential improvements the prototype was placed on the document camera stage and then the image projected was evaluated from the back of the classroom. This test was designed to point out the visual flaws and failures of the existing model. The expected outcomes will describe aesthetic characteristics that can be improved in the next model.

Similarly to the initial qualitative test, the final prototype was tested under a document camera in a lecture hall. A document camera in a lecture hall, similar to the clients, was used. During the test, the same aspects as before (visibility, intuitiveness, and potential improvements) were evaluated. The expected results were improvements in component dimensions, projection visibility, and intuitiveness/ understanding of the model. However, the test still allowed for growth by evaluating and defining areas of physical improvements.

The last test was a repeatability/ quantitative test. This test was used to determine the durability of the electrical components and accuracy of the code. The test consists of changing the perfusion value and the ventilation value by turning the Q and V knobs respectively. Then based on the Q and V values, the V/Q ratio and partial pressure of oxygen were calculated by hand and compared to the displayed values from the code. This process was repeated five times to ensure the results were reliable. The test results will evaluate the ability of electrical components to work in harmony with each other and produce accurate displayed values every time. Additionally, the code is evaluated based on its accuracy and speed. The results will conclude if there are errors or variances in the displayed values when compared to the hand calculated values. The expected outcomes are the displayed values match the calculated values and the program runs smoothly and similarly every time.

VI. Results

The initial qualitative test on the original model yielded results that are congruent with design specifications that the fabrication plans will pursue. For example, the V and Q values were constrained to numbers 1-5 but the model would benefit from a wider range to represent different respiration cases. Additionally, the green colored LEDs representing the alveolus were a strange representation of oxygen in the lungs and confused the viewer. The full results of the initial quantitative test are listed in the appendix.

The final qualitative test on the final model yielded positive results aligning with the end goal of the project. The results varied significantly from the initial qualitative test, sometimes even being the exact opposite description. For example, the V and Q knobs yielded a range from 0.00-100.00, whereas the original model only had a scale from 1-5. Additionally, the originally green colored LEDs in the alveolus were replaced with white LEDs. The White LEDs were more visible on the projected screen and they represented oxygen in the alveolus better. The full results of the final quantitative test are listed in the appendix.

The repeatability test yielded very accurate results. The displayed values all matched with the relevant calculated values; however the discrepancy in significant figures makes the displayed values not exact values. For example during the first data collection, The V value was set at 90.00L/min and the Q value at 100.00L/min, the hand calculated P_aO_2 value was 101.8412mmHg but the displayed P_aO_2 was 101.84mmHg. The attendant uncertainty of the displayed values due to significant figures is ±0.01. The full results from the repeatability test are displayed in the appendix.

VII. Discussion

The implications of results from the initial qualitative test with the original model compared to the final qualitative test with the newest prototype confirms the newest model has properties of an improved teaching model. Specifically, the new model is much easier to view and understand in front of a lecture hall; thus, more students are able to engage and interact with the model in class. According to an article written by Anjana Verma et. al., forms of interaction in a medical classroom setting will positively impact the students' learning [9]. Therefore, the changes made to produce the new teaching model will increase interactiveness and overall understanding of perfusion and ventilation mismatching.

The results from the repeatability test ensure the newest prototype is electronically working properly and displays accurate V/Q ratios and P_aO_2. The model must display accurate calculations for medical students to understand how V/Q mismatching impacts oxygenation in the capillaries.

An ethical consideration for the use of the teaching model is understanding the model's purpose is only to improve medical students' understanding of V/Q mismatching. The model abstractly demonstrates what happens in the alveolus during V/Q mismatching; however, it is not an accurate depiction of what occurs automatically. Additionally, the teaching model should not be used as a diagnostic tool. Instead, the model is produced to help medical students understand what is happening in the human lungs but how to diagnose a patient with hypoxemia.

As a result of the initial qualitative test, the model was changed in the following ways: larger display board, larger baseboard, more accurate alveolus and capillary shape, white alveolus LED lights, black PLA, constant oxygenation gradient in the capillary, V and Q knobs for a wider range of values, and display of P_aO_2 value. The new model included all of the previously listed characteristics but could continue to be improved by building a slightly larger baseboard to comfortably enclose all electrical components. Lastly, the quantitative test confirmed proper calculation code but the display could be changed to show more significant figures for more accurate values.

A potential source of error in the two qualitative tests is missing information that could have better-constructed design specifications that could have been recorded in a more thorough examination of the prototype under the document camera. A potential source of error in the quantitative test is that the same equation was used in the code as it was used in the hand-calculated values. The equation was obtained directly from the client but if it was in any way flawed, the test would not have been able to determine the displayed values of V/Q ratio and P_aO_2 were correct.

VIII. Conclusions

The team was tasked with creating a teaching model for ventilation and perfusion mismatching. This issue is the most common cause of hypoxemia, however students have a difficult time grasping the complex topic. The client, Dr. Chris Green, was seeking an effective teaching model that offers a good visualization of the V/Q ratio in an alveolus of the lung. After much discussion and deliberation, the team finalized the slider with the LEDs design. However, after preliminary testing and with the client's suggestion, it was decided that the display screen had to be made bigger. It was also necessary to make the model more anatomically accurate. The model was hence redesigned to reflect the new requirements. Further, the buttons that controlled V/Q ratio values were replaced with knobs to allow the model to represent a wider range of ratios.

The model was then tested under a document camera that was similar to the one in the health-sciences lecture hall to check for visibility, usability, and intuitiveness. The code was then tested multiple times to check its accuracy. Simultaneously, the durability of the electrical components were tested. Overall, the model is a well functioning prototype; however, more improvements are required, for example making the circuitry within the model more efficient. It is also necessary to make sure that the power supply is solely not dependent on the laptop power, perhaps adding a battery backup to the model would make it more efficient. More testing has to be done on the model to ensure that it is durable enough to handle everyday use. Further, the code used has to be made more readable so that it can be reproduced more easily in future models. Another potential improvement to the model would be to include two alveoli instead of just one alveolus to represent the mechanism in the lungs better, making the model more anatomically accurate.

IX. References

[1] Peter D. Wagner, "VENTILATION-PERFUSION RELATIONSHIPS," Department of Medicine, University of California, San Diego, La Jolla, California 92093 , 1265, 1980 [Online Journal]. Available: https://www.annualreviews.org/doi/pdf/10.1146/annurev.ph.42.030180.001315. [Accessed: 14-Dec-2021]

[2] J. B. West, "Ventilation-perfusion inequality and overall gas exchange in computer models of the lung," Respiration Physiology, vol. 7, no. 1, pp. 88–110, Jun. 1969, doi: 10.1016/0034-5687(69)90071-1. [Online Jounal]. Available: https://linkinghub.elsevier.com/retrieve/pii/0034568769900711. [Accessed: 13-Dec-2021]

[3] Juan Siliezar. (2021, October 1). Finding a hands-on approach to remote learning. [Online Journal]. Available: https://news.harvard.edu/gazette/story/2021/10/study-finds-students-learn-better-through-physical-participation/.

[4] M. D. Lynne Eldridge, "What are the alveoli and how do they work?," *Verywell Health*, 01-Sep-2021. [Online]. Available: https://www.verywellhealth.com/what-are-alveoli-2249043. [Accessed: 20-Oct-2021].

[5] Deborah Leader, R. N. (n.d.). What people with copd should know about v/q mismatch. *Verywell Health*. Retrieved September 24, 2021, from https://www.verywellhealth.com/what-is-vq-mismatch-in-the-lungs-914928.

[6] P. D. Wagner, H. A. Saltzman, and J. B. West, "Measurement of continuous distributions of ventilation-perfusion ratios: theory," Journal of Applied Physiology, vol. 36, no. 5, pp. 588–599, May 1974, doi: 10.1152/jappl.1974.36.5.588. [Online Journal]. Available: https://www.physiology.org/doi/10.1152/jappl.1974.36.5.588. [Accessed: 13-Dec-2021]

[7] A. Yartsev, "Effects of ventilation-perfusion mismatch on gas exchange: Deranged physiology," *Effects of ventilation-perfusion mismatch on gas exchange | Deranged Physiology*, 07-Dec-2019. [Online]. Available: https://rb.gy/3l9agb [Accessed: 20-Oct-2021].

[8] D. Dugdale, MD, “Gas exchange: MedlinePlus Medical Encyclopedia,” 25-Jul-2020. [Online]. Available: https://medlineplus.gov/ency/anatomyvideos/000059.htm. [Accessed: 13-Dec-2021]

[9] A. Verma, A. Patyal, J.K. Meena, M. Mathur, N. Mathur. (2021, April 10th). Interactive teaching in medical education: Experiences and barriers. [Online]. Available: https://aujmsr.com/interactive-teaching-in-medical-education-experiences-and-barriers/#aff1. [Accessed: 14-Dec-2021]

[10] “What is pla? (everything you need to know),” *TWI*. [Online]. Available: https://www.twi-global.com/technical-knowledge/faqs/what-is-pla#Properties. [Accessed: 15-Dec-2021].

X. Appendix

Product Design Specification

Teaching Model for Ventilation and Perfusion Mismatching
Alex Houle, Charlie Zhu, Darshigaa Gurumoorthy, Kendra Besser, and Milica Lukic
09/24/2021

Function:

Ventilation and perfusion mismatching is the most predominant cause of hypoxemia. However, medical students often have a very difficult time understanding this concept. Other than a textbook diagram by John West in his text *Respiratory Physiology* [1], there are no relevant representations of ventilation/perfusion mismatching. Our goal is to improve a prototype completed by previous UW Madison students to create an effective teaching model of ventilation/ perfusion mismatching to be studied by medical students for a deeper understanding of hypoxemia.

Client requirements:

- Sliding knobs for changing the V/Q ratio to represent different levels of mismatching
- Output that shows oxygenation (client will help with calculations)
- A digital display of some sort for the values (or displayed on computer screen)

- Able to be showed in lecture hall under document camera
- Not necessarily realistic, but good representation of what happens in the body at different V/Q levels leading to hypoxemia

Design requirements:

1. **Physical and Operational Characteristics**
   a. Performance requirements:
      i. A physical model to represent the concept of ventilation/perfusion mismatching and how it leads to hypoxemia
      ii. Used in a classroom setting
      iii. Ability to change ventilation/perfusion ratio

   b. Safety:
      i. No danger of electrocution (no loose wires)
      ii. Shell has no sharp corners

   c. Accuracy and Reliability:
      i. All coding should be free of error and reproducible/stored where it can be retrieved easily
      ii. This will be further analyzed after our testing phase

   d. Life in Service:
      i. Arduino Uno may need to be replaced after approximately one year depending on the conditions under which it is stored
      ii. Under good conditions for electrical components, expected life in service should be at least 5 years
      iii. As a teaching model, device should last throughout lectures and hands on learning

   e. Shelf Life:
      i. The product should be able to withstand storage for long periods of time. (At least five years under good condition of electronic components)
      ii. The product needs to be reusable and could be set up easily
      iii. The product will be placed in a sealed container in order to maintain a low moisture level
      iv. Ideal storage temperature is in the range of 10-27℃ [2] (50-80 ℉)

   f. Operating Environment:
      i. Classroom setting, not exposed to harsh elements
      ii. Slight risk of damage due to mishandling between transition from classroom to storage

   g. Ergonomics:
      i. Very light and portable
      ii. Be able to be displayed in a lecture hall using a document camera, or seen in a small-group setting (within 3 meters of the device)

h. Size:
   i. Roughly 22.86cm x 22.86cm

i. Weight:
   i. Easily movable and carryable, no more than 15 lbs

j. Materials:
   i. 3D printed base because it is lightweight and cost effective
   ii. LED lights to represent V/Q ratios because they are energy efficient

k. Aesthetics, Appearance, and Finish:
   i. No specific color
   ii. No loose wires or sharp corners
   iii. Digital display of some kind for relevant values
   iv. Computer program for inputting different V/Q ratios and visualizing effects on the human body if possible

2. Production Characteristics

a. Quantity: number of units needed
   i. 4 units
      1. 3D printed base to hold all components together
      2. LED lights connected to create a string of illumination
      3. Arduino to connect the LEDs and program the model
      4. Sliders/ buttons to change the ventilation/perfusion mismatching ratios

b. Target Product Cost:
   i. To be determined once production phase begins
   ii. Similar cost to previous semster's prototype (about $140)

3. Miscellaneous

a. Standards and Specifications:
   i. No applicable at this time

b. Customer:
   i. Medical students and educators would be the customers
   ii. Should be an effective teaching model, with interactive learning aspects for medical students to understand the complex topic

c. Patient-related concerns:
   i. Device will need to be carefully stored in order to prevent deterioration of electrical components

d. Competition:

i. Currently, there are no effective teaching models on the market

Citations

[1] West, J. B., & Luks, A. (2021). *West's respiratory physiology: The essentials*. Wolters Kluwer.

[2] *Storing electronics in a storage unit: Storing electronics in heat + cold*. EZ Storage. (2019, October 22). Retrieved September 24, 2021, from https://www.ezstoragenow.com/blog/delicate-balance-properly-storing-electronics-heat-cold/#:~:text=The%20trick%20to%20properly%20storing,between%2050%20and%2080%20degrees.

Table 1. Cost and materials chart in order of purchase with the most recent at bottom.

Item	**Manufacturer**	**Quantity**	**Cost/Unit**	**Link**
Digital Display	Adafruit	1	$24.95	https://www.adafruit.com/product/498#technical-details
Panel Mount 10K potentiometer	Adafruit	2	$1.90	https://www.adafruit.com/product/562
Panel Mount Right Angle 10K Linear Potentiometer	Adafruit	2	$3.00	https://www.adafruit.com/product/3395
Solid Machines Metal Knob	Adafruit	2	$7.90	https://www.adafruit.com/product/2056#description
3D printing prototype (1) fabrication cost	Ultimaker	1	$25.92	https://making.engr.wisc.edu/mini-mart/
3D printing prototype_board (2) fabrication cost	Ultimaker	1	$23.28	https://making.engr.wisc.edu/mini-mart/
3D printing prototype_lid (2) fabrication cost	Ultimaker	1	$22.96	https://making.engr.wisc.edu/mini-mart/
3D printing prototype_board (3) fabrication cost	Ultimaker	1	$37.92	https://making.engr.wisc.edu/mini-mart/
3D printing prototype_lid (3) fabrication cost	Ultimaker	1	$16.00	https://making.engr.wisc.edu/mini-mart/
3D printing prototype_lid (4) fabrication cost	Ultimaker	1	$18.32	https://making.engr.wisc.edu/mini-mart/
Super Glue	Pacer	1	$1.15	https://making.engr.wisc.edu/mini-mart/
Arduino Mega	Elegoo	1	$22.00	https://making.engr.wisc.edu/mini-mart/

Large Breadboard	Adafruit	1	$3.00	https://making.engr.wisc.edu/mini-mart/
Led bulbs	Adafruit	16	$4.00	https://making.engr.wisc.edu/mini-mart/
Female to male Arduino wires	Adafruit	40	$2.00	https://making.engr.wisc.edu/mini-mart/
Heat Shrink	Eventronic	9	$0.90	https://making.engr.wisc.edu/mini-mart/
Epoxy	Hardman	5	$7.50	https://making.engr.wisc.edu/mini-mart/
LED Strip	Adafruit	2	$25.00	https://www.adafruit.com/product/3919?gclid=CjwKCAjww5r8BRB6EiwArcckCzEIg95MquQekbTMIV_LZ4VwndfflJ-GjxrnGvsVQTvlRloZGAF2jxoCVIoQAvD_BwE
Bright White 5mm LED (25 pack)	Adafruit	1	$6.95	https://www.adafruit.com/product/754
Total	$254.65			

Raw Experimental Data

Table 2. Comparing the initial qualitative test results to the final qualitative test results, each row evaluates the same topic.

Initial Test	Final Test
Model has to be connected to personal laptop through USB to obtain power	Model has to be connected to personal laptop through USB to obtain power
Grey PLA produces a shine that distracts the viewers eyes from the LED lights, Black PLA would increase visibility of the LEDs	Black PLA contrasted well with the LEDs and made the front face of the model easier to see on the projected screen
Electronic display needs to be roughly 4 times larger than the previous model because display was very hard to read on the projected screen	Display screen was large enough to produce clear and easy to read values
Red and dark colored text was difficult to view on a black display screen	The text on the display was very visible and easy to read against the contrasting background
Green LEDs do not display well under the document camera and make the alveoli difficult to understand	LED lights and LED flex strip are easy to see on the projection
Scratches on the PLA baseboard are very apparent under the document camera	Baseboard has a clean finish and is not distracting to the viewer
Previous model alveolus is too complex and difficult to understand	Labels made the alveolus and capillary representation intuitive and easy to understand
Overall prototype dimensions (17.24cm x 17.24cm) are too small to have model well spaced out	Overall prototype dimensions (22.86cm x 21.59cm) fit well on the projection screen
The V and Q buttons only had values 1-5	The V and Q knobs ranged from values 0.00-100.00

Table 3. Comparing displayed values of V/Q ratio and P_aO_2 (calculated by code) to values calculated manually.

V Value (L/min)	Q Value (L/min)	V/Q Ratio Displayed	P_aO_2 Displayed (mmHg)	V/Q Ratio Calculated	P_aO_2 Calculated (mmHg)
90.00	100.00	0.90	101.84	0.9000	101.8412
6.00	37.00	0.16	50.42	0.1622	50.4199
29.00	56.00	0.52	82.14	0.5179	82.1384
59.00	100.00	0.59	86.86	0.5900	86.8567
6.00	74.00	0.08	43.33	0.0811	43.3342

2021/10/19 Dr. Green V/Q Notes

Kendra Besser - Oct 20, 2021, 1:07 AM CDT

Title: Dr. Green V/Q Notes

Date: 10/19/2021

Content by: Kendra Besser

Present: NA

Goals: Individual work entry to record my notes on the lecture of V/Q ratios, what they are, and why they are important from Dr. Green.

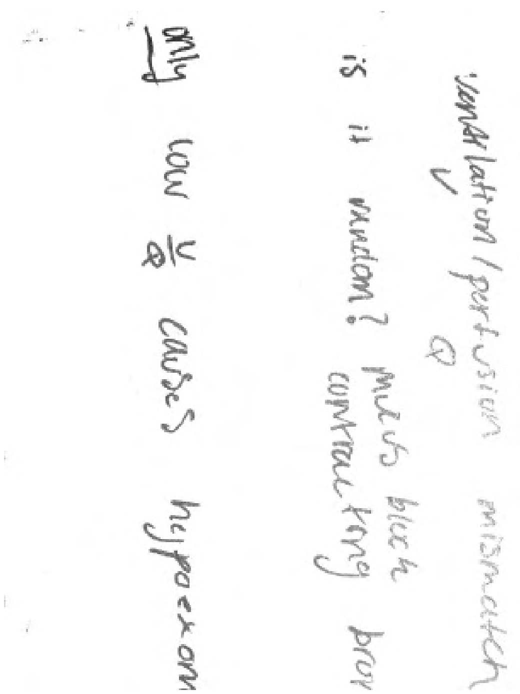
Content:

see attachment below

Conclusions/action items:

During an Early meeting with Dr. Green, he explained to us what exactly ventilation and perfusion mismatching ratios are and why they are so important to recognize as a serious concern in the medical community. I recorded the main take aways from his lecture of V/Q ratios and some asked and answered questions I had during the meeting.

Kendra Besser - Oct 20, 2021, 1:07 AM CDT


ventilation / perfusion mismatch
V Q
is it random? mucus block
constricting bron
only low V/Q causes hypoxem

2021-10-20_00-53.pdf(184.4 KB) - download

2021/10/19 V/Q Understanding

Kendra Besser - Oct 20, 2021, 1:19 AM CDT

Title: V/Q Understanding

Date: 10/19/2021

Content by: Kendra Besser

Present: NA

Goals: Individual work entry to record the youtube video I referenced and learned exactly what V/Q mismatching was.

Content:

https://www.youtube.com/watch?v=1s1pymQlhqU

Conclusions/action items:

Here is a thirteen minuet video that effectively wraps up exactly what V/Q ratios are and what V/Q mismatching is. After watching the video it is clear that ventilation and perfusion mismatching has significant and detrimental effects to the human body, especially when the body is exposed to ventilation and perfusion mismatching for a long time.

2021/10/19 Everything on the market

Kendra Besser - Oct 20, 2021, 1:14 AM CDT

Title: Everything on the Market

Date: 10/19/2021

Content by: Kendra Besser

Present: NA

Goals: Individual work entry to record my notes during a meeting with Dr. Green as he explained everything on the market right now for a teaching model of ventilation and perfusion mismatching.

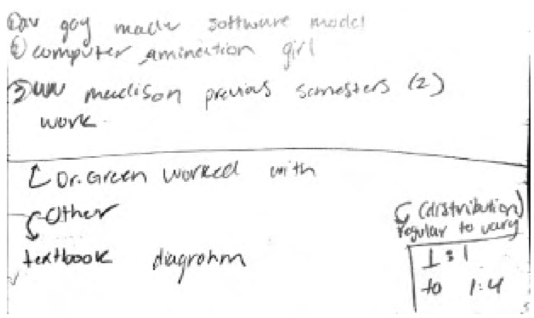
Content:

see attachment below

Conclusions/action items:

During an early meeting with Dr. Green, he explained, in order, who he has collaborated with to create an effective teaching model of ventilation and perfusion mismatching. the top half of the notes include everyone that Dr. has directly worked with to create different forms of this teaching model. The bottom half of the notes include the only other model of the ventilation perfusion mismatching system which is a textbook diagram by John West.

Kendra Besser - Oct 20, 2021, 1:14 AM CDT


1 guy made software model
2 computer amination girl
3 UW madison previous semesters (2) work
Dr. Green worked with
Other
textbook diagrahm
(distribution) regular to vary
1:1 to 1:4

2021-10-20_00-52.pdf(94.5 KB) - download

2021/10/19 Previous UW Students' Work

Kendra Besser - Oct 20, 2021, 1:32 AM CDT

Title: Previous UW Students' Work

Date: 10/19/2021

Content by: Kendra Besser

Present: NA

Goals: Individual work entry to record my notes and references to the two semesters worth of work at UW Madison that have worked on this project already.

Content:

Website to Spring 2021 https://bmedesign.engr.wisc.edu/projects/s21/hypoxemia_model

Website to Fall 2021 https://bmedesign.engr.wisc.edu/projects/f20/hypoxemia_model

Conclusions/action items:

We will be using these two previous semesters work as a starting grounds for our designs. We will build off of what these students have accomplished, especially their prototype. Our client has requested for significant changes from the preexisting prototype so we know that there are changes to be made and challenges to come with that. There will potentially be one other semester that works off of our work for a finalized product so we will get as far as we can in the design process while maintaining the clients needs.

2021/12/15 ventilation and perfusion textbook diagram

Kendra Besser - Dec 15, 2021, 2:06 PM CST

Title: ventilation and perfusion textbook diagram

Date: 12/15/2021

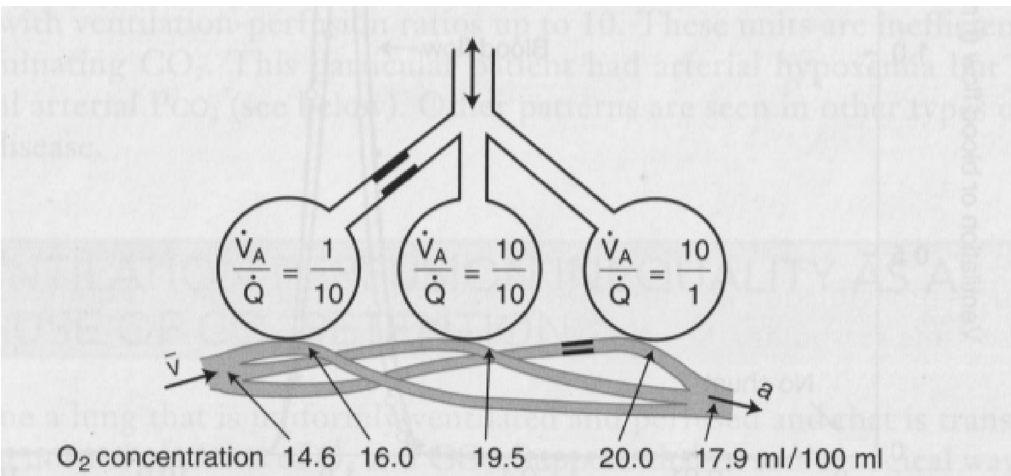
Content by: Kendra

Present: Kendra

Goals: Record the only V/Q mismatching model that is currently used to teach medical students.

Content:

below is the textbook image from *Respiratory Physiology* by John West. The chapter on V/Q mismatching has a few diagrams but the one below is the best representation of the alveolus and capillary. It is not an interactive model and can only represent 3 scenarios instead of an infinite amount like our model can.



J. B. West, "Ventilation-perfusion inequality and overall gas exchange in computer models of the lung," Respiration Physiology, vol. 7, no. 1, pp. 88–110, Jun. 1969, doi: 10.1016/0034-5687(69)90071-1. [Online]. Available: https://linkinghub.elsevier.com/retrieve/pii/0034568769900711. [Accessed: 13-Dec-2021]

Conclusions/action items:

The textbook model is the only V/Q mismatching diagram that is currently used to teach medical students; however, it is not interactive and only shows three different ratios instead of an infinite about of scenarios.

2021/10/19 Design Sketches

Kendra Besser - Oct 20, 2021, 12:45 AM CDT

Title: Design Sketches

Date: 10/19/2021

Content by: Kendra Besser

Present: NA

Goals: Individual work entry to record my original design ideas and rough sketches.

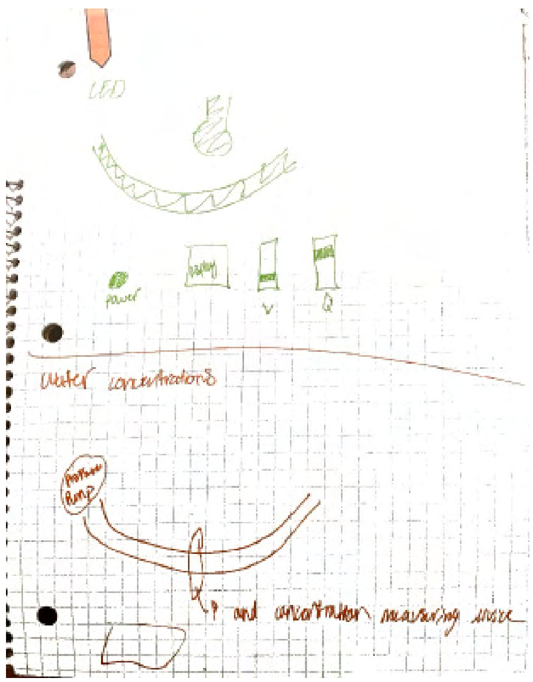
Content:

see attachment below

Conclusions/action items:

Here are a few sketches of original designs that I had came up with during the brainstorming process and tweaked during our team meeting. The first sketch in green is the design of a single alveolus represented by LED lights, a display window, a power button, and v and q separate sliders to create any input ratio value. The second sketch in orange is a rough draft of the water/ dye concentration model. A water pump would be used to change "perfusion levels" and dye would be injected to represent ventilation levels/ oxygenation. The last sketch in green is similar to the first sketch but represent two alveoli that each have their own V and Q sliders to represent contrasting V/Q ratios.

Kendra Besser - Oct 20, 2021, 12:45 AM CDT



2021-10-20_00-35.pdf(474.8 KB) - download

2021/10/19 Design Notes

Kendra Besser - Oct 20, 2021, 12:49 AM CDT

Title: Design Notes

Date: 10/19/2021

Content by: Kendra Besser

Present: NA

Goals: Individual work entry to record my original design notes and specifications.

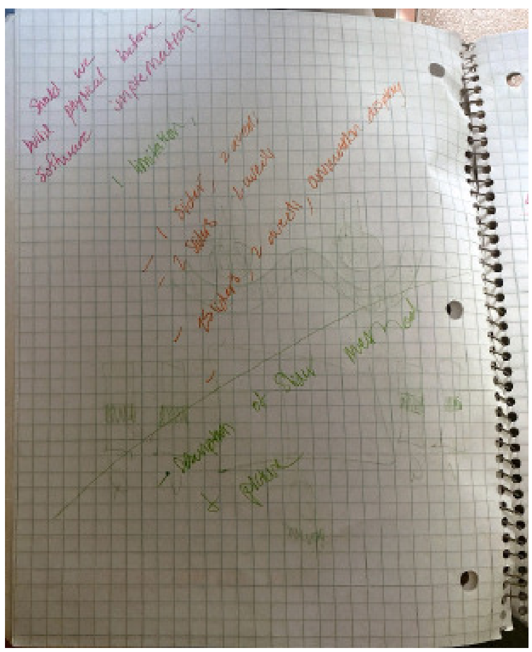
Content:

see attachment below

Conclusions/action items:

Below is a PDF to rough notes I drafted during the team and advisor meeting regarding design ideas. Listed are a few questions along with follow up answers about the design specifications, along with the list of design we went forward with to complete the design matrix, and notes on software resources to help with our coding/ display setup and design matrix criteria notes to fix.

Kendra Besser - Oct 20, 2021, 12:49 AM CDT



2021-10-20_00-37.pdf(573.4 KB) - download

2021/10/19 Design Criteria

Kendra Besser - Oct 20, 2021, 1:00 AM CDT

Title: Design Criteria

Date: 10/19/2021

Content by: Kendra Besser

Present: NA

Goals: Individual work entry to record my notes during a meeting with Dr. Green while he specified the design criteria he was looking for.

Content:

see attachment below

Conclusions/action items:

During an early meeting with Dr. Green, I recorded notes regarding the design criteria that our client was looking for. These elements of design is what will make our design unique to anything else on the market right now and it will make it a better teaching model to help medical students learn about ventilation and perfusion mismatching.

Kendra Besser - Oct 20, 2021, 1:01 AM CDT

-Sliders to increase V and Q s

-Something to show oxygenati

(Ex: high + normal V/Q is norm

but low + shunt is bad.)

-2 alveoli to show different rat

-size of dimmer plate fit on

cam for lecture hall

2021-10-20_00-56.pdf(161.2 KB) - download

2021/10/1 Design Matrix Descriptions

Kendra Besser - Oct 20, 2021, 1:38 AM CDT

Title: Design Matrix Description

Date: 10/19/2021

Content by: Kendra Besser

Present: NA

Goals: Individual work entry to record my original water/dye concentration description on the design matrix.

Content:

My original:

The water and dye model uses a flexible tube that can expand and relax to show different blood flow volume measurements and a colorful dye that can be used to represent oxygenation of the blood. The water would run through the tube at different rates and depending on the alveolus represented some amount of dye would be excreted into the tube to show a colorful oxygenated blood flow. The amount of dye excreted and velocity of water would be controlled by a computer program so that qualitative data can be displayed on a computer to show the V/Q ratios and oxygen levels of the portrayed blood flow.

Collaborated combined:

The water and dye model uses a flexible tube that can expand and relax to show different blood flow volume measurements and a colorful dye that can be used to represent oxygenation of the blood. The water would run through the tube at different rates and depending on the avelious represented some amount of dye would be excreted into the tube to show a colorful oxygenated blood flow. The amount of dye excreted and velocity of water would be controlled by a computer program so that qualitative data can be displayed on a computer to show the V/Q ratios and oxygen levels of the portrayed blood flow.

Conclusions/action items:

As we finalized three designs to compare in our design matrix, I came up with a description of the water/ dye concentration model and how it would work to represent ventilation and perfusion mismatching. After a draft, some teammates helped revise and edit the description to make it very clear and understandable. The first description is my original draft, the second description is the collaborated combined one.

2021/11/4 Design Materials

Kendra Besser - Nov 04, 2021, 8:42 PM CDT

Title: Design Materials

Date: 11/4/2021

Content by: Kendra Besser

Present: NA

Goals: Recall what last year's prototype used for materials, specifically electronic work. Determine what should be reused and what should be replaced/ bought to build a new prototype.

Content:

Last years Prototype reuse items:

- Arduino nano (for coding)
- NeoPixel LED flex strip (blood-flow)
- NeoPixel LED rings - 3 different sizes inter-nested (alveolus)
- only one LED momentary contact button (power)
- Use similar coding pattern as last semester

Buy new items:

- LCD display (same as last year but larger dimensions) https://www.mouser.com/c/optoelectronics/displays/lcd-displays/?gclid=CjwKCAjwiY6MBhBqEiwARFSCPtgfnwPQ-G9ui-LtJAvW_Pr_zBeF4kec_gw1oWsSYjxBTcCHaetlmxoC48sQAvD_BwE
    - https://www.mouser.com/ProductDetail/Gravitech/LCD-20x4Y?qs=sGAEpiMZZMt7dcPGmvnkBq0MZpGAyiOXNk3qeXBf2gA%3D
    - https://store-usa.arduino.cc/products/grove-oled-display-1-12?selectedStore=us
- slider (V/Q ratio input)
    - https://www.mouser.com/ProductDetail/Apem/SLB1570?qs=i1KciFEqNAYRCX6bybaRtw%3D%3D
    - or thumbwheel switch https://www.mouser.com/c/electromechanical/switches/?product%20type=Thumbwheel%20Switches
        - https://www.mouser.com/ProductDetail/TE-Connectivity-Alcoswitch/B5LS?qs=A1HSVPaMh5TU7hkBRRMFsg%3D%3D
    - or rotary switch (no good ones on mouser)
- PLA 3D printed base (new dimensions and black plastic)

Conclusions/action items: We need to order a larger LCD display, Arduino nano sliders, and PLA 3D printed base with new dimensions and in black plastic.

2021/12/3 cura file for design 1

Kendra Besser - Dec 15, 2021, 2:33 PM CST

Title: cura file for design 1

Date: 12/3/2021

Content by: Kendra

Present: Kendra

Goals: Created a cura file from my solidworks drawing of model 1.

Content:

see attachments below. has the back and top pieces.

Conclusions/action items:

The file will be 3D printed at the makerspace, tested, and then revised for another draft.

Kendra Besser - Dec 15, 2021, 2:33 PM CST

VQ_model_1.STL(47.5 KB) - download

Kendra Besser - Dec 15, 2021, 2:33 PM CST

Back_1.STL(1.4 KB) - download

2021/12/7 cura file for design 2

Kendra Besser - Dec 15, 2021, 2:37 PM CST

Title: cura file for design 2

Date: 12/7/2021

Content by: Kendra

Present: Kendra

Goals: Created a cura file from my solidworks drawing of model 2.

Content:

see attachments below. has the back and top pieces.

Conclusions/action items:

The file will be 3D printed at the makerspace, tested, and then revised for another draft.

Kendra Besser - Dec 15, 2021, 2:37 PM CST

VQ_model_2.STL(47.5 KB) - download

Kendra Besser - Dec 15, 2021, 2:37 PM CST

Back_2.STL(1.4 KB) - download

2021/12/7 cura file for design 3

Kendra Besser - Dec 15, 2021, 2:38 PM CST

Title: cura file for design 3

Date: 12/7/2021

Content by: Kendra

Present: Kendra

Goals: Created a cura file from my solidworks drawing of model 3.

Content:

see attachments below. has the back and top pieces.

Conclusions/action items:

The file will be 3D printed at the makerspace, tested, and then revised for another draft.

Kendra Besser - Dec 15, 2021, 2:38 PM CST

Back_3.STL(1.4 KB) - download

Kendra Besser - Dec 15, 2021, 2:38 PM CST

VQ_model_3.STL(46.4 KB) - download

2021/12/9 cura file for design 4

Kendra Besser - Dec 15, 2021, 2:38 PM CST

Title: cura file for design 4

Date: 12/9/2021

Content by: Kendra

Present: Kendra

Goals: Created a cura file from my solidworks drawing of model 4.

Content:

see attachments below. has the back and top pieces.

Conclusions/action items:

The file will be 3D printed at the makerspace, tested, and then revised for another draft.

Kendra Besser - Dec 15, 2021, 2:39 PM CST

back_for_dr._greeen.SLDPRT(65.4 KB) - **download**

Kendra Besser - Dec 15, 2021, 2:39 PM CST

VQ_model_for_dr._green.SLDPRT(217.3 KB) - **download**

Kendra Besser - Dec 15, 2021, 2:39 PM CST

VQ_model_for_dr._green.STL(39.5 KB) - **download**

2021/12/14 Red Permit

Kendra Besser - Dec 15, 2021, 1:15 PM CST

Title: Red Permit

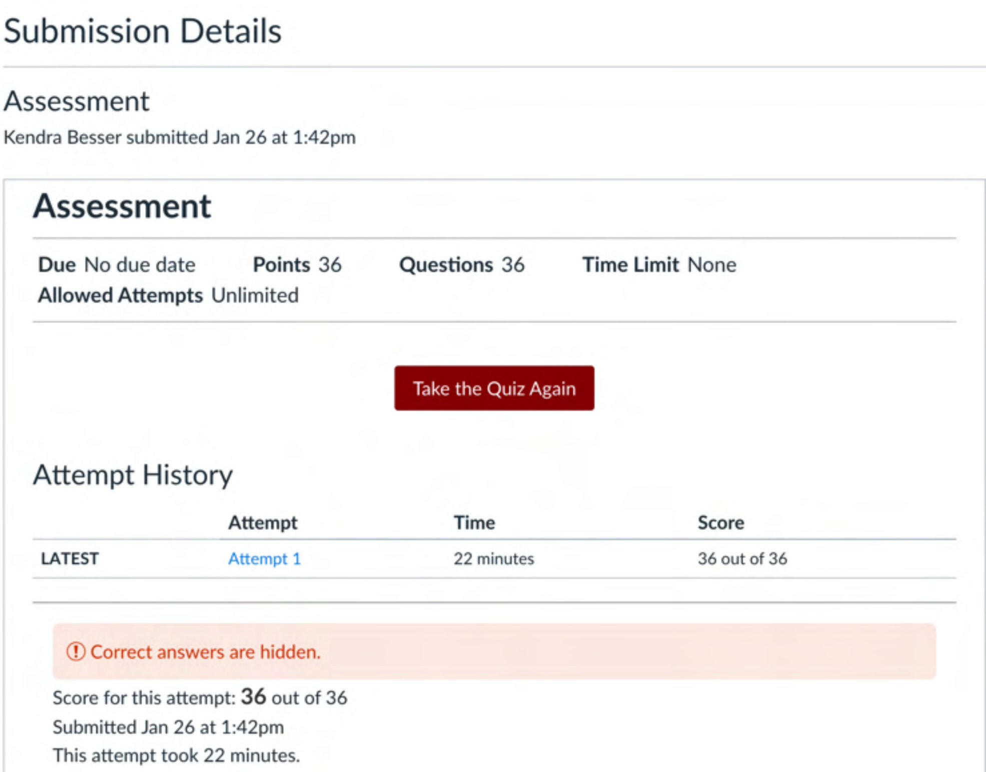
Date: 12/14/2021

Content by: Kendra Besser

Present: Kendra

Goals: Record my red permit standing in the maker space.

Content:



Conclusions/action items:

I have completed my red permit standing in the maker space. I will work to complete the blue permit next.

9/22/21 VQ ratio notes

Alex Houle - Oct 20, 2021, 12:59 PM CDT

Title: Understanding the VQ ratio

Date: 2021/09/21

Content by: Alex Houle

Present: Alex Houle

Goals: Understanding the concept of V/Q ratio

Content:

V: ventilation, amount of air that reaches your alveoli

Q: perfusion, amount of blood that flows to your capillaries

Normal ratio: 0.8

V/Q ratio = liters of oxygen/liters of blood going through the lungs per minute

Too high = V unusually large or Q unusually low

V unusually large = dead space ventilation (more ventilation than needed), less efficient carbon dioxide removal

Q unusually low = not enough blood to lungs, due to blood clot (pulonary embolism, most common) can also be blood disorders, inflammatory diseases, others

Too low: V unusually low or Q unusually high

V unusually low: airway blockage, COPD, asthma, other breathing issues

Q unusually high: not common/not relevant

Mismatch of this ratio: hypoxemia - not enough oxygenated blood in the body

https://erj.ersjournals.com/content/44/4/1023
https://www.mayoclinic.org/diseases-conditions/pulmonary-hypertension/symptoms-causes/syc-20350697

Conclusions/action items:

More research on how alveoli oxygenates blood - relate to project design

Talk to client about unusually high ventilation ratio - cause for concern? Does it actually happen?

10/01/21 Alveoli Notes and Diagrams

Alex Houle - Oct 20, 2021, 1:17 PM CDT

Title: Alveoli Notes and Diagrams

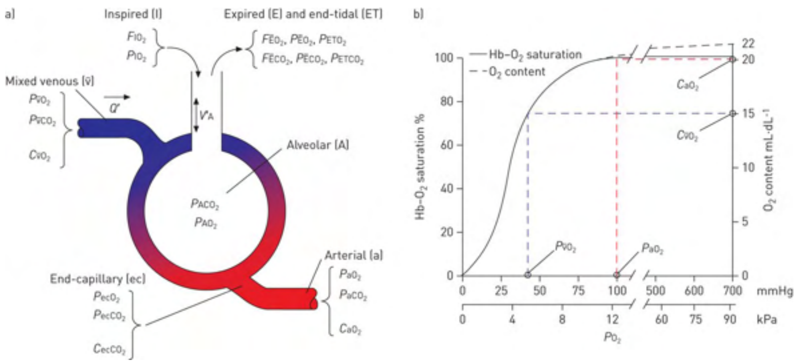
Date: 2021/10/01

Content by: Alex Houle

Present: Alex Houle

Goals: Learn more about the alveoli and find diagrams to study to gather understanding of the concept

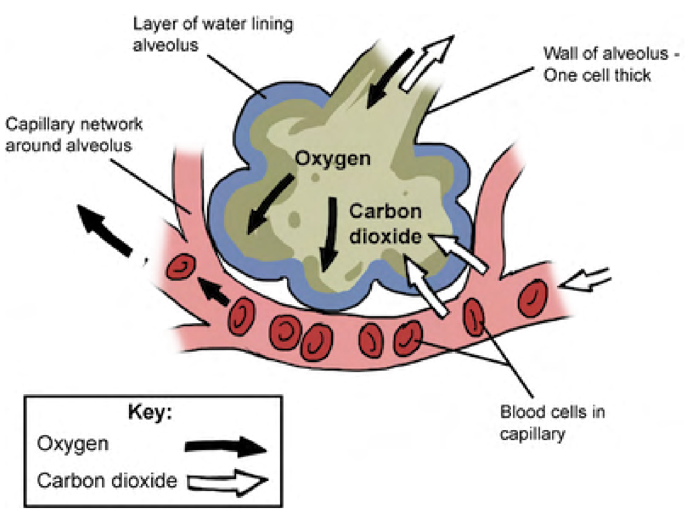
Content:



Vein in blue brings in unoxygenated blood, comes out artery in red.

Inspired air comes into alveoli, oxygenates blood, then expired air exits

Right graph shows oxygenation of tissues, blood must contain normal concentration of hemoglobin. Shifts of this curve can be due to VQ mismatch



Blockage of airways will result in unoxygenated red blood cells

Capillary network around all alveoli in body

600 million alveoli in the body

https://erj.ersjournals.com/content/erj/44/4/1023/F1.medium.gif

https://pmgbiology.files.wordpress.com/2015/10/biobook_animalmovement_graphik_38.png

Conclusions/action items:

Apply knowledge of these diagrams to project - how can I apply this to a physical model?

How do multiple alveoli work together?

11/04/21 Ventilation and Perfusion Notes

Alex Houle - Nov 04, 2021, 9:24 PM CDT

Title: Ventilation and perfusion notes

Date: 2021/11/04

Content by: Alex Houle

Present: Alex Houle

Goals: Learn about the range of ventilation and perfusion

Content:

Minute ventilation is a measurement of the volume of inhaled and exhaled air over 60 seconds. A typical adult VE ranges around 4 to 6 liters in 60 seconds.

Roughly doubles with light activity

Can increase by about 40 with heavy exercise

Cannot find anything about minute ventilation

Need to talk to Dr. Green about where to set range.

For perfusion, areas of lung below the heart having increased perfusion relative to ventilation due to gravity

Average is about 5 liters of blood reaching alveoli per minute

Need to find more information about perfusion rate: difficult to find information about how much blood is

https://www.acepnow.com/article/avoid-airway-catastrophes-extremes-minute-ventilation/

https://teachmephysiology.com/respiratory-system/gas-exchange/ventilation-perfusion/

Conclusions/action items:

Talk to Dr. Green about these ranges!!

How much does he want to be able to customize range?

How is the perfusion rate measured in adults?

Current prototype measures 0-5. Is this too simple?

10/12/21 Textbook diagram

Alex Houle - Oct 20, 2021, 1:46 PM CDT

Title: Textbook Diagram of VQ ratio

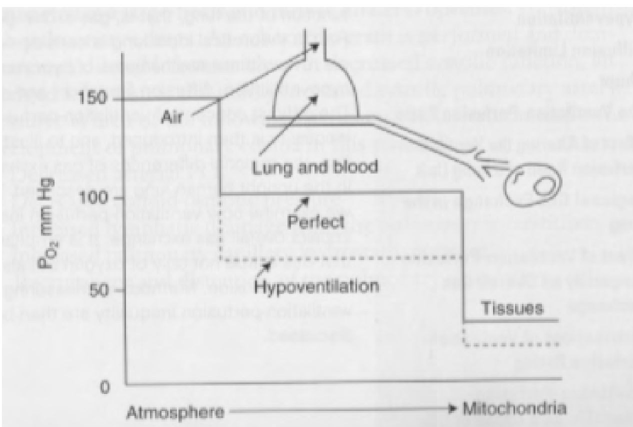
Date: 2021/10/12

Content by: Alex Houle

Present: Alex Houle

Goals: Analyze the diagram of VQ ratio that's currently available, find its pros and cons as a teaching model

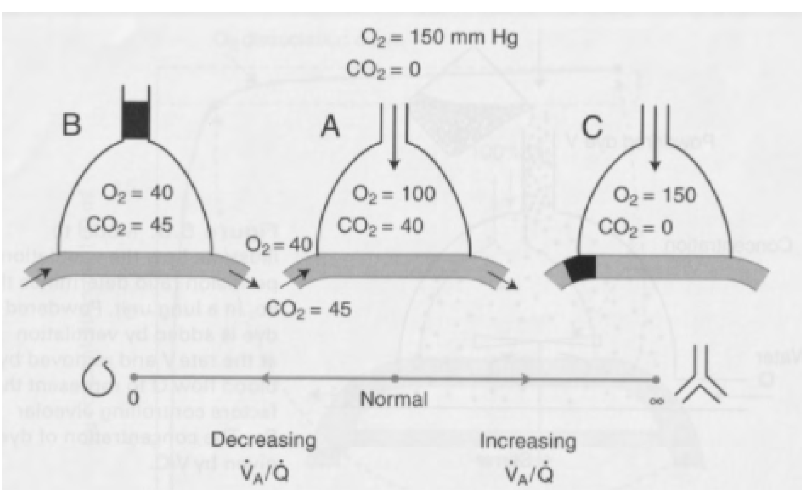
Content:



Y-axis shows partial pressure of oxygen

Solid lines = hypothetically perfect situation

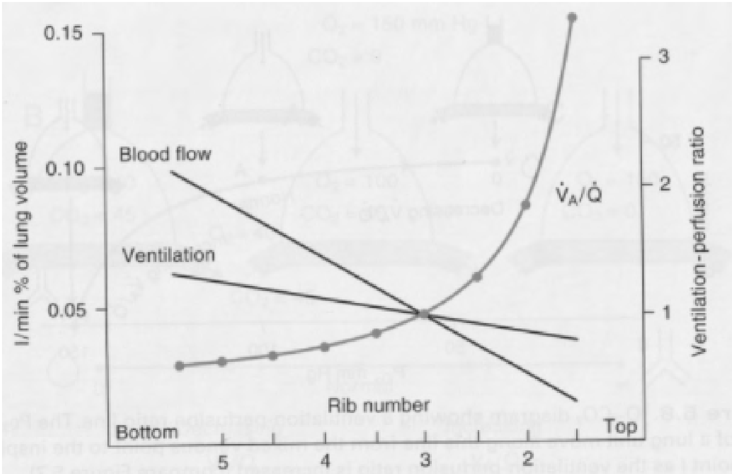
dashed line = partial pressure of oxygen when under hypoventilation



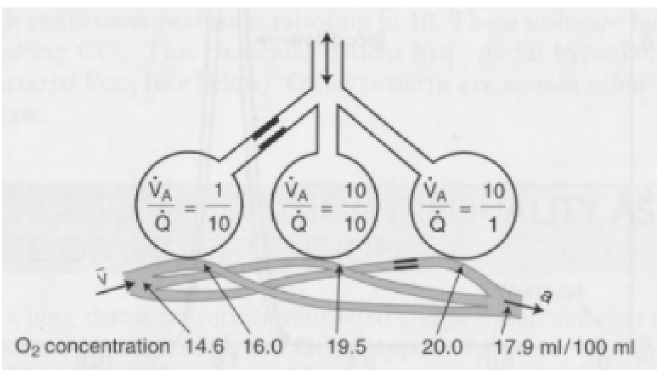
Shows affect of altering V/Q ratio on PO2 and PCO2 in alveoli

lung blockage on left = increased CO2 concentration

blood flow blockage on right = increased O2 concentration due to inability for it to be used for oxygenation



Graph of distribution of ventilation and blood flow as a function of location in the lung. The higher you are in the lung, the lower the VQ ratio tends to be



Shows multiple alveoli with mismatched VQ ratios

Alveoli with high V/Q ratios add relatively little oxygen to the blood compared to the decrement caused by alveoli with low V/Q ratios

This textbook chapter provides many different graphs and diagrams that can be used to learn about the VQ ratio, but the lack of interactivity is its biggest disadvantage. Being able to adjust the ratio and see the consequence by each tweak could be invaluable to understanding this concept clearly. This chapter does provide lots of relevant information that can be used to explain concept that our model will probably not include, such as differences in the ratio that are dependent on where in the lung it is. And the graphs are also key, as our model probably does not have the location and we lack the expertise to be able to design graphs with each tweak of the ratio

West's Respiratory Physiology

Authors: John B. West MD, PhD, DSc, Andrew M. Luks MD

Conclusions/action items:

Use these diagrams to brainstorm more prototype ideas and tweaks to the designs we have

More ideas on how to improve last years project - does last year's model teach this information better than the textbook does? Does the interactivity help understanding more than looking at different examples?

11/30/21 Arduino ellapsedMillis vs DMtimer

Alex Houle - Dec 15, 2021, 1:05 PM CST

Title: Arduino ellapsedMillis vs DMtimer

Date: 11/30/21

Content by: Alex

Goals:

Understand what the differences are between ellapsedMillis and DMtimer, to identify which one will work better for our project.

Content:

ellapsedMillis will avoid code blocking and can be easily downloaded

Numeric values are in milliseconds

Easy to use variables

Name the variable as global at the beginning of the code, then can be iterated over in loop()

Mathematical function are easy, just need to use correct arduino operators

May not be 100% precise timing, but that will not matter for our project

“Using millis() Instead of delay() for Arduino Projects,” STEM Mayhem, 23-Jan-2020. [Online]. Available: https://www.stemmayhem.com/using-millis-instead-of-delay-for-arduino-projects/. [Accessed: 30-Nov-2021]

Times in microseconds

Define timer as global, then rename it to a function of the perfusion value later in the loop

Can use if(myTimer.isTimeReached()){ very easily

when false, stay on current LED; do not move on

when true, move to next LED, check what ventilation value is currently set to, and reset timer to that value

N. Simonnet, DMTimer. 2021 [Online]. Available: https://github.com/toxnico/DMTimer. [Accessed: 30-Nov-2021]

Conclusions/action items:

Will likely go with DMTimer instead of ellapsedMillis. Very easy to do a while() function for when .isTimeReached == false, which is what we want

Need to figure out where to organize code so it will do this for each pixel of the strip, instead of once for the entire strip

Need to make sure to convert to microseconds so timing is accurate (1 s = 1x10^6 μs)

12/6/21 Arduino Uno vs Mega

Alex Houle - Dec 15, 2021, 1:17 PM CST

Title: Arduino Uno vs Mega

Date: 12/6/21

Content by: Alex

Goals:

Decide if an Arudino Uno will work for our project, or see if we will need to purchase an Arduino Mega instead

Content:

Arduino mega cost $22 at makerspace minimart

Both connect to computer using same cord

Arduino mega bigger (4” x 2.1”) than uno (2.7” x 2.1”)

54 digital pins in Mega, 14 in Uno

32 kb of memory in uno vs 256 kb in mega

M. Gudino, Arduino Uno vs. Mega vs. Micro, 28-Feb-2021. [Online]. Available: https://www.arrow.com/en/research-and-events/articles/arduino-uno-vs-mega-vs-micro. [Accessed: 06-Dec-2021]

Conclusions/action items:

We will need to use a mega because of how many digital ports we need. Each LED for ventilation will require one, the LCD display used 7, and the strip uses one, so there is not enough room on the uno. Without having to worry about our budget and having plenty of room for the increased size of the mega, this is the best choice.

Potentiometer Coding 11/25/21

Alex Houle - Dec 15, 2021, 12:17 PM CST

potentiometer_knob.ino(4.6 KB) - download

Alex Houle - Dec 15, 2021, 12:21 PM CST

Title: Potentiometer Coding

Date: 11/25/21

Content by: Alex

Goals:

Understand how potentiometer displays values

Output potentiometer value to use for VQ ratio later

Content:

Was able to use analogRead() to output potentiometer value

Used Serial.printIn to get out value

Conclusions/action items:

Incorporate LEDs into code

Control delay with potentiometer value

Calibrate potentiometers

LED Strip Coding 11/25/21

Alex Houle - Dec 15, 2021, 12:18 PM CST

NeoPixelTest.ino(4.5 KB) - download

Alex Houle - Dec 15, 2021, 12:26 PM CST

Title: LED strip coding

Date: 11/25/21

Content by: Alex

Goals:

Understand how to control each pixel individually

Create color codes so each pixel can be its own color

Content:

used strip.SetPixelColor() to change color and turn on each pixel

used.SetPixelColor(hslBlack) to turn off pixel

Used Delay() to turn on, then turn off

Conclusions/action items:

Create loop to avoid typing each LED individually

Only have one LED on at a time

Arduino Code Draft 1 11/29/21

Alex Houle - Dec 15, 2021, 12:04 PM CST

Version_1.ino(5.2 KB) - download

Alex Houle - Dec 15, 2021, 12:06 PM CST

Alex Houle - Dec 15, 2021, 12:29 PM CST

Title: Arduino Code Draft 1

Date: 11/29/21

Content by: Alex

Present: Alex, Charlie

Goals:

Use ellapsedmillis function to replace delay

Control colors of led strip

Incorporate all 15 pixels in strip

Start using LCD screen

Content:

used lcd.begin(20,4) to write on LCD screen

Calculated VQ ratio and displayed that on screen

Calculated PaO2 and displayed on screen, but equation may be wrong

Attempted to use ellapsedMillis, but having difficulties resetting loop after each LED

Conclusions/action items:

Learn how to use ellapsedMillis better

Talk to client to get updated PaO2 equation

Change colors of strip

Begin ventilation LEDs

Arduino Code Draft 2 12/3/21

Alex Houle - Dec 15, 2021, 12:09 PM CST

Version_2.ino(7.4 KB) - download

Alex Houle - Dec 15, 2021, 12:33 PM CST

Title: Arduino Code Draft 2

Date: 12/3/21

Content by: Alex

Present: Alex, Charlie

Goals:

Create function that will update board to organize code

Create ventilation code

try using DMtimer instead of ellapsedMillis

Content:

Created ventilation LEDs, much easier than perfusion, but not finished yet

Created updateBoard function, seems to work well

Perfusion loop is still having trouble even when using DMtimer, need to find a better place to add line of code resetting timer

Conclusions/action items:

Finish ventilation LED code

Finalize perfusion strip (!!!)

Create loop checking if perfusion is 0 (or close to zero)

Arduino Code Draft 3 12/7/21

Alex Houle - Dec 15, 2021, 12:10 PM CST

Version_4.ino(7.7 KB) - download

Alex Houle - Dec 15, 2021, 12:33 PM CST

Alex Houle - Dec 15, 2021, 12:37 PM CST

Title: Arduino Code Draft 3

Date: 12/7/21

Content by: Alex

Present: Alex, Charlie

Goals:

Finish ventilation code

Try incorporating power button

Finish perfusion code

Content:

Created new function called readDials, similar to updateBoard, but will get values from potentiometer bettwe

Was able to finish perfusion code. It works when the timer resetting function goes inside the function readDials.

Created ranges for ventilation LED that accurately goes through if loops to find range and turn corresponding amount of LEDs

Created gradient of different colors to represent deoxygenated vs oxygenated

Incorporated all code into one loop

Conclusions/action items:

Very close to a final code, but need to find a way to improve interactions between ventilation and perfusion code loops

If statement for perfusion = 0 still must be made

Decide if we will move on with power button (probably not)

Ardino Code Draft 4 (poster showing) 12/10/21

Alex Houle - Dec 15, 2021, 12:10 PM CST

Version_5.ino(8 KB) - download

Alex Houle - Dec 15, 2021, 12:42 PM CST

Title: Arduino Code Draft 4 (poster showing)

Date: 12/10/21

Content by: Alex

Present: Alex, Charlie

Goals:

Eliminate Power button

Finish if loop for perfusion == 0

Make sure code is ready for poster showing

Content:

Created if loop for perfusion = 0. Works, except will not update colors until loop finishes.

Took out code for power button. the button we were using is damaged and will not accurately check for button state being active or not. Will not be needed for final design.

No problems with ventilation code, works just fine

Display looks good, except potentiometer value fluctuates between 2 values occasionally

Conclusions/action items:

Fix perfusion = 0 loop, but can be done after poster showing

Reprint model without hole for power button

Find a library that will fix fluctuating potentiometer value

Arduino Code Draft 5 12/12/21

Alex Houle - Dec 15, 2021, 12:10 PM CST

Alex Houle - Dec 15, 2021, 12:10 PM CST

Version_6.ino(7.7 KB) - download

Alex Houle - Dec 15, 2021, 12:44 PM CST

Title: Arduino Code Draft 5

Date: 12/12/21

Content by: Alex

Goals:

Make perfusion strip go straight to white when Q = 0

Content:

Ended up being an easier fix than I thought. After much experimenting, it will set it to 0 immediately if the loop goes into the readDials function, and it does not interrupt ventilation LED function.

Conclusions/action items:

Fix fluctuating of potentiometer values, then should be finalized to give to client.

2021/09/21-Learning from Previous Related Project

Charlie ZHU - Sep 24, 2021, 12:05 AM CDT

Title: Learning from Previous Related Project

Date: 2021/09/21

Content by: Charlie Zhu

Present: Charlie Zhu

Goals: Understanding the goal and the improvement of the project could be done, gaining background information of the project

Content:

Related project from Fall 2020

V/Q mismatching is the unbalance relationship between the amount of air enters alveoli and the amount of blood flow go through the capillaries in the lungs

Our goal is to design a teaching model which could be used by professors to teach graduated students

Fall 2020 team chose to use silicone diffused LEDs and LED ring to complish the goal

Previous PDS:

Could be used multiple times in given lecture and require minimum setup and clean up.

Large enough for every students in the hall to see the model clearly

Be able to withstand storage for long periods of time

Alter the brightness and rate of flow on led in order to make sure colorblind student can also see the model

Weigh less than 6.8kg (15lbs)

Method Used: 3D printing

Color represent:

Green : Ozygen flow

Blue: Deoxygenated blood

Red: Oxygenated blood

Purple: Gas exchange

Future work:

Determine proficient brightness and color ratio

Incorporate interactive component

Cover material to mimic diffusion process in the capillary tube

Conclusions/action items:

The method of 3D printing could be used in our project since it provides enough accuracy and ease of fabrication

Future improvement could be done including adjustable button to control to V/Q ratio, Testing of brightness

The size of the previous project is great which can be emulated in our project

LED lights works perfect to represent flow of oxygen and blood, but the brightness of light should be able to be adjusted in order to represent different level of oxygination

More research of V/Q ratio should be done in order to understand the function process better.

2021/09/24- Fundamental Research of V/Q mismatching

Charlie ZHU - Sep 24, 2021, 12:32 AM CDT

Title: Fundamental Research of V/Q mismatching

Date: 2021/09/24

Content by: Charlie Zhu

Present: Charlie Zhu

Goals: Understanding the fundamental causes and consequence of V/Q mismatching

Content:

Cause of V/Q mismatching:

Impairment of ventilation and perfusion

Lack of oxygen transfers to blood

Majorly caused by chronic lung diseases or a sudden lung impairment

Symptoms of V/Q mismatching:

Headache

Dizzy and lack of energy

Irregular breathing rhythm

Grayish or bluish tint to the skin

May cause hypoxemia and hypoxia which leads to low oxygen level in the blood and tissue

Both increasing or decreasing of V/Q mismatching is not good.

Increasing V/Q ratio caused by decreasing blood flow through the lung

Decreasing V/Q ratio caused by decreasing air flow through the lung

https://www.verywellhealth.com/what-is-vq-mismatch-in-the-lungs-914928

Deborah Leader, R. N. (n.d.). *What people with copd should know about v/q mismatch*. Verywell Health. Retrieved September 24, 2021, from https://www.verywellhealth.com/what-is-vq-mismatch-in-the-lungs-914928.

Conclusions/action items:

V/Q ratio mismatching could cause serious issue thorughout the whole body since the level of oxygen could chronicly decreases to a low level in the whole body

In our project, it is important to show that decreasing and increasing V/Q ratio are both harmful to the body. (Increase V/Q ratio is also bad!)

2021/09/28- Perfusion and Ventilation function

Charlie ZHU - Oct 19, 2021, 11:48 PM CDT

Title: Perfusion and Ventilation function

Date: 2021/09/28

Content by: Charlie Zhu

Present: Charlie Zhu

Goals: Background research of the project

Content:

Role of ventilation and perfusion is facilitate gas exchange. Ventilation refers to the flow of air in and out of aveoli and perfusion refers to flow of blood to alveolar capillaries.

Changing ratio could lead to serious consequences including hypoxemia

Adjacent Alveoli connects each other through small opening which allow collateral airflow and equalized pressure among alveoli.

Gas exchange primary through diffusion which transfer oxygen from alveoli to capillary blood.

Decreasing value of perfusion can caused by right-to-left shunts, pulmonary arteriovenous malformations, and congenital heart defects.

Decreasing value of ventilation can caused by Bronchoconstriction

Other factors causing V/Q mismatching: oulmonary edema, the effective thickness of alveolar wall which decrease the diffusion rate. It can lead to lower level of oxygen in the bloodstream since less oxygen can transfer from alveoli to the capillary bloodvessels.

https://www.ncbi.nlm.nih.gov/books/NBK539907/

K. A. Powers, “Physiology, pulmonary ventilation and perfusion,” *StatPearls [Internet].*, 20-Aug-2021. [Online]. Available: https://www.ncbi.nlm.nih.gov/books/NBK539907/. [Accessed: 20-Oct-2021].

Conclusions/action items:

2021/11/15-Material Property of PLA

Charlie ZHU - Dec 15, 202

Title: Material Property of PLA

Date: 12/15/2021

Content by: Charlie Zhu

Present: Charlie Zhu

Goals: Investigate material property of PLA in order to make sure the strength of the material is desired

Content:

PLA is a type of polyester made from fermented plant starch from corn, cassava, maize, sugarcane or sugar beet pulp. The sugar in these renewable materials are fermented anc lactic acid, when is then made into polylactic acid, or PLA.

Property	Value
Heat Deflection Temperature (HDT)	126 °F (52 °C)
Density	1.24 g/cm³
Tensile Strength	50 MPa
Flexural Strength	80 MPa
Impact Strength (Unnotched) IZOD (J/m)	96.1
Shrink Rate	0.37-0.41% (0.0037-0.0041 in/in)

Advantage :

Environmentally friendly

3D printable

Wide rage of color

Disadvantage:

Low heat resistance

Hard to be processed through machine

"What is pla? (everything you need to know)," *TWI*. [Online]. Available: https://www.twi-global.com/technical-knowledge/faqs/what-is-pla#Properties. [Accessed: 15-Dec-2021].

Conclusions/action items:

PLA has high Tensil Strength and Flexural Strength which makes PLA a desired material for the outer surface of our model.

2021/09/28-Teaching model from previous team

Charlie ZHU - Oct 20, 2021, 2:27 PM CDT

Title: Teaching model from previous team

Date: 10/20/2021

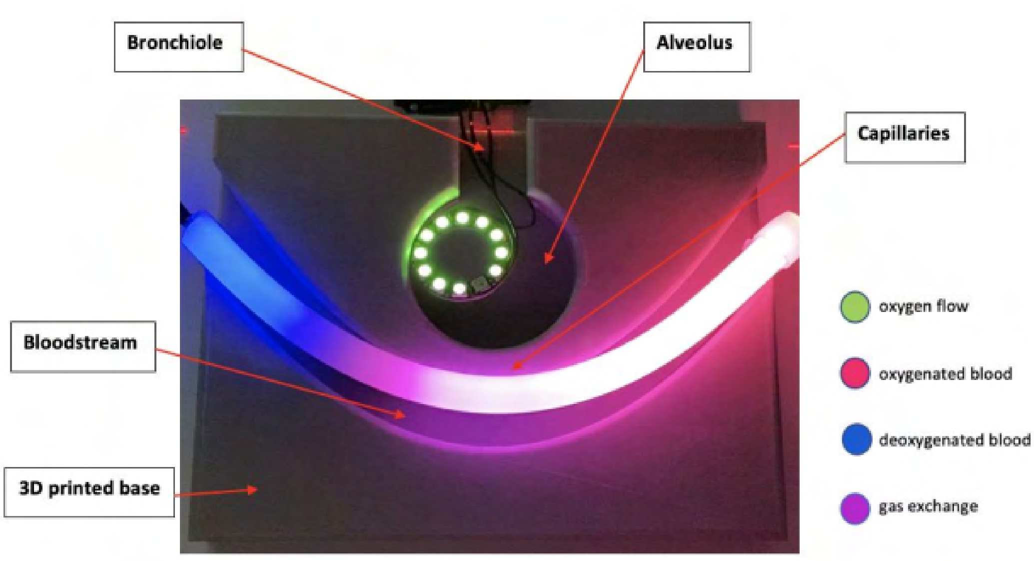
Content by: Charlie Zhu

Present:Charlie Zhu

Goals: Understand the teaching model from previous team

Content:

There are totally four bottom located at the bottom side of the board which can be used to change V/Q ratio in order to represent V/Q mismatch. One LED strip is located at the middle of the board which represent capillary bloodstream. The color of the LEDs strip can varies from blue and red in order to show the oxygenation process of the blood. There is no slider can be used to change the ratio of V/Q.



Conclusions/action items: Previous teaching model is not good enough since the intuitive of use is not clear enough. The client might having trouble using the model during the lecture. Furthermore, there is no slider can be used to control V/Q ratio. The ratio is fixed to 4 values which is not good enough to represent the changing oxygen level during different level of V/Q mismatching. We can add two sliders and label each of them clearly so that our client can easily show the graduated student without any trouble.

2021/10/24-Ventilation and perfusion competing design

Charlie ZHU - Dec 15, 2021, 12:05 PM CST

Title: Ventilation and perfusion competing design

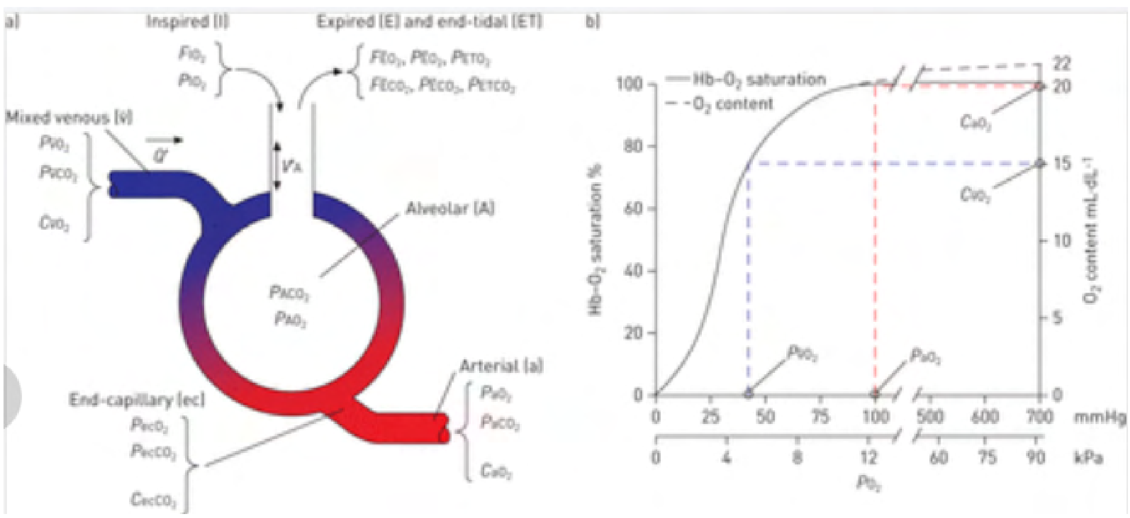
Date: 10/24/2021

Content by: Charlie Zhu

Present: Charlie Zhu

Goals: Understand competing design idea and learn from the peer prospective

Content:



This is a design idea from Petersson and Glenny. They design the visualization of the ventilation perfusion exchange process as the capillary surrounding the alveolar and exchange gas surrounding the whole alveolar. The left side of the capillary are colored by blue representing low oxygen concentration, and right side of the capillary are colored by red representing high oxygen concentration.

J. Petersson and R. W. Glenny, “Gas exchange and ventilation–perfusion relationships in the lung,” *European Respiratory Society*, 01-Oct-2014. [Online]. Available: https://erj.ersjournals.com/content/44/4/1023. [Accessed: 15-Dec-2021].

Conclusions/action items:

From this design idea, I learned that capillary is surrounding the whole capillary and the gas exchange process happens at every single place of the alveolar. The color gradient can be used to represent the oxygen level change in the capillary. This concept could be used in our future design.

2021/10/27-Ventilation and perfusion competing design(2)

Charlie ZHU - Dec 15, 2021, 3:11 PM CST

Title: Ventilation and perfusion competing design(2)

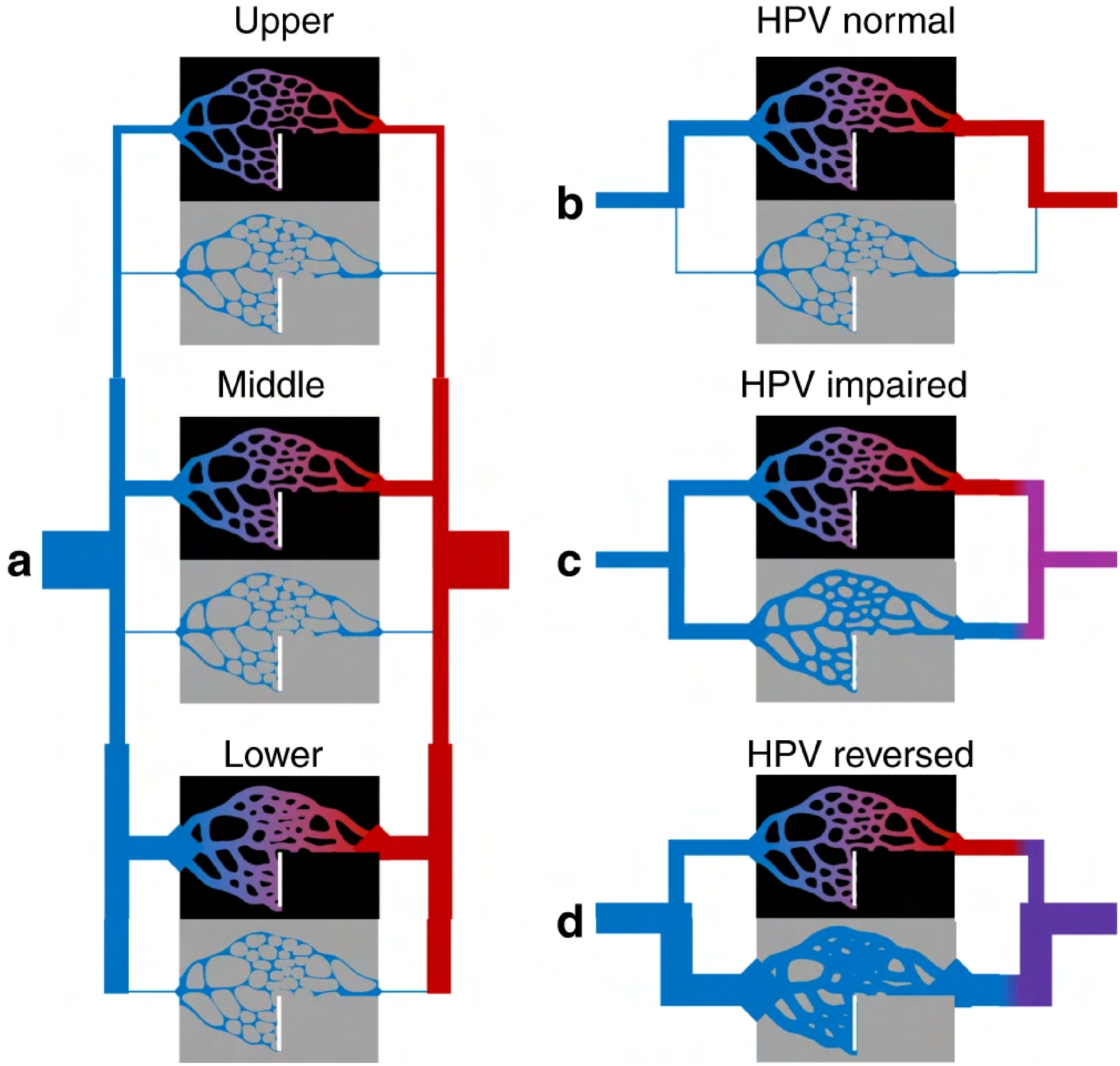
Date: 10/27/2021

Content by: Charlie Zhu

Present: Charlie Zhu

Goals: Understand competing design idea and learn from the peer prospective

Content:



This design shows the capillary as a net structure and the alveolar located at the empty space within the network structure. This design also used blue represent low oxygen level and red for high oxygen level.

J. Herrmann, V. Mori, J. H. T. Bates, and B. Suki, “Modeling lung perfusion abnormalities to explain early COVID-19 hypoxemia,” *Nature News*, 28-Sep-2020. [Online]. Available: https://www.nature.com/articles/s41467-020-18672-6. [Accessed: 15-Dec-2021].

Conclusions/action items:

This design is not very useful to our design since it will be hard to use led strip to represent a network structure. However, this design also used blue and red gradient represent oxygen level which is desired to be used in our model.

2021/11/09- Comparing Arduino Uno and Arduino Mega

Charlie ZHU - Dec 15, 2021, 3:09 PM CST

Title: Comparing Arduino Uno and Arduino Mega

Date: 2021/11/09

Content by: Charlie Zhu

Present: Charlie Zhu

Goals: Comparing difference between arduino uno and arduino mega

Content:

Arduino Uno:

$19-23

2.7in x 2.1in

14 digital pins

6 Analog pins

Standard A/B USB connection

32 kb Flash Memory

Arduino Mega:

$36.61-39.00

4in x2.1in

54 Digital pins

16 Analog pins

Standard A/B USB connection

254kb Flash Memory

Miguel Gudino Arrow Electronics Miguel Gudino is an electrical engineer that specializes in electronic passive components and computer organization. He believes t... Read more, Miguel Gudino Arrow Electronics, M. Gudino, A. Electronics, and Miguel Gudino is an electrical engineer that specializes in electronic passive components and computer organization. He believes t... Read more, “Arduino board comparison guide,” *Arrow.com*, 28-Feb-2021. [Online]. Available: https://www.arrow.com/en/research-and-events/articles/arduino-uno-vs-mega-vs-micro. [Accessed: 15-Dec-2021].

Conclusions/action items:

Since we need 10 LED Bulbs to be connected to Arduino board, we need more than 15 digital pins on Arduino to fulfill the requirement. The original Arduino Uno only has 14 digital pins which is not enough. Arduino Mega is chosen because it is only a little bit larger and more expensive compare to Arduino Uno, but it has 54 digital pins which is definitely enough for our circuit design.

2021/10/11-LEDs with sliders Design Idea

Charlie ZHU - Oct 19, 2021, 11:06 PM CDT

Title: LEDs with sliders Design Idea

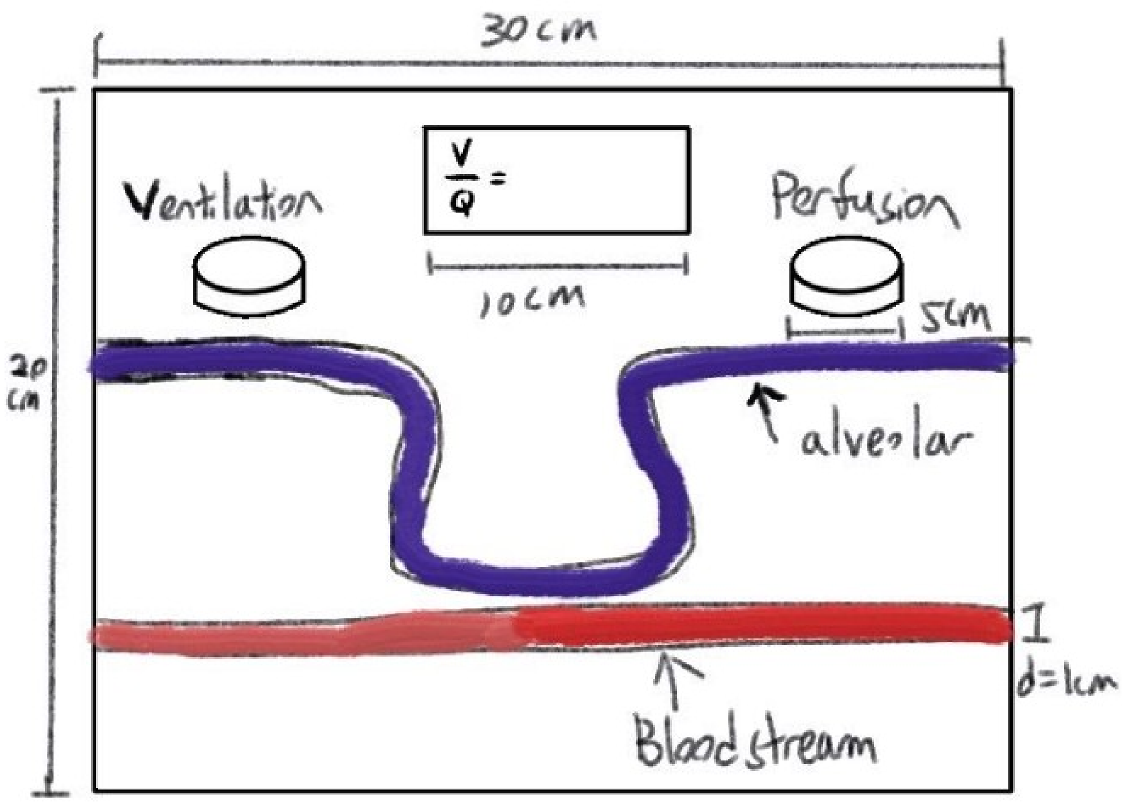
Date: 10/11/2021

Content by: Charlie Zhu

Present: Charlie Zhu

Goals: Come up with valid design ideas

Content:



Conclusions/action items: This design is the combination of both LEDs strips and slider which can be used to control ventilation and perfusion level. By changing those value, the V/Q ratio could be changed and affect the brightness of LEDs strips in both LEDs lines. The brightness of LEDs represents the level of oxygen in both alveolar and blood stream.

2021/10/13-Water and Dye Design Idea

Charlie ZHU - Oct 19, 2021, 11:02 PM CDT

Title: Water and Dye Design Idea

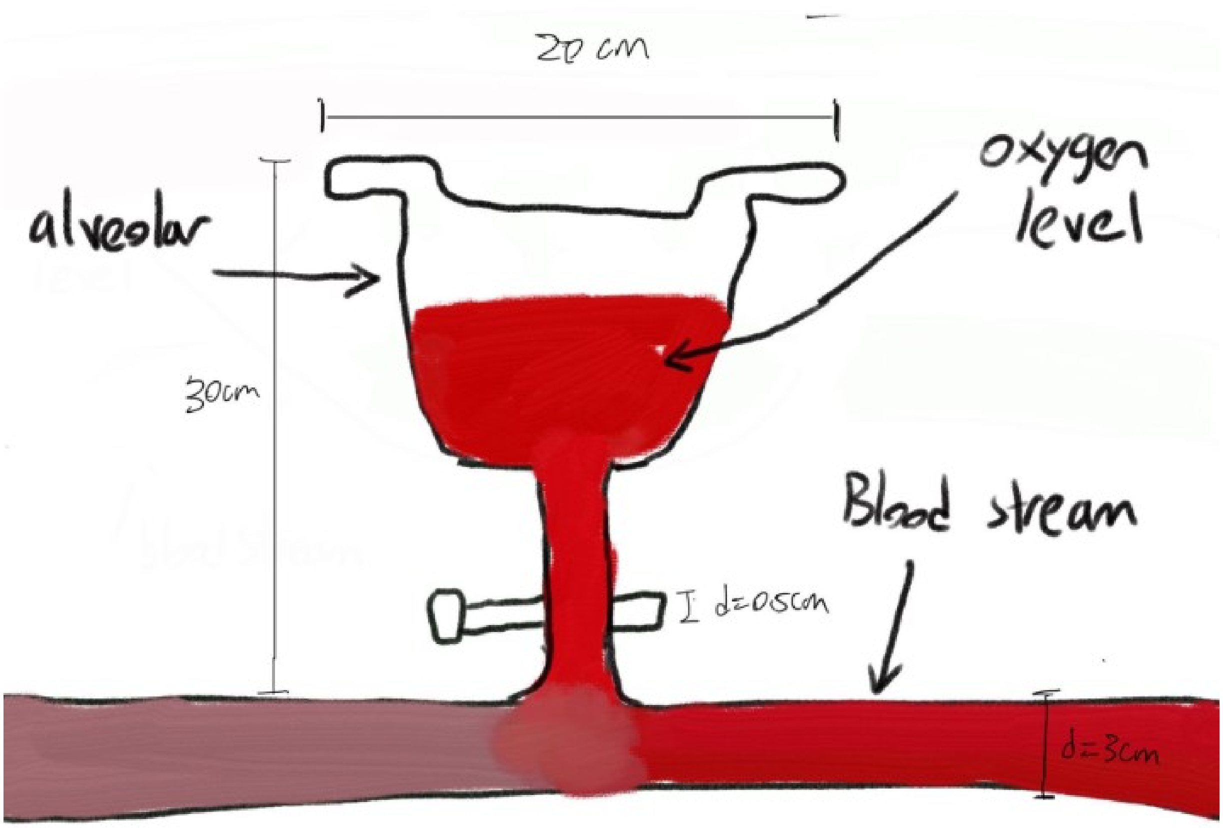
Date: 10/13/2021

Content by: Charlie Zhu

Present: Charlie Zhu

Goals: Come up with valid design ideas

Content:



Conclusions/action items: This is the design of water/dye concentration. The design is composed by three parts including a funnel-like channel, tube, and a valve. The liquid in the channel represents air flow and the dye represents concentration of oxygen level in both the alveolar and bloodstream. The valve is used to control the inflow of liquid from the channel to the tube. The changing color in the tube from faint red to dark red shows the increase of oxygen level in the blood stream.

2021/10/12-Computer animation

Charlie ZHU - Oct 20, 2021, 2:33 PM CDT

Title: Computer animation

Date: 10/12/2021

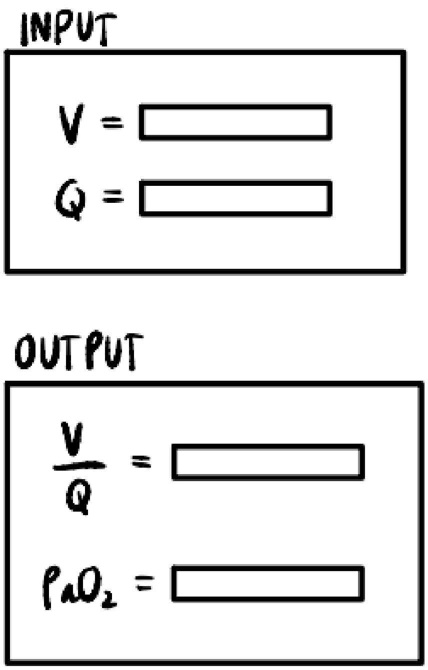
Content by: Milica Lukic

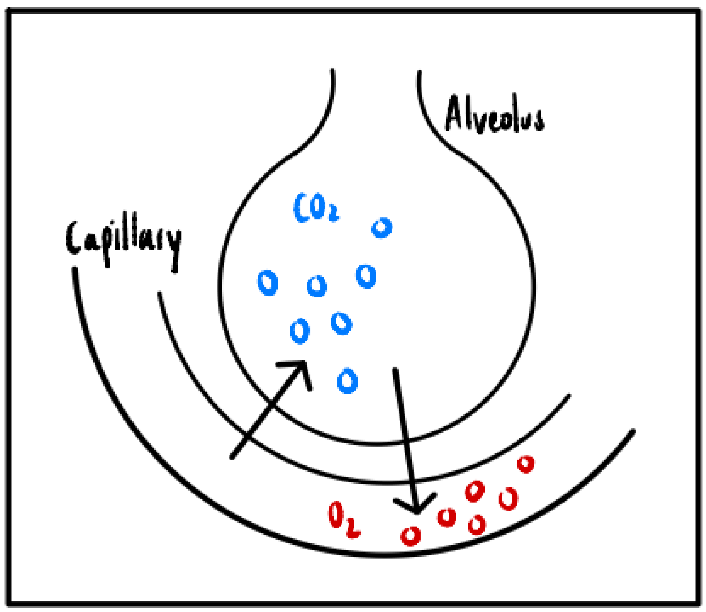
Present: Charlie Zhu

Goals: Come up with different design idea in order to be evaluated in design matrix

Content:

The software animation model refers to use of a programming language to create a software where V and Q values could be input and the V/Q ratio, partial pressure of oxygen, and any other levels the client would like to calculate would be output. Along with these values, the program would provide an animation of one or multiple alveoli with flow rates depicted through use of arrows, number of molecules, and speed at which the molecules flow through the animation.





Conclusions/action items: Computer animation can be used to visualize the ventilation perfusion process well. The client can get concentration of oxygen in blood immediately after entering ventilation and perfusion value. However, animation requires high computer programming skill which none of us acquired. Furthermore, lack of physical model is not desired by our client. Further evaluation is needed during compare with other designs in design matrix.

2021/10/15-Design Matrix

Charlie ZHU - Oct 20, 2021, 2:39 PM CDT

Title: Design Matrix

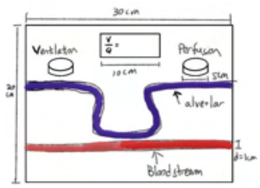
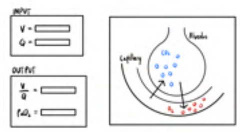
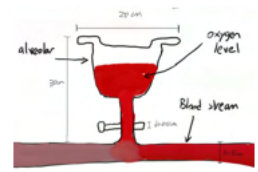
Date: 10/15/2021

Content by: Charlie Zhu

Present: the whole team

Goals: Come up with the winning design

Content:

Criteria (Weight)	Slider with LEDs and Screen*		Computer Animation*		Water/Dye Concentrations	
						
Intuitive use (30%)	5/5	30%	4/5	24%	2/5	12%
Learning Outcomes (30%)	4/5	24%	2/5	12%	4/5	24%
Adjustability (20%)	4/5	16%	5/5	20%	4/5	16%
Ease of fabrication (10%)	3/5	6%	2/5	4%	1/5	2%
Cost (5%)	2/5	2%	5/5	5%	2/5	2%
Safety (5%)	4/5	4%	5/5	5%	5/5	5%
Total		**82%**		**70%**		**61%**

Design matrix part done by myself:

Intuitive use is the ability of the client to understand and use the product immediately after receiving it. The weight of this criteria is 30%, as the product will be used as a teaching model, and both the client and students must be able to use the model easily. The LEDs and Screen design receives 5/5 points for intuitive use since the only interactive part of the design is the slider which is used to control the V/Q ratio.

Learning outcomes refers to the design's effectiveness in leading students to understand the concept of ventilation and perfusion mismatching. Since the major purpose of the design is teaching, the weight of this criteria is given 30%. The LEDs and Screen design allows students to understand the concept without confusion because the slider in the design allows LED light to represent oxygen levels at different V/Q ratios. But since the exact V/Q ratio could not be shown in the design, 4 out of 5 points are given to this design.

In our design, adjustability refers to the ability to adjust the design in order to better accomplish the teaching purpose. The weight of adjustability is 20% because high adjustability will allow the client to better explain the concept of V/Q mismatching to different students. The adjustability of the LEDs and Screen design is considered high because the slider in the design allows the client to adjust the ratio of V/Q in order to show the effects that different ratios have on flow rates. However, factors other than the V/Q ratio (e.g. amount of hemoglobins) could not be changed in the design. Hence, 4 out of 5 points is given to The LEDs and Screen design

Ease of fabrication refers to the amount of time and effort needed in order to build the product. Since our team has the whole semester to complete the project, the weight of this criteria is only given 10%. The Slider with LEDs and Screen receives 3 out of 5 points because the model needs to be 3D printed, which may require a lot of time.

Cost refers to the cost needed to be spent on raw materials. Since the client's budget is high ($1000), the weight of this criteria is only given 5%. The slider with LEDs and Screen receives 2 out of 5 points because the cost of both 3D printing raw material and LED lights are relatively high, however well within the budget.

The criteria of safety refers to any risks associated with use of the device. The safety criteria is given a weight of 5% as there are little to no safety risks in any of the designs and in the way it will be used. The slider with LEDs and Screen is considered safe because the only risk of causing safety issues is the potential short-circuit of any electronic components in the design which is unlikely to happen. Based on this, 4 out of 5 points are given to this design.

Conclusions/action items: The slider with LEDs and Screen is the winning design due to the high intuitive use, great learning outcome and ease of use. Although this is the winning design, further work need to be done in order to modify and eliminate defect of the design.

2021/12/07 - SolidWorks Board Design

Charlie ZHU - Dec 15, 2021, 2:31 PM CST

Title: Solidwork design of the board

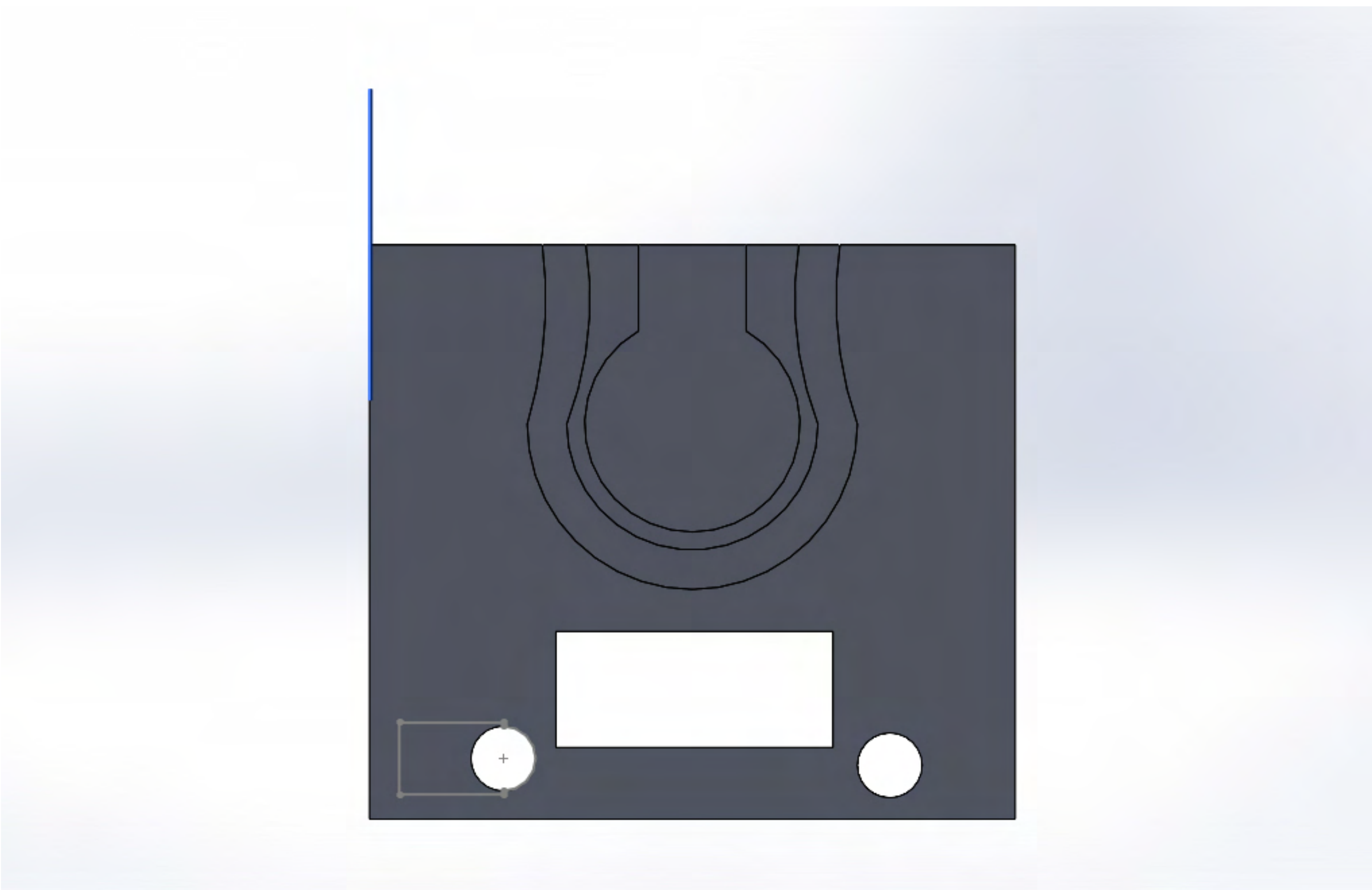
Date: 2021/12/07

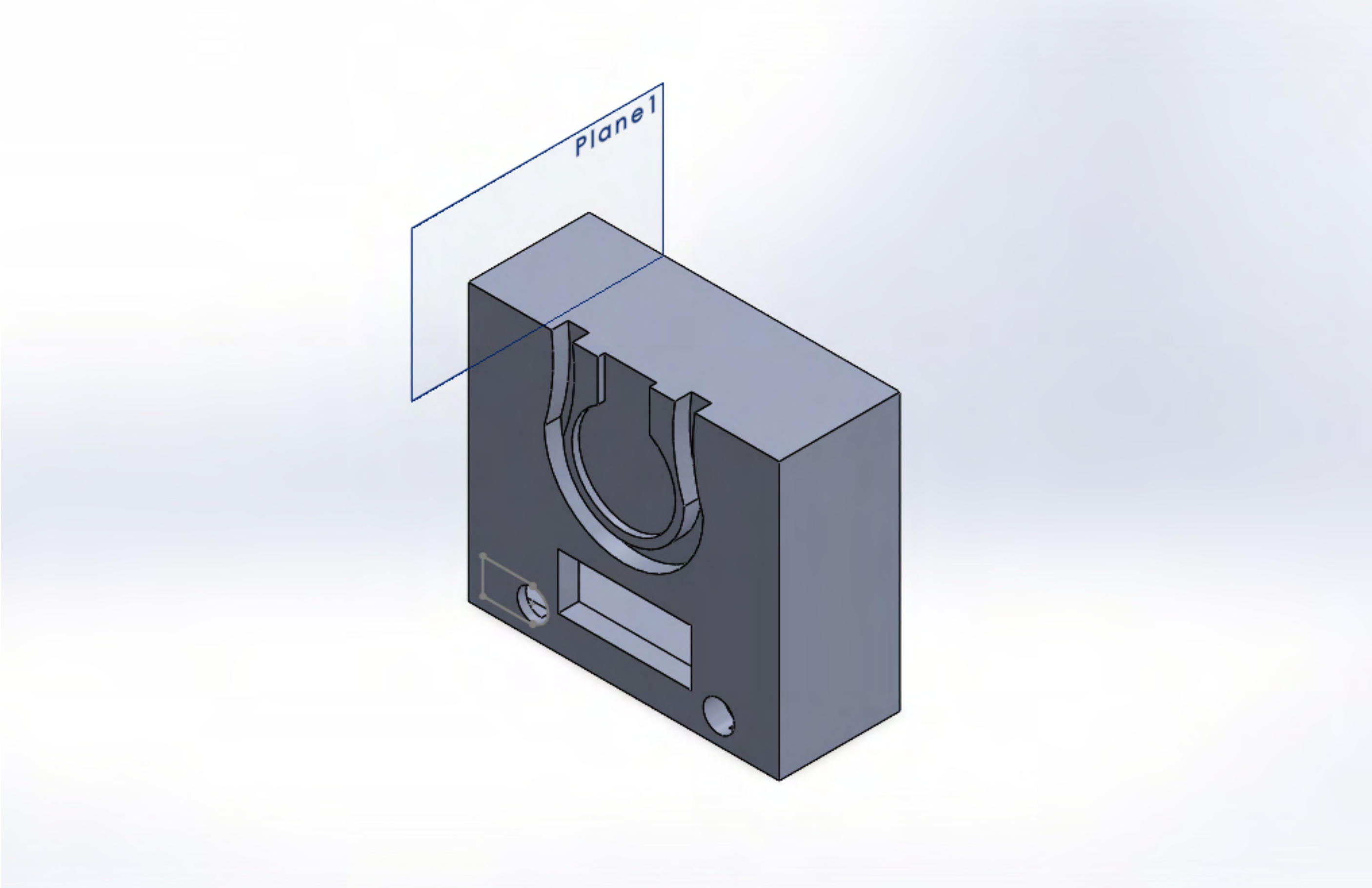
Content by: Charlie Zhu and Kendra Besser

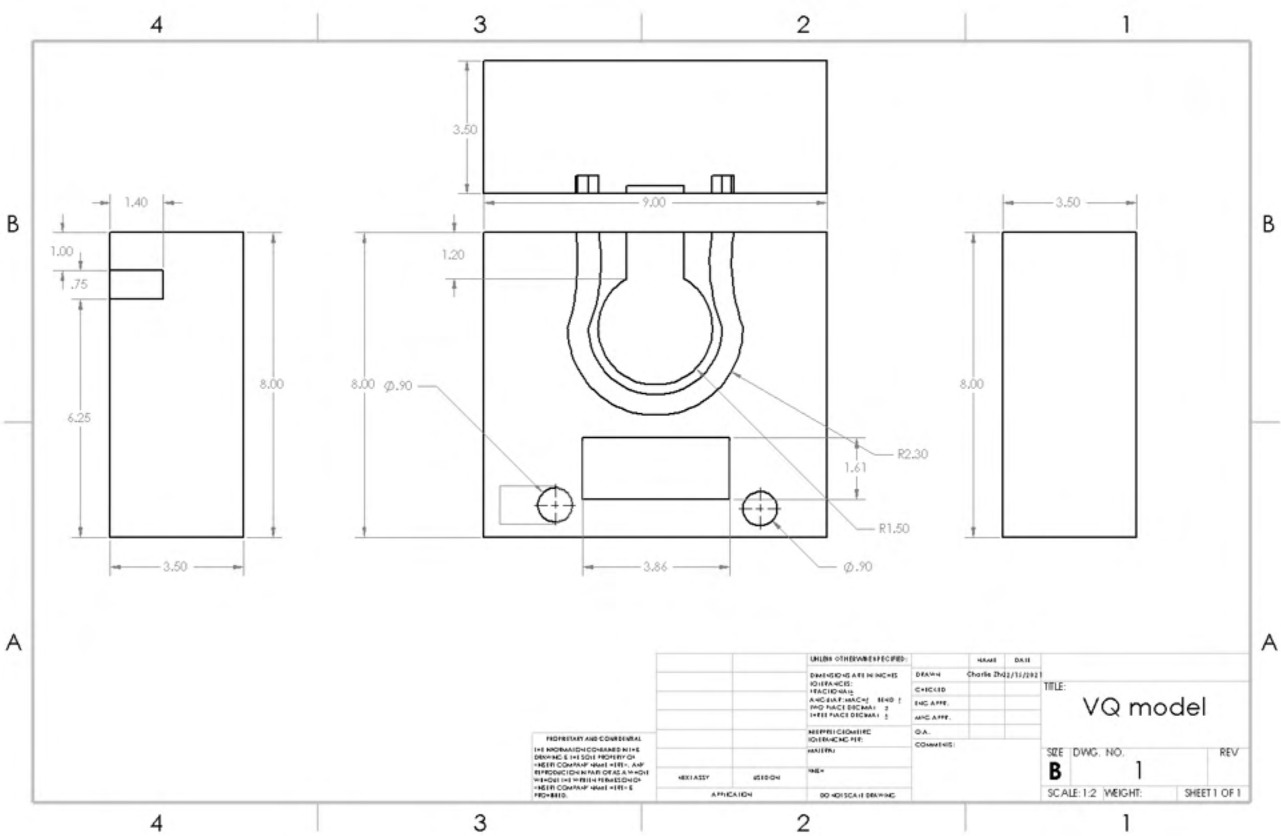
Present: Charlie Zhu and Kendra Besser

Goals: Finalize 3D Model of our project for 3D printing

Content:







Conclusions/action items:

3D model of V/Q model. Final design with all dimensions. Will be printed through 3D printing.

2021/12/07 - SolidWorks Back Design

Charlie ZHU - Dec 15, 2021, 2:31 PM CST

Title: Solidwork design of the back

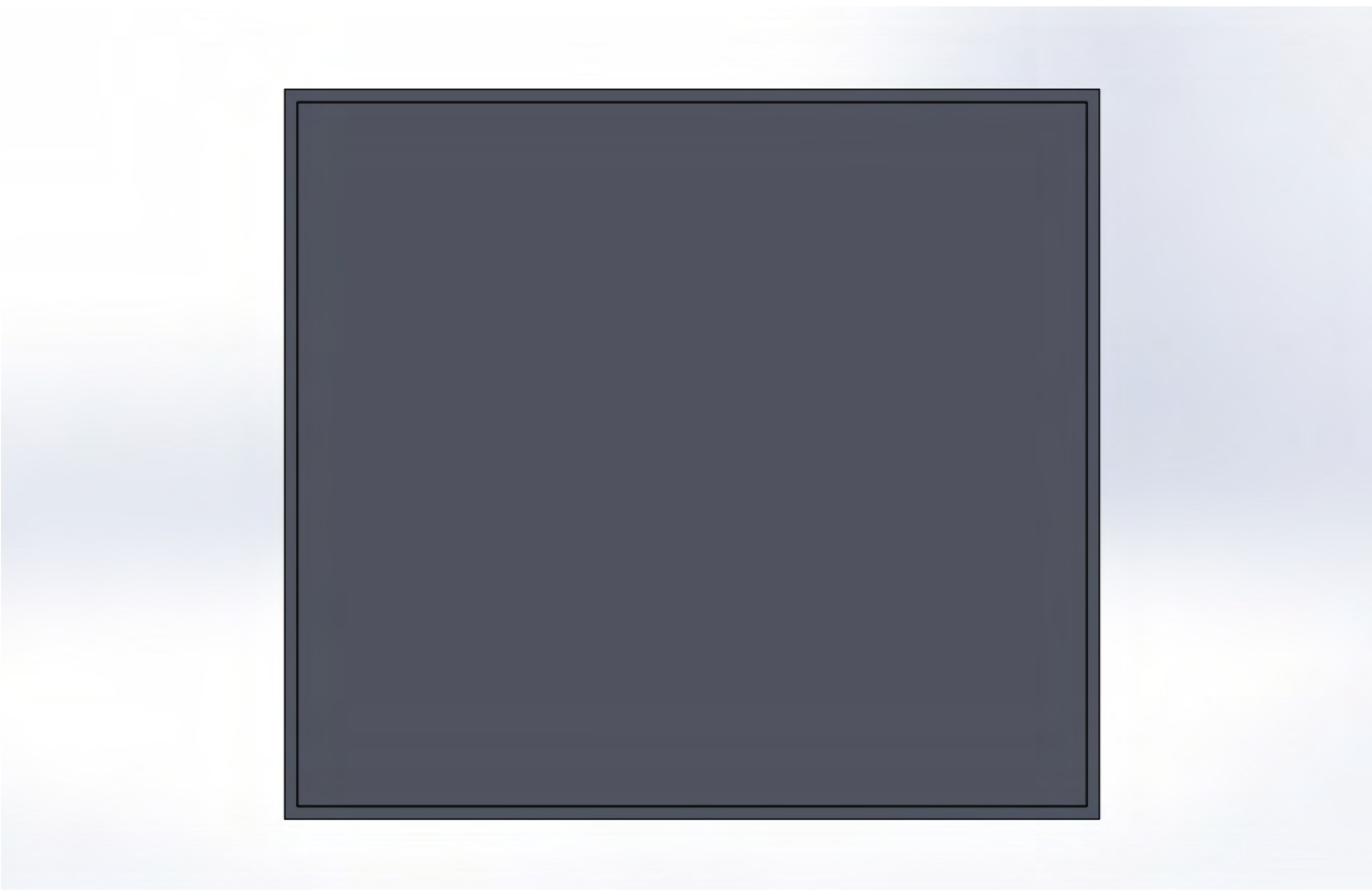
Date: 2021/12/07

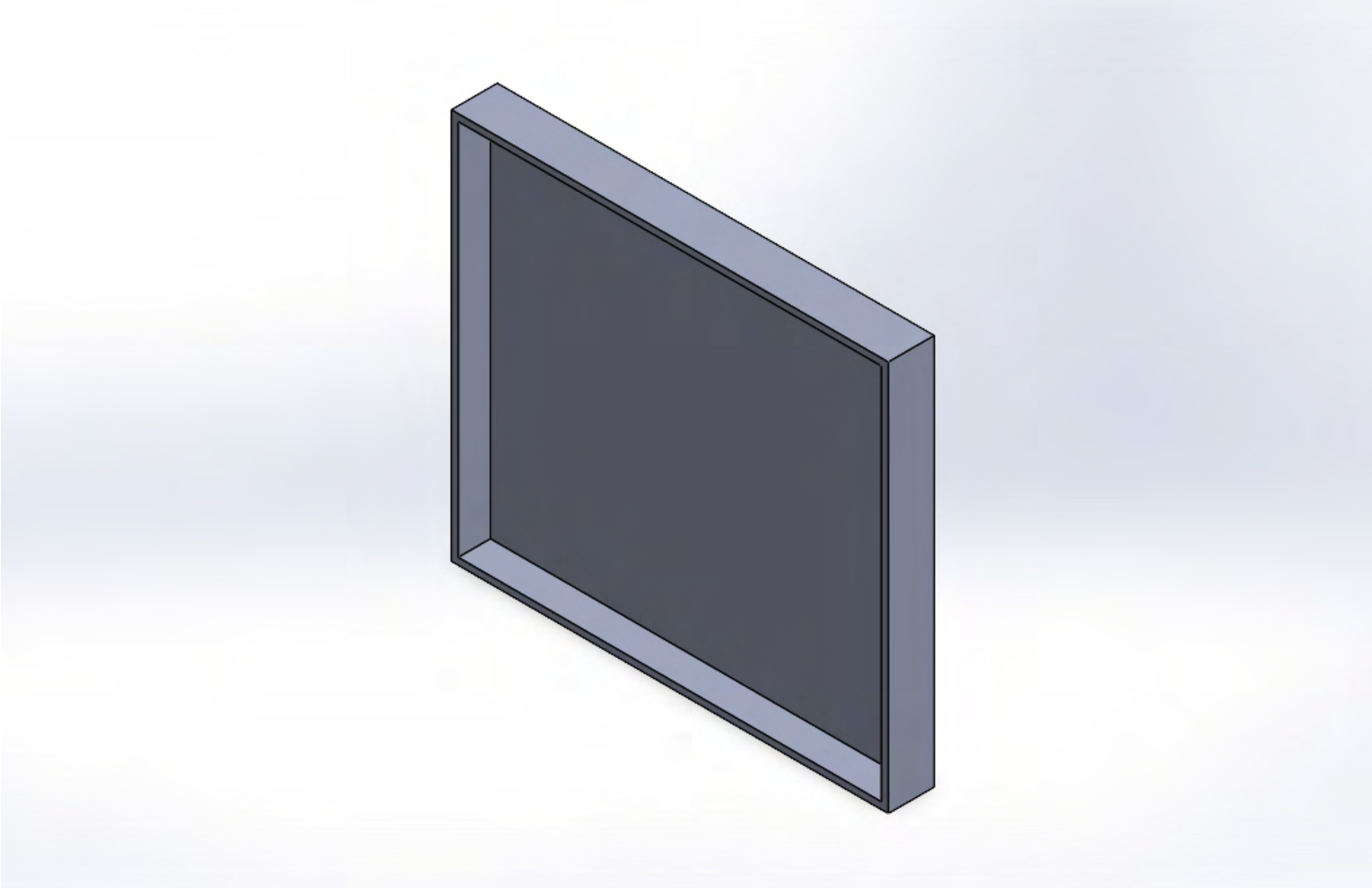
Content by: Charlie Zhu and Kendra Besser

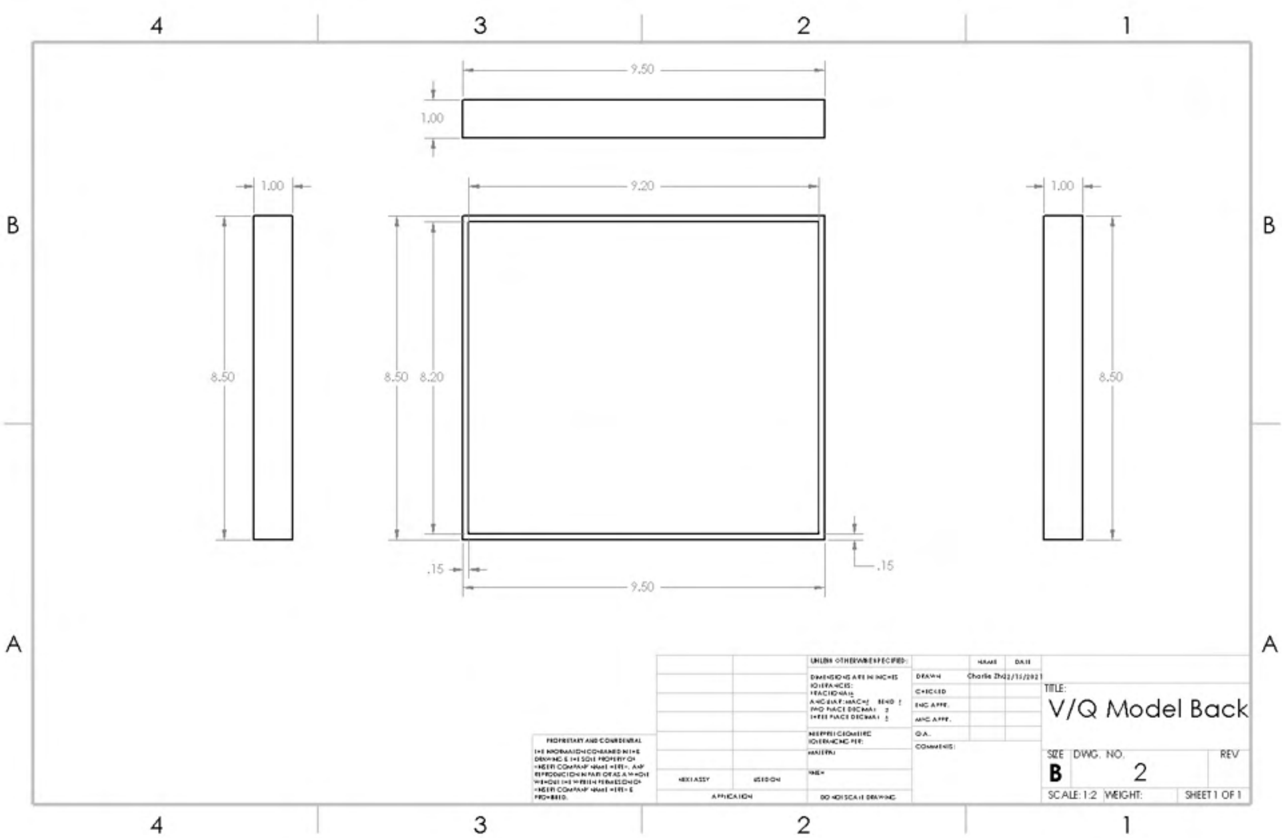
Present: Charlie Zhu and Kendra Besser

Goals: Finalize 3D Model of our project for 3D printing

Content:







Conclusions/action items:

3D model of V/Q model's back. Final design with all dimensions. Will be printed through 3D printing.

2021/11/28-Green Permit upgrade

Charlie ZHU - Dec 15, 2021, 12:25 PM CST

Title: Green Permit upgrade

Date: 11/28/2021

Content by: Charlie Zhu

Present: Charlie Zhu

Goals: Obtain a green permit

Content:

Materials Fee is paid through 2022-06-30. See Receipt

You may apply for the following upgrades:

Name
Welding 1
CNC Mill 1
Laser 1
Woodworking 2
CNC Lathe Haas 1

You have the following permits and upgrades:

Name	Date
Green Permit	10/24/2019
Red Permit	09/26/2019
Woodworking 1	10/16/2019

View Upcoming Seminars

You have used the following:

Type	Machine	Hours
Lathe	Lathe 4	3.5
Lathe Total		**3.5**
Mill	Mill 3	1.0
	Mill 4	0.5
Mill Total		**1.5**
Grand Total		**5.0**

Conclusions/action items:

Obtain a green permit in order to get permission to drill holes and do 3D printing.

2021/12/05-Coding Final Version

Charlie ZHU - Dec 15, 2021, 1:45 PM CST

Title: Coding Final Version

Date: 2021/12/05

Content by: Charlie Zhu and Alex Houle

Present: Charlie Zhu and Alex Houle

Goals: Coding for V/Q model

Content:

```
#include <NeoPixelBus.h>

#include <elapsedMillis.h>

#include <LiquidCrystal.h>

#include <Wire.h>

#include <dmtimer.h>

#define REDLITE 7

#define GREENLITE 8

#define BLUELITE 9

int brightness = 255;


const uint16_t PixelCount = 15; // this example assumes 4 pixels, making it smaller will cause a failure

const uint8_t PixelPin = 10;  // make sure to set this to the correct pin, ignored for Esp8266




const int rs = 12, en = 11, d4 = 5, d5 = 4, d6 = 3, d7 = 2;

LiquidCrystal lcd(rs, en, d4, d5, d6, d7);

#define colorSaturation 128

elapsedMillis valueTime = 0;

elapsedMillis lightTime = 0;

elapsedMillis lightDelay = 0;
```

```
elapsedMillis ledTime = 0;

DMTimer ledUpdateTimer(1000000); //Create a timer and specify its interval in microseconds

DMTimer ventiUpdateTimer(1000000);

// three element pixels, in different order and speeds

NeoPixelBus<NeoGrbFeature, Neo800KbpsMethod> strip(PixelCount, PixelPin);

//NeoPixelBus<NeoRgbFeature, Neo400KbpsMethod> strip(PixelCount, PixelPin);


RgbColor red(colorSaturation, 0, 0);

RgbColor green(0, colorSaturation, 0);

RgbColor blue(0, 0, colorSaturation);

RgbColor white(colorSaturation);

RgbColor black(0);

RgbColor grey(128,128,128);


RgbColor a(17,0,232);

RgbColor b(34,0,215);

RgbColor c(51,0,193);

RgbColor d(68,0,178);

RgbColor e(85,0,162);

RgbColor f(103,0,145);

RgbColor g(123,0,123);

RgbColor h(145,0,103);

RgbColor j(162,0,85);

RgbColor k(178,0,68);

RgbColor l(193,0,51);

RgbColor m(215,0,34);

RgbColor n(232,0,17);


int buttonPin = 23;
```

```
int LED1 = 35;

int LED2 = 37;

int LED3 = 39;

int LED4 = 41;

int LED5 = 43;

int LED6 = 45;

int LED7 = 47;

int LED8 = 49;

int LED9 = 51;

int LED10 = 53;



HslColor hslRed(red);

HslColor hslGreen(green);

HslColor hslBlue(blue);

HslColor hslWhite(white);

HslColor hslBlack(black);

int x = 500;

int sensorValue;

float PerfusionValue;

float VentiValue;

float sensorPerValue;

float sensorVenValue;

int buttonState = 0;



// the setup routine runs once when you press reset:

void setup() {

  Serial.begin(9600);
```

```
while (!Serial); // wait for serial attach// initialize serial communication at 9600 bits per second:


 Serial.println();

 Serial.println("Initializing...");

 Serial.flush();


   // this resets all the neopixels to an off state

 strip.Begin();

 for (int i=0; i<15; i++){

  strip.SetPixelColor(i,red);

 }

 strip.Show();



 Serial.println();

 Serial.println("Running...");

pinMode(LED1,OUTPUT);

pinMode(LED2,OUTPUT);

pinMode(LED3,OUTPUT);

pinMode(LED4,OUTPUT);

pinMode(LED5,OUTPUT);

pinMode(LED6,OUTPUT);

pinMode(LED7,OUTPUT);

pinMode(LED8,OUTPUT);

pinMode(LED9,OUTPUT);

pinMode(LED10,OUTPUT);



lcd.begin(20, 4);
```

```
  lcd.setCursor(0,0);

  lcd.print("V Value = ");

  lcd.setCursor(0,1);

  lcd.print("Q Value =");

  lcd.setCursor(0,2);

  lcd.print("V/Q ratio = ");

  lcd.setCursor(0,3);

  lcd.print("PaO2 = ");

  pinMode(REDLITE, OUTPUT);

  pinMode(GREENLITE, OUTPUT);

  pinMode(BLUELITE, OUTPUT);

  analogWrite(REDLITE, 0);

  analogWrite(GREENLITE, 0);

  analogWrite(BLUELITE, 0);

  }


void readDials(){

  float PerfusionValue = 0;

  float VentiValue = 0;

  float sensorPerValue = analogRead(A0);

    PerfusionValue = round((sensorPerValue/7.24));

  float sensorVenValue = analogRead(A3);

    VentiValue = round((sensorVenValue/7.06));

    ledUpdateTimer.setInterval((105-PerfusionValue)*8000);

  float VQratio = VentiValue / PerfusionValue;

  float PaO2=(485.596*( pow((VQratio),2))+VQratio*62.9359+21.4172)/(0.533853+1.60718*VQratio+3.26961*
(pow(VQratio,2)));

    if (valueTime> 150){ //150ms delay: Updates screen every 150ms
```

```
Serial.print ("Perfusion value is ");

Serial.println (PerfusionValue);

Serial.print ("Ventilation value is ");

Serial.println (VentiValue);

Serial.print ("V/Q ratio is ");

Serial.println (VQratio);

Serial.print ("PaO2 value is ");

Serial.println (PaO2);


lcd.setCursor(11,0);

lcd.print(VentiValue  ,2);

lcd.print("  ");

lcd.setCursor(11,1);

lcd.print(PerfusionValue  ,2);

lcd.print("  ");

lcd.setCursor(12,2);

lcd.print(VQratio  ,2);

lcd.print("  ");

lcd.setCursor(7,3);

lcd.print(PaO2 ,2);

lcd.print("   ");

valueTime = 0;}

if (PerfusionValue < 2){

   for (int i=0;i<15;i++){

     strip.SetPixelColor(i,grey);

     strip.Show();

   }

    readDials();

  VentilationLEDs();
```

```
    }

  }

  void VentilationLEDs (){

   float VentiValue = 0;

   float sensorVenValue = analogRead(A3);

   VentiValue = round((sensorVenValue/7.06));

   if ((VentiValue >0) && (VentiValue<= 10)){

    for (int i=35; i<54; i+=2){

      digitalWrite(i, LOW);

    }

    readDials();

   }

   if ((VentiValue >10) && (VentiValue<= 20)){

    digitalWrite(35,HIGH);

    for (int i=37; i<54; i+=2){

      digitalWrite(i, LOW);

    }   readDials();

    }

   if ((VentiValue >20) && (VentiValue<= 30)){

    digitalWrite(35,HIGH);

    digitalWrite(37,HIGH);

    for (int i=39; i<54; i+=2){

      digitalWrite(i, LOW);

    }  readDials();

     }

   if ((VentiValue >30) && (VentiValue<= 40)){

    for (int i=35; i<40; i+=2){

    digitalWrite(i,HIGH);

    }
```

```
  for (int i=41; i<54; i+=2){
    digitalWrite(i, LOW);
  }readDials(); }
 if ((VentiValue >40) && (VentiValue<= 50)){
  for (int i=35; i<42; i+=2){
  digitalWrite(i,HIGH);
  }
  for (int i=43; i<54; i+=2){
    digitalWrite(i, LOW);

  }readDials();  }



 if ((VentiValue >50) && (VentiValue<= 60)){
  for (int i=35; i<44; i+=2){
  digitalWrite(i,HIGH);
  }
  for (int i=45; i<54; i+=2){
    digitalWrite(i, LOW);
  }readDials();



  }
 if ((VentiValue >60) && (VentiValue<= 70)){
  for (int i=35; i<46; i+=2){
  digitalWrite(i,HIGH);
  }
  for (int i=47; i<54; i+=2){
    digitalWrite(i, LOW);
```

```
 } readDials();




 }

if ((VentiValue >70) && (VentiValue<= 80)){

 for (int i=35; i<48; i+=2){

 digitalWrite(i,HIGH);

 }

 for (int i=49; i<54; i+=2){

   digitalWrite(i, LOW);

 }readDials();




   }

if ((VentiValue >80) && (VentiValue<= 90)){

 for (int i=35; i<50; i+=2){

 digitalWrite(i,HIGH);

 }

 for (int i=51; i<54; i+=2){

   digitalWrite(i, LOW);

 }   readDials();


 }

if ((VentiValue) > 90){

 digitalWrite(35, HIGH);

 for (int i=35; i<54; i+=2){

 digitalWrite(i,HIGH);

 } readDials();

 }
```

```
    }

  void allLIGHTS(){

    float sensorPerValue = analogRead(A0);

    PerfusionValue = round((sensorPerValue/7.24));

  //   if (PerfusionValue < 6){

  //      for (int i=0;i<15;i++){

  //        strip.SetPixelColor(i,grey);

  //        strip.Show();

  //      }

  //       readDials();

  //    VentilationLEDs();

  //    }

    if(PerfusionValue >=6) {

      for (int i=0; i<15; i++){ //there is 15 LEDs so this goes over each one, one by one

        while (ledUpdateTimer.isTimeReached() == false){

          strip.SetPixelColor(i,hslBlack); // start by setting the pixel that you're working on to red (turn it on)

          strip.Show(); // this command is needed to update the LED

      }

      readDials();

      VentilationLEDs();

      Serial.println (PerfusionValue);

      strip.SetPixelColor(0,blue);

      strip.SetPixelColor(1,a);

      strip.SetPixelColor(2,b);

      strip.SetPixelColor(3,c);

      strip.SetPixelColor(4,d);

      strip.SetPixelColor(5,e);

      strip.SetPixelColor(6,f);

      strip.SetPixelColor(7,g);
```

```
    strip.SetPixelColor(8,h);

    strip.SetPixelColor(9,j);

    strip.SetPixelColor(10,k);

    strip.SetPixelColor(11,l);

    strip.SetPixelColor(12,m);

    strip.SetPixelColor(13,n);

    strip.SetPixelColor(14,red);

    }

}}



  void loop (){

    allLIGHTS();

  }
```

Conclusions/action items:

All coding work are done, the circuit works are expected.

2021/11/22-Coding document Version 4

Charlie ZHU - Dec 15, 2021, 1:45 PM CST

Title: Coding document Version 4

Date: 2021/11/22

Content by: Charlie Zhu and Alex Houle

Present: Charlie Zhu and Alex Houle

Goals: Coding for V/Q model

Content:

```
/*

  AnalogReadSerial


  Reads an analog input on pin 0, prints the result to the Serial Monitor.

  Graphical representation is available using Serial Plotter (Tools > Serial Plotter menu).

  Attach the center pin of a potentiometer to pin A0, and the outside pins to +5V and ground.


  This example code is in the public domain.


  https://www.arduino.cc/en/Tutorial/BuiltInExamples/AnalogReadSerial

*/

#include <NeoPixelBus.h>

#include <elapsedMillis.h>

#include <LiquidCrystal.h>

#include <Wire.h>

#include <dmtimer.h>

#define REDLITE 7

#define GREENLITE 8

#define BLUELITE 9

int brightness = 255;
```

```
const uint16_t PixelCount = 15; // this example assumes 4 pixels, making it smaller will cause a failure

const uint8_t PixelPin = 10;  // make sure to set this to the correct pin, ignored for Esp8266



const int rs = 12, en = 11, d4 = 5, d5 = 4, d6 = 3, d7 = 2;

LiquidCrystal lcd(rs, en, d4, d5, d6, d7);

#define colorSaturation 128

elapsedMillis valueTime = 0;

elapsedMillis lightTime = 0;

elapsedMillis lightDelay = 0;

elapsedMillis ledTime = 0;

DMTimer ledUpdateTimer(1000000); //Create a timer and specify its interval in microseconds

DMTimer ventiUpdateTimer(1000000);

// three element pixels, in different order and speeds

NeoPixelBus<NeoGrbFeature, Neo800KbpsMethod> strip(PixelCount, PixelPin);

//NeoPixelBus<NeoRgbFeature, Neo400KbpsMethod> strip(PixelCount, PixelPin);


// For Esp8266, the Pin is omitted and it uses GPIO3 due to DMA hardware use.

// There are other Esp8266 alternative methods that provide more pin options, but also have

// other side effects.

// for details see wiki linked here https://github.com/Makuna/NeoPixelBus/wiki/ESP8266-NeoMethods


// You can also use one of these for Esp8266,

// each having their own restrictions

//

// These two are the same as above as the DMA method is the default

// NOTE: These will ignore the PIN and use GPI03 pin

//NeoPixelBus<NeoGrbFeature, NeoEsp8266Dma800KbpsMethod> strip(PixelCount, PixelPin);
```

```
//NeoPixelBus<NeoRgbFeature, NeoEsp8266Dma400KbpsMethod> strip(PixelCount, PixelPin);


// Uart method is good for the Esp-01 or other pin restricted modules

// for details see wiki linked here https://github.com/Makuna/NeoPixelBus/wiki/ESP8266-NeoMethods

// NOTE: These will ignore the PIN and use GPI02 pin

//NeoPixelBus<NeoGrbFeature, NeoEsp8266Uart1800KbpsMethod> strip(PixelCount, PixelPin);

//NeoPixelBus<NeoRgbFeature, NeoEsp8266Uart1400KbpsMethod> strip(PixelCount, PixelPin);


// The bitbang method is really only good if you are not using WiFi features of the ESP

// It works with all but pin 16

//NeoPixelBus<NeoGrbFeature, NeoEsp8266BitBang800KbpsMethod> strip(PixelCount, PixelPin);

//NeoPixelBus<NeoRgbFeature, NeoEsp8266BitBang400KbpsMethod> strip(PixelCount, PixelPin);


// four element pixels, RGBW

//NeoPixelBus<NeoRgbwFeature, Neo800KbpsMethod> strip(PixelCount, PixelPin);


RgbColor red(colorSaturation, 0, 0);

RgbColor green(0, colorSaturation, 0);

RgbColor blue(0, 0, colorSaturation);

RgbColor white(colorSaturation);

RgbColor black(0);


RgbColor a(17,0,232);

RgbColor b(34,0,215);

RgbColor c(51,0,193);

RgbColor d(68,0,178);

RgbColor e(85,0,162);

RgbColor f(103,0,145);

RgbColor g(123,0,123);
```

```
RgbColor h(145,0,103);

RgbColor j(162,0,85);

RgbColor k(178,0,68);

RgbColor l(193,0,51);

RgbColor m(215,0,34);

RgbColor n(232,0,17);






HslColor hslRed(red);

HslColor hslGreen(green);

HslColor hslBlue(blue);

HslColor hslWhite(white);

HslColor hslBlack(black);

int x = 500;

int sensorValue;

float PerfusionValue;

float VentiValue;

float sensorPerValue;

float sensorVenValue;



// the setup routine runs once when you press reset:

void setup() {

  Serial.begin(9600);

  while (!Serial); // wait for serial attach// initialize serial communication at 9600 bits per second:


    Serial.println();
```

```
    Serial.println("Initializing...");

    Serial.flush();


      // this resets all the neopixels to an off state

    strip.Begin();

    for (int i=0; i<15; i++){

     strip.SetPixelColor(i,red); // start by setting the pixel that you're working on to red (turn it on)

    }

    strip.Show();




    Serial.println();

    Serial.println("Running...");

     // set up the LCD's number of columns and rows:


 for (int thispin = 35;thispin<52; thispin +=2){

   pinMode(thispin,OUTPUT);

 }

  for (int thispin = 35;thispin<52; thispin +=2){

  digitalWrite(thispin, HIGH);}

   lcd.begin(20, 4);

    lcd.setCursor(0,0);

   lcd.print("V Value = ");

   lcd.setCursor(0,1);

   lcd.print("Q Value =");

   lcd.setCursor(0,2);

   lcd.print("V/Q ratio = ");

   lcd.setCursor(0,3);

   lcd.print("PaO2 = ");
```

```
  pinMode(REDLITE, OUTPUT);

  pinMode(GREENLITE, OUTPUT);

  pinMode(BLUELITE, OUTPUT);

   analogWrite(REDLITE, 0);

  analogWrite(GREENLITE, 0);

  analogWrite(BLUELITE, 0);




}


void readDials(){

  float PerfusionValue = 0;

  float VentiValue = 0;

  float sensorPerValue = analogRead(A0);

     PerfusionValue = round((sensorPerValue/7.24));

float sensorVenValue = analogRead(A3);

     VentiValue = round((sensorVenValue/7.06));

      ledUpdateTimer.setInterval((105-PerfusionValue)*8000);

float VQratio = VentiValue / PerfusionValue;

float PaO2=(485.596*( pow((VQratio),2))+VQratio*62.9359+21.4172)/(0.533853+1.60718*VQratio+3.26961*
(pow(VQratio,2)));

  if (valueTime> 150){ //150ms delay

  // print out the value you read:


  Serial.print ("Perfusion value is ");

  Serial.println (PerfusionValue);

  Serial.print ("Ventilation value is ");

  Serial.println (VentiValue);

  Serial.print ("V/Q ratio is ");
```

```
  Serial.println (VQratio);

   Serial.print ("PaO2 value is ");

  Serial.println (PaO2);



   lcd.setCursor(11,0);

  lcd.print(VentiValue  ,2);

  lcd.print("  ");

  lcd.setCursor(11,1);

  lcd.print(PerfusionValue  ,2);

  lcd.print("  ");

   lcd.setCursor(12,2);

  lcd.print(VQratio  ,2);

  lcd.print("  ");

  lcd.setCursor(7,3);

  lcd.print(PaO2 ,2);

  lcd.print("   ");

    valueTime = 0;}

}

  void loop (){

  sensorPerValue = analogRead(A0);

  PerfusionValue = round((sensorPerValue/7.24));

  sensorVenValue = analogRead(A3);

  VentiValue = round((sensorVenValue/7.06));

    for (int i=0; i<15; i++){ //there is 15 LEDs so this goes over each one, one by one


    while (ledUpdateTimer.isTimeReached() == false){

      strip.SetPixelColor(i,hslBlack); // start by setting the pixel that you're working on to red (turn it on)

      strip.Show(); // this command is needed to update the LED
```

```
 }
  readDials();
  Serial.println (PerfusionValue);

 strip.SetPixelColor(0,blue);
 strip.SetPixelColor(1,a);
 strip.SetPixelColor(2,b);
 strip.SetPixelColor(3,c);
 strip.SetPixelColor(4,d);
 strip.SetPixelColor(5,e);
 strip.SetPixelColor(6,f);
 strip.SetPixelColor(7,g);
 strip.SetPixelColor(8,h);
 strip.SetPixelColor(9,j);
 strip.SetPixelColor(10,k);
 strip.SetPixelColor(11,l);
 strip.SetPixelColor(12,m);
 strip.SetPixelColor(13,n);
 strip.SetPixelColor(14,red);
 }

}
 //Comment the code below this line to let the code work
void Led(){

  Serial.print(VentiValue);
  while (VentiValue < 25){
```

```
     if (ledTime < 1500) {

      for (int thispin = 35;thispin<52; thispin +=2){

digitalWrite(thispin, HIGH);




  }}

  else if (ledTime >=1500&&ledTime<2000){

   for (int thispin = 35;thispin<52; thispin +=2){

digitalWrite(thispin, LOW);


  }

   ledTime = 0;

   }}

      while (VentiValue >=25&&VentiValue<75){

      if (ledTime < 1000) {

      for (int thispin = 35;thispin<52; thispin +=2){

digitalWrite(thispin, HIGH);




  }}


  else if (ledTime >=1000&&ledTime<1500){

   for (int thispin = 35;thispin<52; thispin +=2){

digitalWrite(thispin, LOW);


  }

   ledTime = 0;

   }

     }
```

```
    while (VentiValue >=75){

        if (ledTime < 500) {

     for (int thispin = 35;thispin<52; thispin +=2){

 digitalWrite(thispin, HIGH);




  }}

  else if (ledTime >=500&&ledTime<1000){

   for (int thispin = 35;thispin<52; thispin +=2){

 digitalWrite(thispin, LOW);


  }

   ledTime = 0;

   }}}
```

Conclusions/action items:

10 LED bulbs are connected to the circuit, but they are not coded correctly which means they could not be turned on correctly corresponding to the changing of sensor value.

2021/11/19-Coding document Version 3

Charlie ZHU - Dec 15, 2021, 1:45 PM CST

Title: Coding document Version 3

Date: 2021/11/19

Content by: Charlie Zhu and Alex Houle

Present: Charlie Zhu and Alex Houle

Goals: Coding for V/Q model

Content:

```
#include <NeoPixelBus.h>

#include <elapsedMillis.h>

#include <LiquidCrystal.h>

#include <Wire.h>

#include <dmtimer.h>

#define REDLITE 7

#define GREENLITE 8

#define BLUELITE 9

int brightness = 255;


const uint16_t PixelCount = 15; // this example assumes 4 pixels, making it smaller will cause a failure

const uint8_t PixelPin = 10;  // make sure to set this to the correct pin, ignored for Esp8266




const int rs = 12, en = 11, d4 = 5, d5 = 4, d6 = 3, d7 = 2;

LiquidCrystal lcd(rs, en, d4, d5, d6, d7);

#define colorSaturation 128

elapsedMillis valueTime = 0;

elapsedMillis lightTime = 0;

elapsedMillis lightDelay = 0;
```

```
DMTimer ledUpdateTimer(1000000); //Create a timer and specify its interval in microseconds

// three element pixels, in different order and speeds

NeoPixelBus<NeoGrbFeature, Neo800KbpsMethod> strip(PixelCount, PixelPin);

//NeoPixelBus<NeoRgbFeature, Neo400KbpsMethod> strip(PixelCount, PixelPin);


// For Esp8266, the Pin is omitted and it uses GPIO3 due to DMA hardware use.

// There are other Esp8266 alternative methods that provide more pin options, but also have

// other side effects.

// for details see wiki linked here https://github.com/Makuna/NeoPixelBus/wiki/ESP8266-NeoMethods


// You can also use one of these for Esp8266,

// each having their own restrictions

//

// These two are the same as above as the DMA method is the default

// NOTE: These will ignore the PIN and use GPI03 pin

//NeoPixelBus<NeoGrbFeature, NeoEsp8266Dma800KbpsMethod> strip(PixelCount, PixelPin);

//NeoPixelBus<NeoRgbFeature, NeoEsp8266Dma400KbpsMethod> strip(PixelCount, PixelPin);


// Uart method is good for the Esp-01 or other pin restricted modules

// for details see wiki linked here https://github.com/Makuna/NeoPixelBus/wiki/ESP8266-NeoMethods

// NOTE: These will ignore the PIN and use GPI02 pin

//NeoPixelBus<NeoGrbFeature, NeoEsp8266Uart1800KbpsMethod> strip(PixelCount, PixelPin);

//NeoPixelBus<NeoRgbFeature, NeoEsp8266Uart1400KbpsMethod> strip(PixelCount, PixelPin);


// The bitbang method is really only good if you are not using WiFi features of the ESP

// It works with all but pin 16

//NeoPixelBus<NeoGrbFeature, NeoEsp8266BitBang800KbpsMethod> strip(PixelCount, PixelPin);

//NeoPixelBus<NeoRgbFeature, NeoEsp8266BitBang400KbpsMethod> strip(PixelCount, PixelPin);
```

```
// four element pixels, RGBW
//NeoPixelBus<NeoRgbwFeature, Neo800KbpsMethod> strip(PixelCount, PixelPin);


RgbColor red(colorSaturation, 0, 0);
RgbColor green(0, colorSaturation, 0);
RgbColor blue(0, 0, colorSaturation);
RgbColor white(colorSaturation);
RgbColor black(0);


RgbColor a(17,0,232);
RgbColor b(34,0,215);
RgbColor c(51,0,193);
RgbColor d(68,0,178);
RgbColor e(85,0,162);
RgbColor f(103,0,145);
RgbColor g(123,0,123);
RgbColor h(145,0,103);
RgbColor j(162,0,85);
RgbColor k(178,0,68);
RgbColor l(193,0,51);
RgbColor m(215,0,34);
RgbColor n(232,0,17);




HslColor hslRed(red);
HslColor hslGreen(green);
HslColor hslBlue(blue);
```

```
HslColor hslWhite(white);

HslColor hslBlack(black);

int x = 500;

int sensorValue;

float PerfusionValue;

float VentiValue;

float sensorPerValue;

float sensorVenValue;



// the setup routine runs once when you press reset:

void setup() {

  Serial.begin(9600);

  while (!Serial); // wait for serial attach// initialize serial communication at 9600 bits per second:


    Serial.println();

    Serial.println("Initializing...");

    Serial.flush();


        // this resets all the neopixels to an off state

    strip.Begin();

    for (int i=0; i<15; i++){

      strip.SetPixelColor(i,red); // start by setting the pixel that you're working on to red (turn it on)

    }

    strip.Show();



    Serial.println();

    Serial.println("Running...");
```

```
    // set up the LCD's number of columns and rows:



   lcd.begin(20, 4);

  lcd.setCursor(0,0);

  lcd.print("V/Q ratio = ");

  lcd.setCursor(0,2);

  lcd.print("PaO2 = ");

  pinMode(REDLITE, OUTPUT);

  pinMode(GREENLITE, OUTPUT);

  pinMode(BLUELITE, OUTPUT);

   analogWrite(REDLITE, 0);

  analogWrite(GREENLITE, 0);

  analogWrite(BLUELITE, 0);



}


void readDials(){

  float PerfusionValue = 0;

  float VentiValue = 0;

  float sensorPerValue = analogRead(A0);

     PerfusionValue = round((sensorPerValue/7.24));

float sensorVenValue = analogRead(A3);

     VentiValue = round((sensorVenValue/7.06));

      ledUpdateTimer.setInterval(PerfusionValue*10000);

float VQratio = VentiValue / PerfusionValue;

float Xvalue = log10(VQratio) ;
```

```
float PaO2=(485.596*( pow((VQratio),2))+VQratio*62.9359+21.4172)/(0.533853+1.60718*VQratio+3.26961*
(pow(VQratio,2)));

  if (valueTime> 150){ //150ms delay

  // print out the value you read:



  Serial.print ("Perfusion value is ");

  Serial.println (PerfusionValue);

  Serial.print ("Ventilation value is ");

  Serial.println (VentiValue);

  Serial.print ("V/Q ratio is ");

  Serial.println (VQratio);

   Serial.print ("PaO2 value is ");

  Serial.println (PaO2);



   lcd.setCursor(12,0);

  lcd.print(VQratio  ,2);

  lcd.print("  ");

  lcd.setCursor(7,2);

  lcd.print(PaO2 ,2);

  lcd.print("   ");



    valueTime = 0;}

}

  void loop (){

  sensorPerValue = analogRead(A0);

  PerfusionValue = round((sensorPerValue/7.24));

  sensorVenValue = analogRead(A3);

  VentiValue = round((sensorVenValue/7.06));

    for (int i=0; i<15; i++){ //there is 15 LEDs so this goes over each one, one by one
```

```
while (ledUpdateTimer.isTimeReached() == false){
  strip.SetPixelColor(i,hslBlack); // start by setting the pixel that you're working on to red (turn it on)
  strip.Show(); // this command is needed to update the LED




}
 readDials();
 Serial.println (PerfusionValue);

strip.SetPixelColor(0,blue);
strip.SetPixelColor(1,a);
strip.SetPixelColor(2,b);
strip.SetPixelColor(3,c);
strip.SetPixelColor(4,d);
strip.SetPixelColor(5,e);
strip.SetPixelColor(6,f);
strip.SetPixelColor(7,g);
strip.SetPixelColor(8,h);
strip.SetPixelColor(9,j);
strip.SetPixelColor(10,k);
strip.SetPixelColor(11,l);
strip.SetPixelColor(12,m);
strip.SetPixelColor(13,n);
strip.SetPixelColor(14,red);
}

}
```

```
//  heatshrink
```

Conclusions/action items:

LED strip is set up correctly with the sensor value. The color of the LED strip is set corresponding to the position of the LEDs. Next step is inserting LED bulbs and code for ventilation value.

2021/11/04-Coding document Version 2

Charlie ZHU - Dec 15, 2021, 1:45 PM CST

Title: Coding document Version 2

Date: 2021/11/04

Content by: Charlie Zhu and Alex Houle

Present: Charlie Zhu and Alex Houle

Goals: Coding for V/Q model

Content:

```
#include <NeoPixelBus.h>

#include <elapsedMillis.h>

#include <LiquidCrystal.h>

#include <Wire.h>

#define REDLITE 7

#define GREENLITE 8

#define BLUELITE 9

int brightness = 255;


const uint16_t PixelCount = 15; // this example assumes 4 pixels, making it smaller will cause a failure

const uint8_t PixelPin = 10;  // make sure to set this to the correct pin, ignored for Esp8266



const int rs = 12, en = 11, d4 = 5, d5 = 4, d6 = 3, d7 = 2;

LiquidCrystal lcd(rs, en, d4, d5, d6, d7);

#define colorSaturation 128

elapsedMillis valueTime = 0;

elapsedMillis lightTime = 0;

elapsedMillis lightDelay = 0;

// three element pixels, in different order and speeds
```

```
NeoPixelBus<NeoGrbFeature, Neo800KbpsMethod> strip(PixelCount, PixelPin);
//NeoPixelBus<NeoRgbFeature, Neo400KbpsMethod> strip(PixelCount, PixelPin);

// For Esp8266, the Pin is omitted and it uses GPIO3 due to DMA hardware use.
// There are other Esp8266 alternative methods that provide more pin options, but also have
// other side effects.
// for details see wiki linked here https://github.com/Makuna/NeoPixelBus/wiki/ESP8266-NeoMethods

// You can also use one of these for Esp8266,
// each having their own restrictions
//
// These two are the same as above as the DMA method is the default
// NOTE: These will ignore the PIN and use GPI03 pin
//NeoPixelBus<NeoGrbFeature, NeoEsp8266Dma800KbpsMethod> strip(PixelCount, PixelPin);
//NeoPixelBus<NeoRgbFeature, NeoEsp8266Dma400KbpsMethod> strip(PixelCount, PixelPin);

// Uart method is good for the Esp-01 or other pin restricted modules
// for details see wiki linked here https://github.com/Makuna/NeoPixelBus/wiki/ESP8266-NeoMethods
// NOTE: These will ignore the PIN and use GPI02 pin
//NeoPixelBus<NeoGrbFeature, NeoEsp8266Uart1800KbpsMethod> strip(PixelCount, PixelPin);
//NeoPixelBus<NeoRgbFeature, NeoEsp8266Uart1400KbpsMethod> strip(PixelCount, PixelPin);

// The bitbang method is really only good if you are not using WiFi features of the ESP
// It works with all but pin 16
//NeoPixelBus<NeoGrbFeature, NeoEsp8266BitBang800KbpsMethod> strip(PixelCount, PixelPin);
//NeoPixelBus<NeoRgbFeature, NeoEsp8266BitBang400KbpsMethod> strip(PixelCount, PixelPin);

// four element pixels, RGBW
//NeoPixelBus<NeoRgbwFeature, Neo800KbpsMethod> strip(PixelCount, PixelPin);
```

```
RgbColor red(colorSaturation, 0, 0);
RgbColor green(0, colorSaturation, 0);
RgbColor blue(0, 0, colorSaturation);
RgbColor white(colorSaturation);
RgbColor black(0);

HslColor hslRed(red);
HslColor hslGreen(green);
HslColor hslBlue(blue);
HslColor hslWhite(white);
HslColor hslBlack(black);
int x = 500;
int sensorValue;


// the setup routine runs once when you press reset:
void setup() {
 // initialize serial communication at 9600 bits per second:
  Serial.begin(9600);
  while (!Serial); // wait for serial attach

  Serial.println();
  Serial.println("Initializing...");
  Serial.flush();

    // this resets all the neopixels to an off state
  strip.Begin();
  strip.Show();
```

```
    Serial.println();
    Serial.println("Running...");
     // set up the LCD's number of columns and rows:


   lcd.begin(20, 4);
  lcd.setCursor(0,0);
  lcd.print("V/Q ratio = ");
  lcd.setCursor(0,2);
  lcd.print("PaO2 = ");
  pinMode(REDLITE, OUTPUT);
  pinMode(GREENLITE, OUTPUT);
  pinMode(BLUELITE, OUTPUT);
   analogWrite(REDLITE, 0);
  analogWrite(GREENLITE, 0);
  analogWrite(BLUELITE, 0);

}

// the loop routine runs over and over again forever:

  void loop (){
  // read the input on analog pin 0:


  //Completed Value calibration
float PerfusionValue = 0;
```

```
float VentiValue = 0;

float sensorPerValue = analogRead(A0);

   PerfusionValue = round((sensorPerValue/7.24));

float sensorVenValue = analogRead(A3);

   VentiValue = round((sensorVenValue/7.06));

float VQratio = VentiValue / PerfusionValue;

float Xvalue = log10(VQratio) ;

float PaO2=(485.596*( pow((VQratio),2))+VQratio*62.9359+21.4172)/(0.533853+1.60718*VQratio+3.26961*
(pow(VQratio,2)));

 if (valueTime > 150){ //150ms delay

 // print out the value you read:



 Serial.print ("Perfusion value is ");

 Serial.println (PerfusionValue);

 Serial.print ("Ventilation value is ");

 Serial.println (VentiValue);

 Serial.print ("V/Q ratio is ");

 Serial.println (VQratio);

  Serial.print ("PaO2 value is ");

 Serial.println (PaO2);



  lcd.setCursor(12,0);

 lcd.print(VQratio  ,2);

 lcd.print("  ");

 lcd.setCursor(7,2);

 lcd.print(PaO2 ,2);

 lcd.print("   ");



   valueTime = 0;
```

```
}

//unsigned long currentDelay = millis();

  //for (int i=0; i<15;){

   // strip.SetPixelColor(i,red);

    //strip.Show();

   // if ((currentDelay - lightDelay) >= (PerfusionValue*100)){

    //  currentDelay = lightDelay;

    //  strip.SetPixelColor(i, hslBlack);

      //i=i+1;

 //   }



// }

}
```

Conclusions/action items:

LED strip is connected to the Arduino, but it is not flashing corresponding to the value of potentiometer correctly yet. Alex and I am going to meet with previous team member discuss how to fix the problem.

2021/11/02-Coding document Version 1

Charlie ZHU - Dec 15, 2021, 1:46 PM CST

Title: Coding document Version 1

Date: 2021/11/02

Content by: Charlie Zhu and Alex Houle

Present: Charlie Zhu and Alex Houle

Goals: Coding for V/Q model

Content:

```
/*
  AnalogReadSerial

  Reads an analog input on pin 0, prints the result to the Serial Monitor.
  Graphical representation is available using Serial Plotter (Tools > Serial Plotter menu).
  Attach the center pin of a potentiometer to pin A0, and the outside pins to +5V and ground.

  This example code is in the public domain.

  https://www.arduino.cc/en/Tutorial/BuiltInExamples/AnalogReadSerial
*/
#include <NeoPixelBus.h>
#include <elapsedMillis.h>
#include <LiquidCrystal.h>
#include <Wire.h>
#define REDLITE 7
#define GREENLITE 8
#define BLUELITE 9
int brightness = 255;
```

```
const uint16_t PixelCount = 15; // this example assumes 4 pixels, making it smaller will cause a failure

const uint8_t PixelPin = 10;  // make sure to set this to the correct pin, ignored for Esp8266



const int rs = 12, en = 11, d4 = 5, d5 = 4, d6 = 3, d7 = 2;

LiquidCrystal lcd(rs, en, d4, d5, d6, d7);

#define colorSaturation 128

elapsedMillis valueTime = 0;

elapsedMillis lightTime = 0;

elapsedMillis lightDelay = 0;

// three element pixels, in different order and speeds

NeoPixelBus<NeoGrbFeature, Neo800KbpsMethod> strip(PixelCount, PixelPin);

//NeoPixelBus<NeoRgbFeature, Neo400KbpsMethod> strip(PixelCount, PixelPin);


// For Esp8266, the Pin is omitted and it uses GPIO3 due to DMA hardware use.

// There are other Esp8266 alternative methods that provide more pin options, but also have

// other side effects.

// for details see wiki linked here https://github.com/Makuna/NeoPixelBus/wiki/ESP8266-NeoMethods


// You can also use one of these for Esp8266,

// each having their own restrictions

//

// These two are the same as above as the DMA method is the default

// NOTE: These will ignore the PIN and use GPI03 pin

//NeoPixelBus<NeoGrbFeature, NeoEsp8266Dma800KbpsMethod> strip(PixelCount, PixelPin);

//NeoPixelBus<NeoRgbFeature, NeoEsp8266Dma400KbpsMethod> strip(PixelCount, PixelPin);


// Uart method is good for the Esp-01 or other pin restricted modules

// for details see wiki linked here https://github.com/Makuna/NeoPixelBus/wiki/ESP8266-NeoMethods
```

```
// NOTE: These will ignore the PIN and use GPI02 pin

//NeoPixelBus<NeoGrbFeature, NeoEsp8266Uart1800KbpsMethod> strip(PixelCount, PixelPin);

//NeoPixelBus<NeoRgbFeature, NeoEsp8266Uart1400KbpsMethod> strip(PixelCount, PixelPin);


// The bitbang method is really only good if you are not using WiFi features of the ESP

// It works with all but pin 16

//NeoPixelBus<NeoGrbFeature, NeoEsp8266BitBang800KbpsMethod> strip(PixelCount, PixelPin);

//NeoPixelBus<NeoRgbFeature, NeoEsp8266BitBang400KbpsMethod> strip(PixelCount, PixelPin);


// four element pixels, RGBW

//NeoPixelBus<NeoRgbwFeature, Neo800KbpsMethod> strip(PixelCount, PixelPin);


RgbColor red(colorSaturation, 0, 0);

RgbColor green(0, colorSaturation, 0);

RgbColor blue(0, 0, colorSaturation);

RgbColor white(colorSaturation);

RgbColor black(0);


HslColor hslRed(red);

HslColor hslGreen(green);

HslColor hslBlue(blue);

HslColor hslWhite(white);

HslColor hslBlack(black);

int x = 500;

int sensorValue;



// the setup routine runs once when you press reset:

void setup() {
```

```
// initialize serial communication at 9600 bits per second:
  Serial.begin(9600);
  while (!Serial); // wait for serial attach

  Serial.println();
  Serial.println("Initializing...");
  Serial.flush();

      // this resets all the neopixels to an off state
  strip.Begin();
  strip.Show();


  Serial.println();
  Serial.println("Running...");
   // set up the LCD's number of columns and rows:


 lcd.begin(20, 4);
lcd.setCursor(0,0);
lcd.print("V/Q ratio = ");
lcd.setCursor(0,2);
lcd.print("PaO2 = ");
pinMode(REDLITE, OUTPUT);
pinMode(GREENLITE, OUTPUT);
pinMode(BLUELITE, OUTPUT);
 analogWrite(REDLITE, 0);
analogWrite(GREENLITE, 0);
analogWrite(BLUELITE, 0);
```

```
}

// the loop routine runs over and over again forever:

  void loop (){
  // read the input on analog pin 0:



  //Completed Value calibration
float PerfusionValue = 0;
float VentiValue = 0;
float sensorPerValue = analogRead(A0);
     PerfusionValue = round((sensorPerValue/7.24));
float sensorVenValue = analogRead(A3);
     VentiValue = round((sensorVenValue/7.06));
float VQratio = VentiValue / PerfusionValue;
float Xvalue = log10(VQratio) ;
float PaO2=166*( pow((Xvalue+5),6)/(pow(4.68,6)+pow((Xvalue+5),6)));
  if (valueTime > 150){ //150ms delay
  // print out the value you read:

  Serial.print ("Perfusion value is ");
  Serial.println (PerfusionValue);
  Serial.print ("Ventilation value is ");
  Serial.println (VentiValue);
  Serial.print ("V/Q ratio is ");
  Serial.println (VQratio);
   Serial.print ("PaO2 value is ");
```

```
Serial.println (PaO2);


 lcd.setCursor(12,0);

lcd.print(VQratio  ,2);

lcd.print("  ");

lcd.setCursor(7,2);

lcd.print(PaO2 ,2);

lcd.print("   ");


  valueTime = 0;

}

unsigned long currentDelay = millis();

  for (int i=0; i<15;){

    strip.SetPixelColor(i,red);

    strip.Show();

    if ((currentDelay - lightDelay) >= (PerfusionValue*100)){

      currentDelay = lightDelay;

      strip.SetPixelColor(i, hslBlack);

      i=i+1;

    }




}

}
```

Conclusions/action items:

Potentiometer is calibrated and the display board is connected to Arduino. Led strip and bulbs need to be connected in the future.

2021/12/03 - 3D printing Version1 V/Q Model

Charlie ZHU - Dec 15, 2021, 2:29 PM CST

Title: 3D printing Version 1 V/Q Model

Date: 2021/12/03

Content by: Charlie Zhu

Present: Charlie Zhu

Goals: 3D print our V/Q model Version 1

Content:

uwmadmaker@gmail.com
Fri 12/3/2021 1:13 PM
To: Charlie ZHU

Hi Charlie Zhu:

The print job "Ventilation Perfusion Model" is printing on a Ultimaker printer. You'll receive another email when the print job is ready to be picked or if there is an issue.

Although the estimated print time is 21 hours, please do not come to the Makerspace to pick-up the print until you have received a pick-up email.

If 21 + 1 whole business day has passed. Email <maker-3dprint@engr.wisc.edu> and reference this job # 1978595702.

This is an automated message from the Makerspace 3D Print System (I'm a bot). Do not reply to this email.

Happy Making,
The 3D Printing Team

Reply | Forward

Conclusions/action items:

Dimension does not fit, second time reprint is needed

2021/12/10 - 3D printing Version3 V/Q Model

Charlie ZHU - Dec 15, 2021, 2:29 PM CST

Title: 3D printing Version 3 V/Q Model

Date: 2021/12/10

Content by: Charlie Zhu

Present: Charlie Zhu

Goals: 3D print our V/Q model Version 3

Content:


Q
ALVEOLUS
V
CAPILLARY

U

uwmadmaker@gmail.com
Fri 12/10/2021 2:37 PM
To: Charlie ZHU

Hi Charlie Zhu:

The print job "VQ model" is printing on a Ultimaker printer. You'll receive another email when the print job is ready to be picked or if there is an issue.

Although the estimated print time is 53 hours, please do not come to the Makerspace to pick-up the print until you have received a pick-up email.

If 53 + 1 whole business day has passed. Email <maker-3dprint@engr.wisc.edu> and reference this job # 2009636839.

This is an automated message from the Makerspace 3D Print System (I'm a bot). Do not reply to this email.

Happy Making,
The 3D Printing Team

Reply | Forward

Conclusions/action items:

Final fabrication, and everything fits fine. No need to reprint.

2021/12/07 - 3D printing Version2 V/Q Model

Charlie ZHU - Dec 15, 2021, 2:29 PM CST

Title: 3D printing Version 2 V/Q Model

Date: 2021/12/07

Content by: Charlie Zhu

Present: Charlie Zhu

Goals: 3D print our V/Q model Version 2

Content:

U

uwmadmaker@gmail.com
Tue 12/7/2021 1:24 PM
To: Charlie ZHU

Hi Charlie Zhu:

The print job "V/Q Model" is printing on a Ultimaker printer. You'll receive another email when the print job is ready to be picked or if there is an issue.

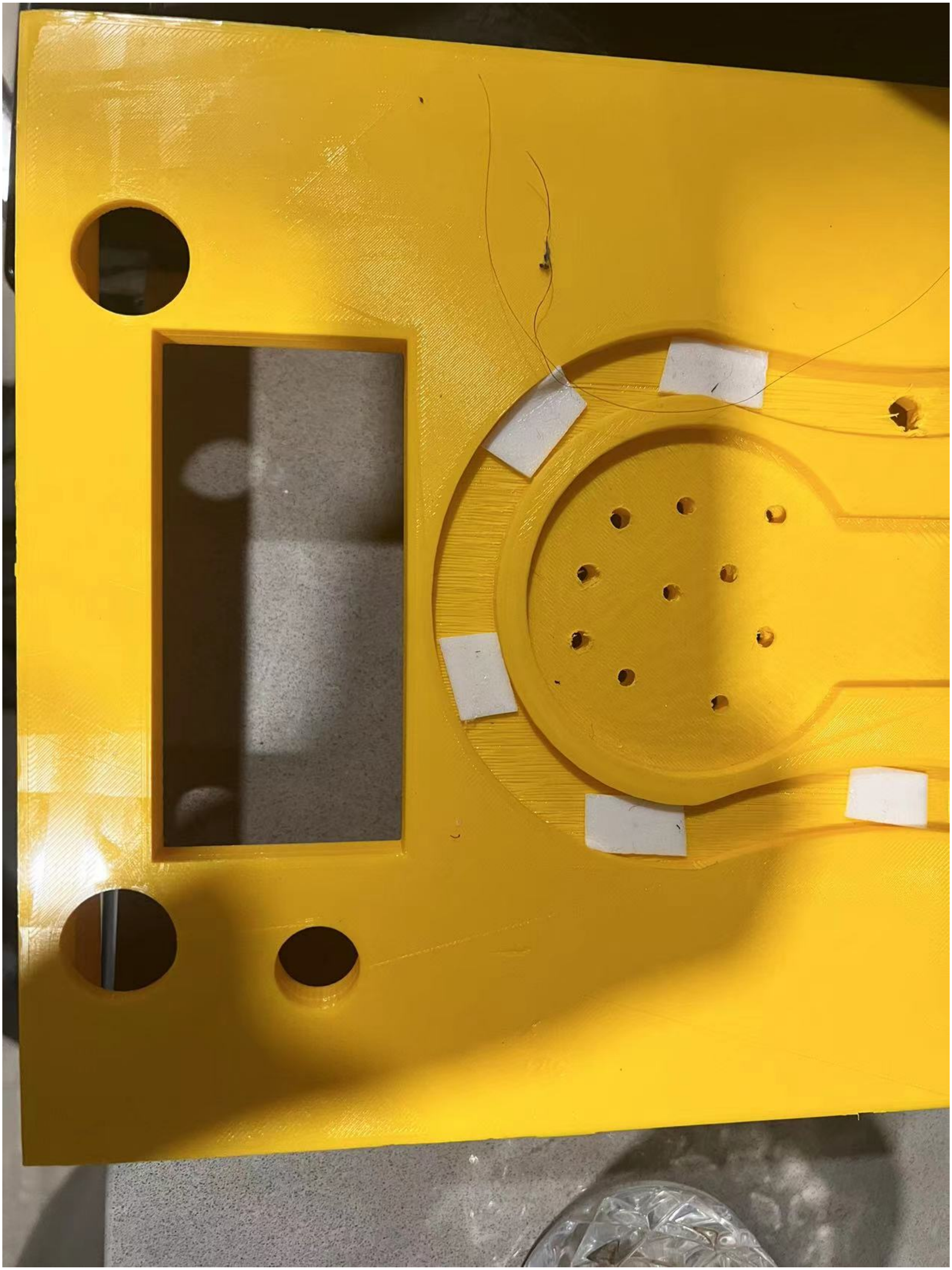
Although the estimated print time is 20 hours, please do not come to the Makerspace to pick-up the print until you have received a pick-up email.

If 20 + 1 whole business day has passed. Email <maker-3dprint@engr.wisc.edu> and reference this job # 1992092255.

This is an automated message from the Makerspace 3D Print System (I'm a bot). Do not reply to this email.

Happy Making,
The 3D Printing Team

Reply | Forward



Conclusions/action items:

Display board Dimension does not fit, Black color is more desired than yellow. Third time reprint is needed

2021/12/08 - 3D printing back Version1 V/Q Model

Charlie ZHU - Dec 15, 2021, 2:30 PM CST

Title: 3D printing back Version 1 V/Q Model

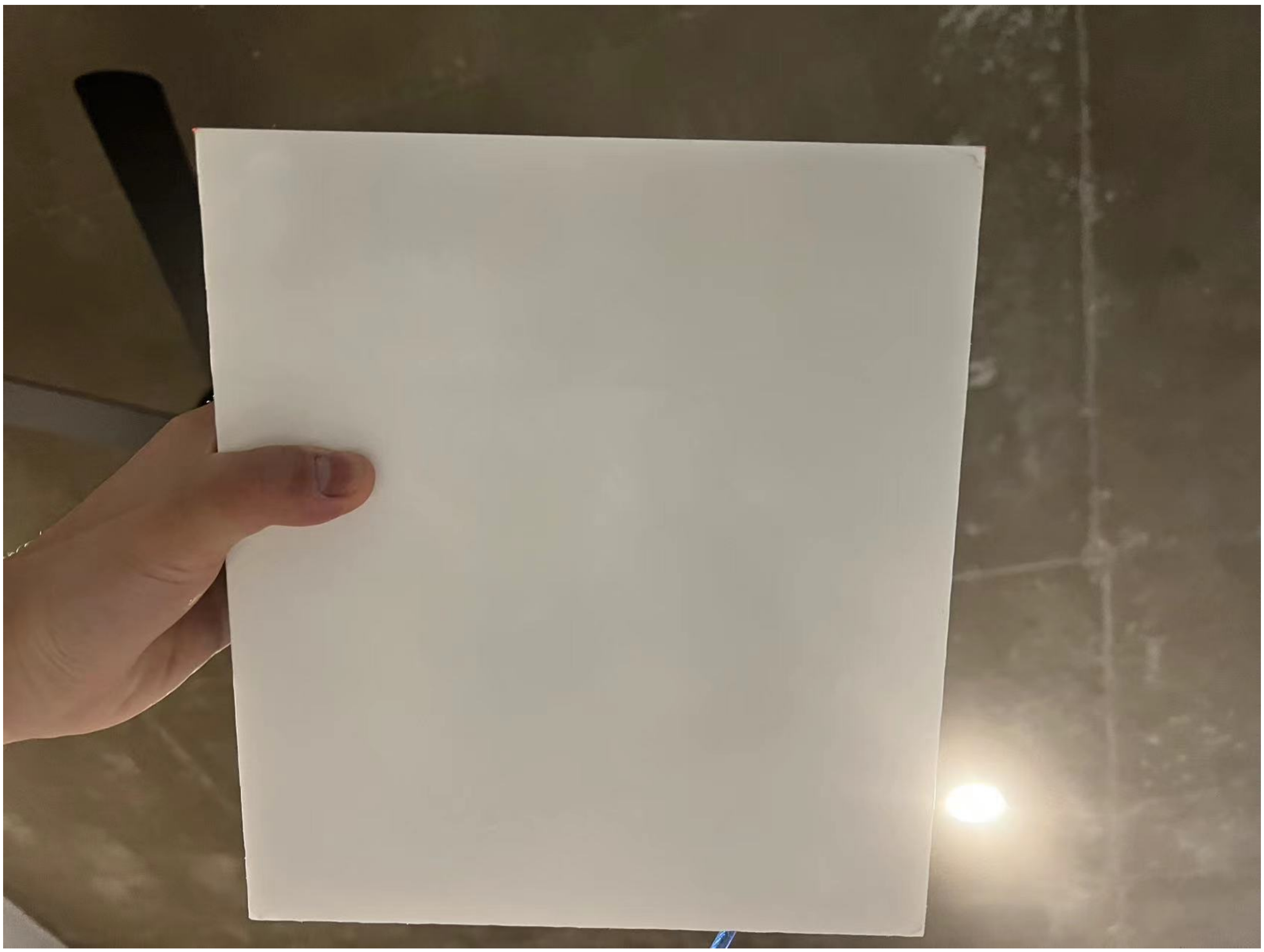
Date: 2021/12/08

Content by: Charlie Zhu

Present: Charlie Zhu

Goals: 3D print our V/Q model back Version 1

Content:



U

uwmadmaker@gmail.com
Wed 12/8/2021 9:18 AM

To: Charlie ZHU

Hi Charlie Zhu:

The print job "V/Q model lid" is printing on a Ultimaker printer. You'll receive another email when the print job is ready to be picked or if there is an issue.

Although the estimated print time is 30 hours, please do not come to the Makerspace to pick-up the print until you have received a pick-up email.

If 30 + 1 whole business day has passed. Email <maker-3dprint@engr.wisc.edu> and reference this job # 1997686115.

This is an automated message from the Makerspace 3D Print System (I'm a bot). Do not reply to this email.

Happy Making,
The 3D Printing Team

Reply | Forward

Conclusions/action items:

Dimension does not fit, second time reprint is needed

2021/12/14 - 3D printing back Version2 V/Q Model

Charlie ZHU - Dec 15, 2021, 2:30 PM CST

Title: 3D printing back Version 2 V/Q Model

Date: 2021/12/14

Content by: Charlie Zhu

Present: Charlie Zhu

Goals: 3D print our V/Q model back Version 2

Content:

uwmadmaker@gmail.com
Tue 12/14/2021 2:23 PM
To: Charlie ZHU

Hi Charlie Zhu:

The print job "V/Q Model Lid" is printing on a Ultimaker printer. You'll receive another email when the print job is ready to be picked or if there is an issue.

Although the estimated print time is 16 hours, please do not come to the Makerspace to pick-up the print until you have received a pick-up email.

If 16 + 1 whole business day has passed. Email <maker-3dprint@engr.wisc.edu> and reference this job # 2025319984.

This is an automated message from the Makerspace 3D Print System (I'm a bot). Do not reply to this email.

Happy Making,
The 3D Printing Team

Reply | Forward

Conclusions/action items:

Dimension does not fit, third time reprint is needed

2021/12/15 - 3D printing back Version 3 V/Q Model

Charlie ZHU - Dec 15, 2021, 2:30 PM CST

Title: 3D printing back Version 3 V/Q Model

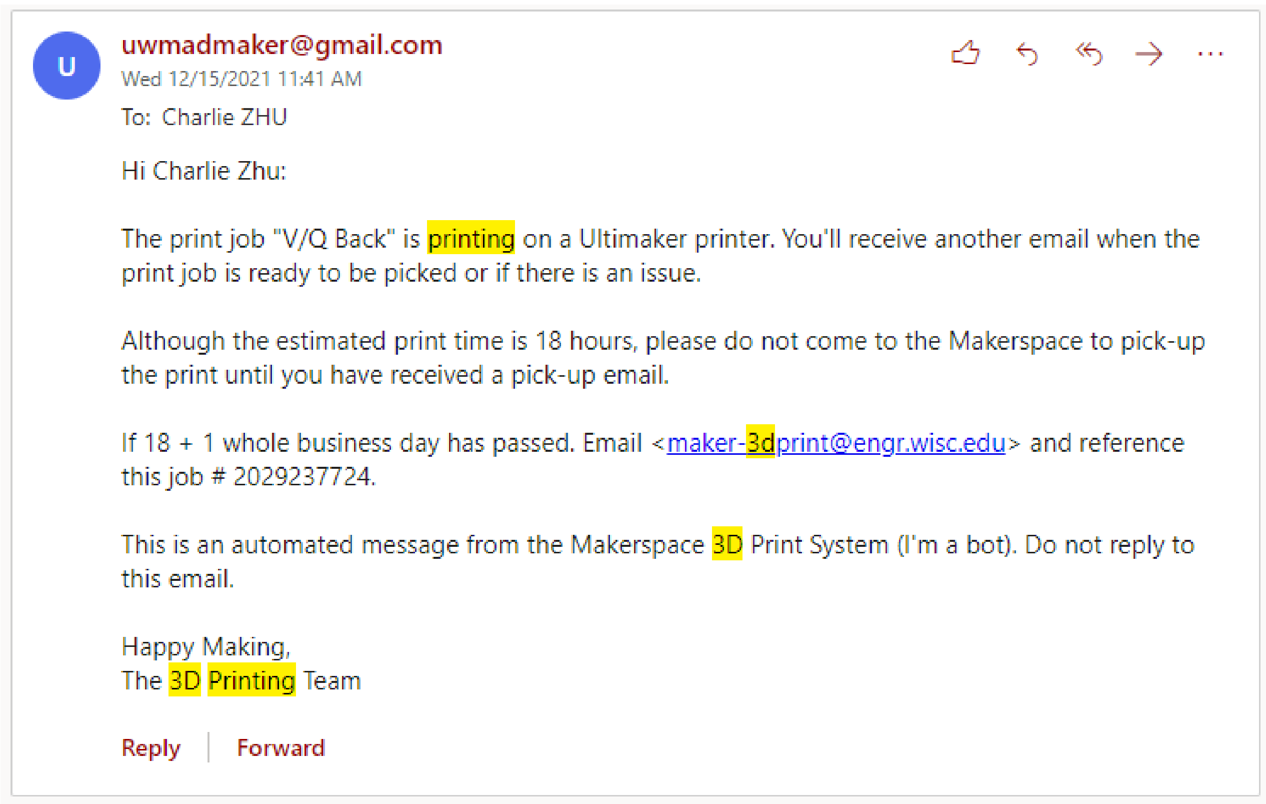
Date: 2021/12/15

Content by: Charlie Zhu

Present: Charlie Zhu

Goals: 3D print our V/Q model back Version 3

Content:


uwmadmaker@gmail.com
Wed 12/15/2021 11:41 AM
To: Charlie ZHU

Hi Charlie Zhu:

The print job "V/Q Back" is printing on a Ultimaker printer. You'll receive another email when the print job is ready to be picked or if there is an issue.

Although the estimated print time is 18 hours, please do not come to the Makerspace to pick-up the print until you have received a pick-up email.

If 18 + 1 whole business day has passed. Email <maker-3dprint@engr.wisc.edu> and reference this job # 2029237724.

This is an automated message from the Makerspace 3D Print System (I'm a bot). Do not reply to this email.

Happy Making,
The 3D Printing Team

Reply | Forward

Conclusions/action items:

Final fabrication of the lid. Dimension are verified correct. It will be printed out on 12/16.

2021/09/12 - Anatomy of the Lungs And Respiration Process

DARSHIGAA GURUMOORTHY - Oct 20, 2021, 5:52 AM CDT

Title: Ventilation

Date: 09/12/2021

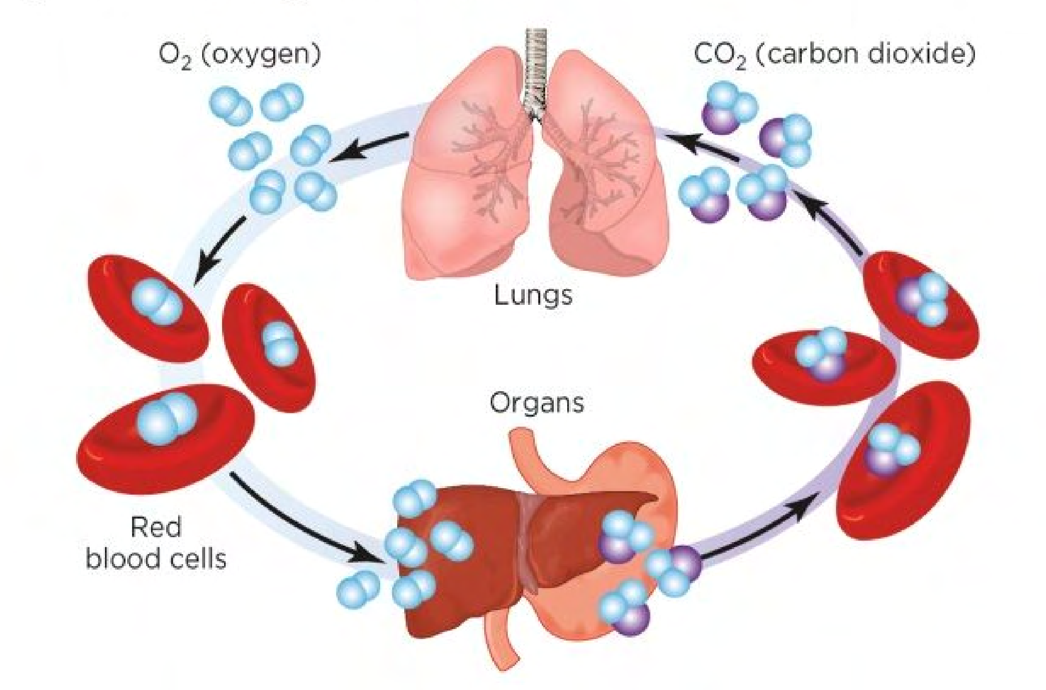
Content by: Darshigaa Gurumoorthy

Present: N/A

Goals: A basic Overview of the Anatomy of the Lungs and the Respiratiory Process

Content:

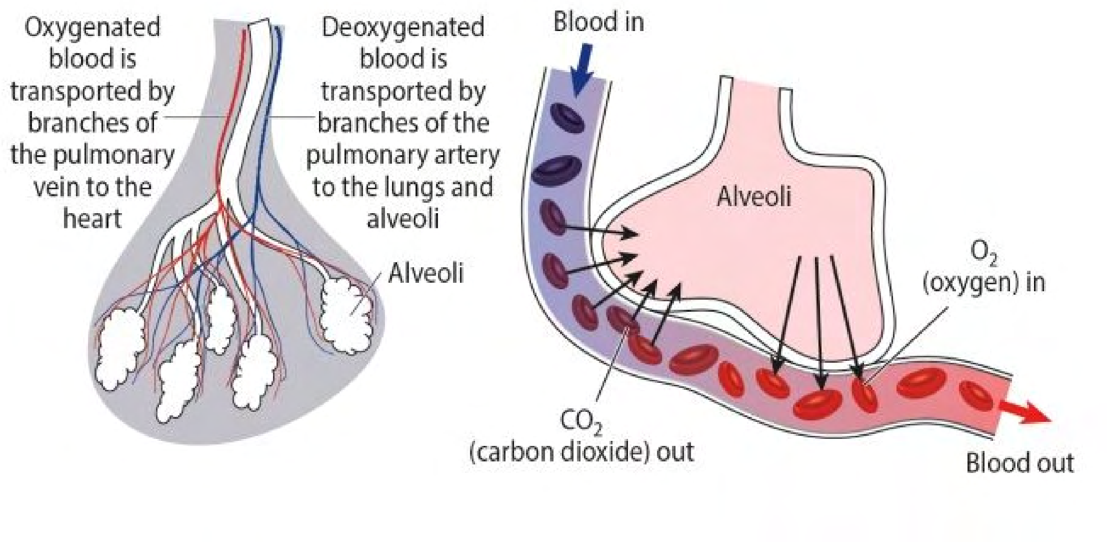
Fig 1. **Gas exchange in humans**



https://cdn.ps.emap.com/wp-content/uploads/sites/3/2018/01/Fig-1-Gas-exchange-in-humans_660.jpg

1. The lining of the pharynx and larynx (which form the upper respiratory tract) and the lining of the trachea - Cillia (Hair), trap airborne particles

Fig 2. **Gas exchange in the lungs**



https://cdn.ps.emap.com/wp-content/uploads/sites/3/2018/01/Fig-2-Gas-exchange-in-the-lungs_660.jpg

- Oxygen diffuses from the alveoli into the pulmonary capillaries because there is a high concentration of oxygen in the lungs and a low concentration in the blood;
- Carbon dioxide diffuses from the pulmonary capillaries into the alveoli because there is a high concentration of carbon dioxide in the blood and a low concentration in the lungs;
- Nitrogen diffuses both ways.

1. While the deoxygenated blood travels in the veins, detectors in the brain and blood vessels (chemoreceptors) measure the blood's pH.
2. The peripheral chemoreceptors mainly monitor oxygen. T
3. The central chemoreceptors, located in the brain constitute the control centres for breathing, as they are especially sensitive to pH changes in the blood.
4. As carbon dioxide levels rise, blood pH falls; this is picked up by the central chemoreceptors and, through feedback mechanisms, signals are sent to alter breathing.

Sources:

1. https://www.nursingtimes.net/clinical-archive/respiratory-clinical-archive/every-breath-you-take-the-process-of-breathing-explained-08-01-2018/
2. https://oxfordmedicine.com/view/10.1093/med/9780198784975.001.0001/med-9780198784975-chapter-3

Conclusions/action items:

1. Humans have two lungs, surrounded by ribs
2. Gas exchange occurs at the alveolus level.
3. There are feedback mechanisms that regulate breathing and respiration

2021/09/13 - Ventilation Mechanism in Lungs

DARSHIGAA GURUMOORTHY - Oct 20, 2021, 5:59 AM CDT

Title: Ventilation Mechanism in the Lungs

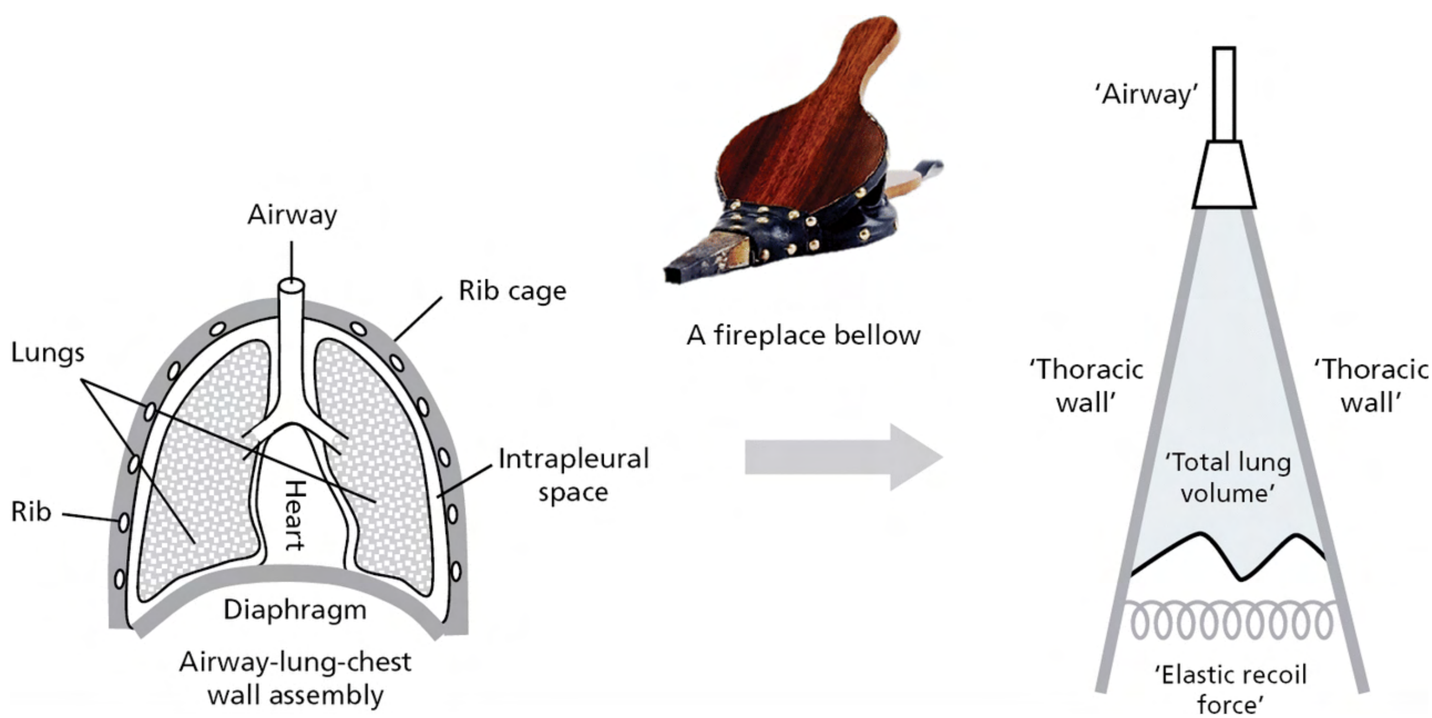
Date: 09/13/2021

Content by: Darshigaa Gurumoorthy

Present: N/A

Goals: To Understand the Ventilation Mechanism in Lungs

Content:



https://oxfordmedicine.com/doc/10.1093/med/9780198784975.001.0001/med-9780198784975-graphic-162-inline.gif

1. Regularly replacing air to ensure continuous breathing
2. *Description of the above model*: Modified pair of fireplace bellows with 'extendable thoracic walls,' an 'airway,' and a 'total lung volume.' A spring is added between the two handles of the bellow to mimic 'elastic recoil force'. Another modification is that the model does not have a one-way valve, so the air enters and exits exclusively through the nozzle.
3. Two opposite forces always: Lung Expansion + Lung Retraction
4. Inflated - Expansion force > Retraction force
5. Deflated - Expansion force < Retraction force
6. Lung volume unchanged: Expansion Force = Retraction Forces

Process:

During Natural Inspiration:

1. The contraction of respiratory muscles (mainly the diaphragm) increases the chest volume
2. This generates a temporary negative alveolar pressure (Palv).
3. Air sucked into the lungs, and is mixed with the gases present there.
4. This inhaled gas volume is called the inspiratory tidal volume.
5. During inspiration the elastic recoil force (shown as the stretched spring) is loaded.

During Natural Expiration:

1. The respiratory muscles relax T
2. The elastic recoil force pulls the chest and lungs back to their resting position
3. This generates a temporary positive Palv.
4. A certain amount of gas is pushed out of the lungs.
5. This expelled gas volume is called expiratory tidal volume.

**A breath must include both an inspiratory action and an expiratory action. Inspiratory and expiratory tidal volumes are roughly equal.

<u>The tidal volume:</u>

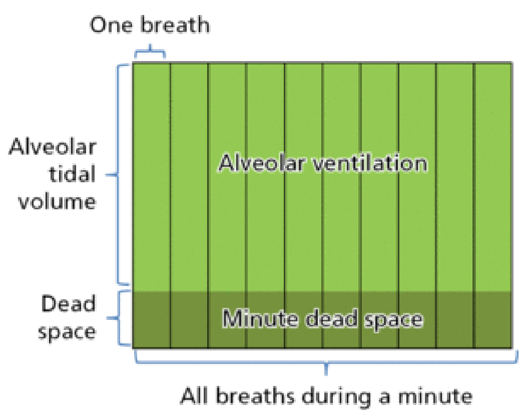
- Two parts

1. The part that participates in alveolar gas exchange is alveolar tidal volume.
2. The part that does not participate in the gas exchange is (anatomical) dead space.
3. **Dead space volume is always moved in or out first.

Dead space is inevitable.

Notes on Deadspace:

1. During mechanical ventilation, the dead space usually increases due to the presence of the artificial airway.
2. Effective alveolar ventilation is determined by the difference between the tidal volume and the total dead space.
3. If the tidal volume is very close to, or equal to, the dead space volume, the alveolar ventilation is (nearly) zero, i.e. CO_2 removal is (nearly) zero.
4. This unwanted situation is known as dead space ventilation.



https://oxfordmedicine.com/doc/10.1093/med/9780198784975.001.0001/med-9780198784975-graphic-085-inline.gif

◆ Respiratory Rate: The number of breaths occurring per minute;

◆ Minute Volume: The sum of the tidal volume (inspiratory or expiratory) of all breaths occurring per minute;

◆ Alveolar Ventilation: The sum of the alveolar tidal volume (inspiratory or expiratory) of all breaths occurring per minute.

$$\textbf{Alveolar minute volume} = \textbf{Rate} \times (\textbf{Tidal volume} - \textbf{Dead space})$$

SOURCES:

1. **https://oxfordmedicine.com/view/10.1093/med/9780198784975.001.0001/med-9780198784975-chapter-3**

Conclusions/action items:

1. A bellow can b used to model the ventilation mechanism in the lungs
2. Breath includes both respiratory and expiratory action
3. There is space that participates in alveolar gas exchange, and one that doesn't (deadspace).
4. Deadspace ventilation - CO_2 removal is close to zero.

2021/09/14 - Perfusion in the Lungs

DARSHIGAA GURUMOORTHY - Oct 20, 2021, 5:44 AM CDT

Title: Perfusion in Lungs

Date: 09/14/2021

Content by: Darshigaa Gurumoorthy

Present: N/A

Goals: To Understand the Perfusion Mechanism in Lungs

Content:

Perfusion Definition:-

Amount of blood reaching the pulmonary capillaries

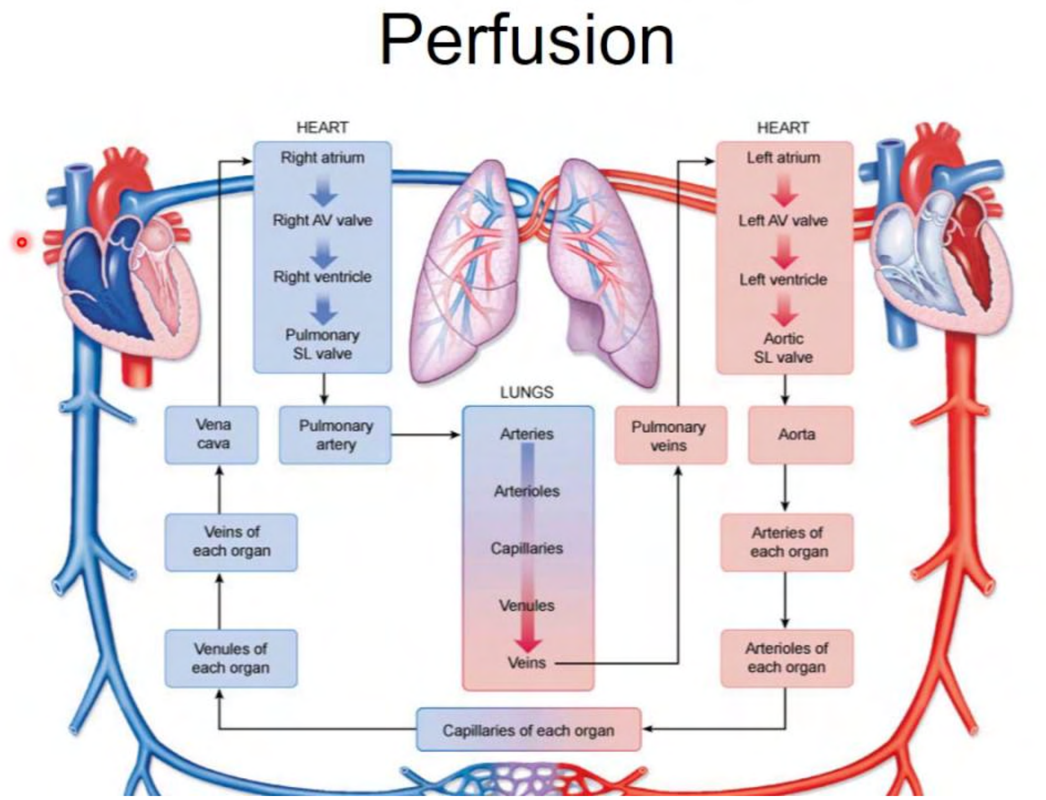
Factors affecting Perfusion:

Gravity:

1. Pleural pressure:
    1. More pressure, more compliant alveoli, more ventilation
2. Hydrostatic Pressure:
    1. Decreased at the apex of lung, decreased flow and decreased perfusion

Apical and middle zones of the lungs see the greatest increase in perfusion rates as gravity increases - like during cardiac exercise.

Schematic



https://i.ytimg.com/vi/WeRo-ScRG8E/maxresdefault.jpg

Conclusions/action items:

1. Perfusion is the amount of blood that flows into alveolar capillaries
2. It is gravity dependent
3. Perfusion rates vary across the lung, but increases as we go down the base of the lungs.

2021/09/19 - Ventilation/Perfusion, V/Q Ratios

DARSHIGAA GURUMOORTHY - Oct 20, 2021, 5:50 AM CDT

Title: Ventilation/Perfusion Ratios

Date: 09/19/2021

Content by: Darshigaa Gurumoorthy

Present: N/A

Goals: To Understand V/Q Ratios and the factors affecting it

Content:

V --> Flow of Air into Alveoli (Ventilation)

Q --> Flow of Blood into Alveolar capillaries (Perfusion)

V/Q Ratio - Affects Gas Exchange in lungs

1. Gas Exchange in Alveoli - Primarily occurs through diffusion
2. The alveolar septum has numerous capillaries and thin walls for gaseous exchange.
3. The capillary endothelial cells have type I pneumocytes that are thin and line the wall of the capillary.
4. They also have Type II pnuemocytes that secrete dipalmitoylphosphatidylcholine (DPPT) that helps reduce the surface tension in the alveolus.
5. Alveolar Macrophages defend against pathogens and irritants

Fick's Law of Diffusion:

Diffusion of a gas across the alveolar membrane increases with:

1. Increased surface area of the membrane
2. Increased alveolar pressure difference (PA-Pa)
3. Increased solubility of the gas
4. Decreased membrane thickness

**Exchange of both oxygen and carbon dioxide is perfusion limited.

Diffusion of gases reaches equilibrium one-third of the way through the capillary/alveolar interface.

Deoxygenated blood from the pulmonary arteries has a PVO2 of 40 mmHg, and alveolar air has a PAO2 of 100 mmHg, resulting in a movement of oxygen into capillaries until arterial blood equilibrates at 100 mmHg (PaO2). Meanwhile, carbon dioxide partial pressure decreases from a PVCO2 of 46 mmHg to a PaCO2 of 40 mmHg in alveolar capillaries due to a PACO2 of 40 mmHg.

Mechanism:

V/Q ratio evaluates the matching of Ventilation (V) to Perfusion (Q)

** There is variation in the V/Q ratio at different parts of the lungs

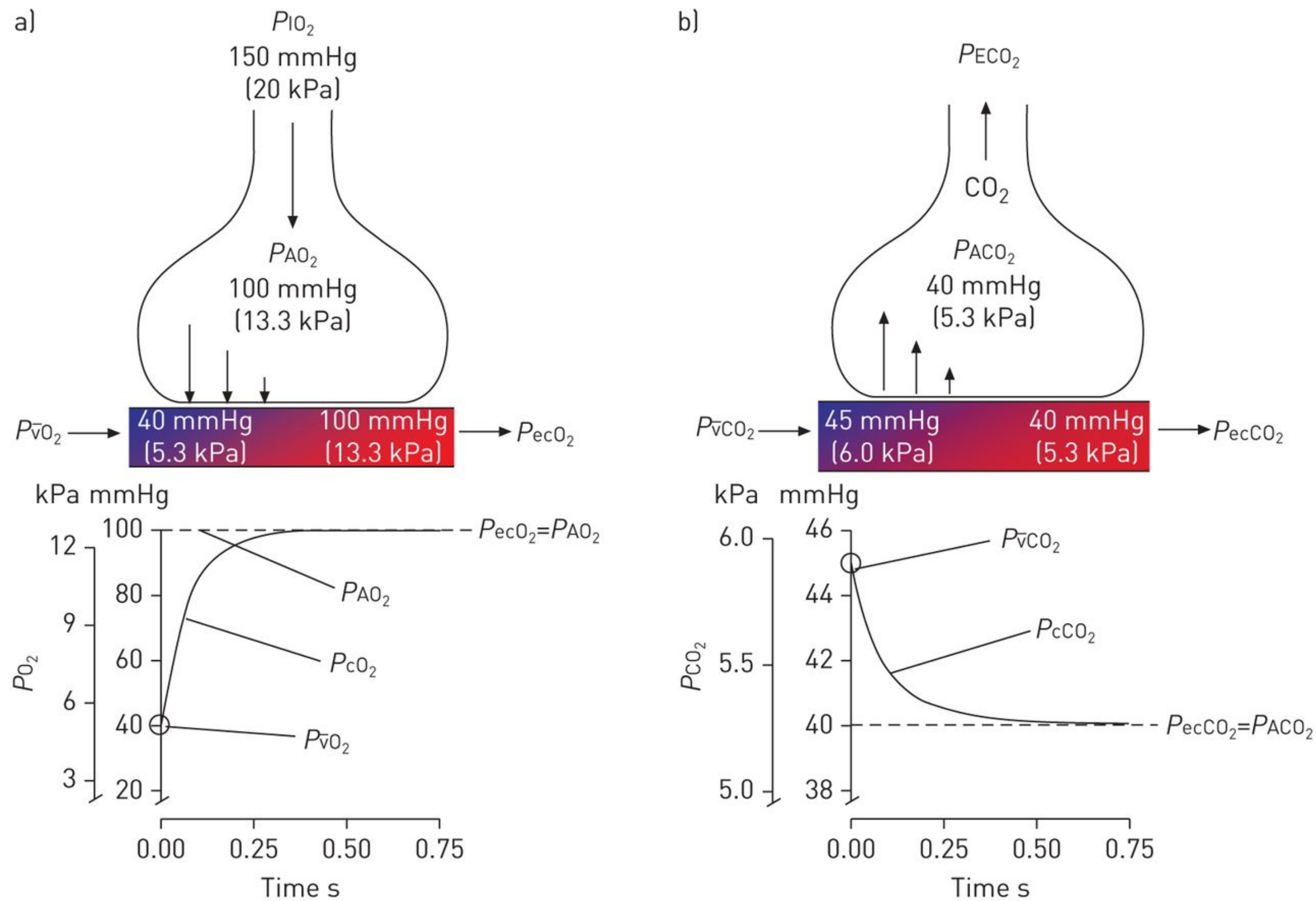
Ventilation is 50% greater at the base of the lungs than the apex.

Weight of fluid increases in the pleural cavity at the base as a less negative value. Alveoli are less expanded and have more compliance at the base.

Perfusion greater at the base --> Gravity pulling the blood towards the base. Overall greater perfusion increase towards base than ventilation, => Lower V/Q Ratio at the base than the apex.

In Healthy Individual - V/Q Ratio 1 in the middle of the lung, with a spread of ratios between 0.3 to 2.1 across the lung from bottom to the top. Overall value in lungs around 0.8.

** In cases of high V/Q ratios, PO2 increases and PCO2 decreases as alveolar air more closely matches the larger volume of inspired air than perfused blood. On the other hand, low V/Q ratios result in a decreased PO2, and an increased PCO2.



https://erj.ersjournals.com/content/erj/44/4/1023/F2.large.jpg

**The above figure shows PO2 in different compartments and how diffusion of O2 along the capillary allows PecO2 to equal PAO2 well before the blood leaves the unit. Note that the result is a PA–aO2 of zero. b) PCO2 illustrated in a similar manner. The time scale on the diagrams in both panels refers to the transit time for the erythrocytes through the alveolar capillaries, normally 0.25–0.75 s.

SOURCES:

1. **https://www.ncbi.nlm.nih.gov/books/NBK539907/**
2. **https://teachmephysiology.com/respiratory-system/gas-exchange/ventilation-perfusion/**

3. https://erj.ersjournals.com/content/44/4/1023

Conclusions/action items:

1. Fick's Laws of Diffusion apply and affect V/Q Ratios
2. V/Q Ratios are the smallest at the base of the lung and greatest at the top of the lung.
3. The average V/Q Ratio is about 0.8

2021/09/20 - Clinical Significance of V/Q Ratios

DARSHIGAA GURUMOORTHY - Oct 20, 2021, 6:44 AM CDT

Title: Clinical Significance of V/Q Ratios

Date: 09/20/2021

Content by: Darshigaa Gurumoorthy

Present: N/A

Goals: To Understand the clinical significance of V/Q Ratios

Content:

Ventilation-Perfusion Mismatch:

1. Occurs when there is a mismatch between alveolar ventilation and alveolar blood flow.
2. If V/Q ratio is reduced due to inadequate ventilation, then the gas exchange within those alveoli will be affected.
    1. Hypoxic Vasoconstriction occurs, diverts blood into areas with high ventilation levels
    2. However, chances are that Haemoglobin (absorbs oxygen in the blood) in those areas are already saturated
    3. PO2, therefore, remains low
    4. Leads to Hyper-ventilation --> Low to normal CO2 level
3. Can also occur when there is reduced perfusion in the lungs.

Causes of Reduced Ventilation:

1. Pneumonia: Alveoli filled with liquid - Impairing delivery of air to alveoli --> lengthening diffusion pathway for respiratory gases.
2. Asthma: Smooth muscle contraction --> increased resistance to airflow --> Lower Ventilation rates
3. COPD (Chronic Obstructive Pulmonary Disease): Structural Airway Damages --> Impaired Gas Exchange
4. Pulmonary Edema
5. Airway Obstruction (choking on food etc.)
6. Sleep apnea

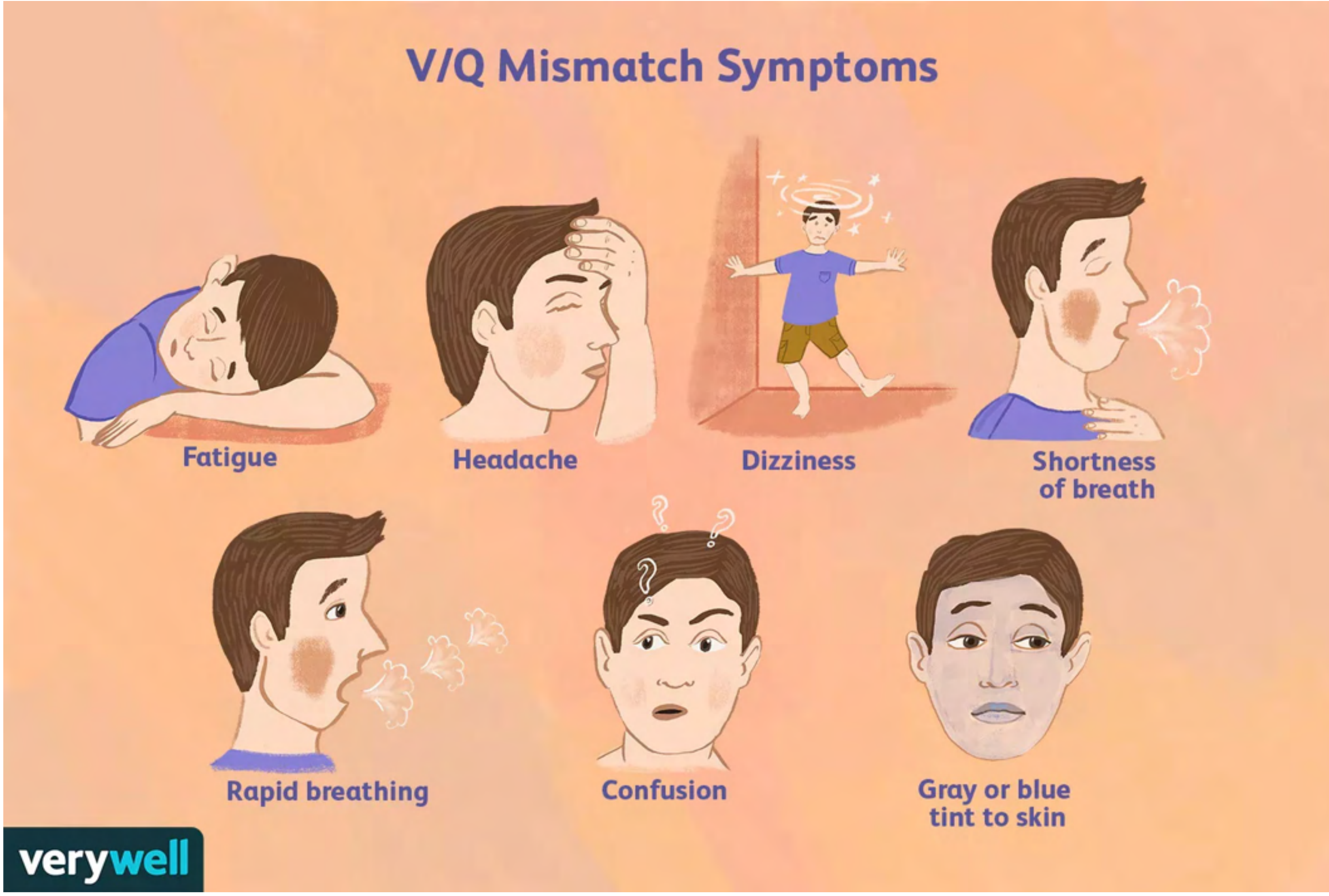
Effect of Reduced Ventilation is **Hypoxia (Insufficient Oxygen Available at the tissue level to maintain bodily function)

**Hypercapnia (Increased CO2 levels in the bloodstream) does not occur unless ventilation is severely impaired.

Causes of Reduced Perfusion in Lungs:

1. Pulmonary Embolism
    1. Areas of pulmonary circulation are obstructed, limiting blood flow to alveoli
    2. Blood redirected to other parts of lungs
    3. Hypoxia still occurs since other areas are still operating at V/Q < 1 level.
2. Emphysema (COPD)
3. Heart Disease
4. Liver Disease
5. Pulmonary Hypertension

**Hypoxemia - Reduced oxygen levels in the blood is also a consequence.



https://www.verywellhealth.com/thmb/y-o1pXKFwetYpBvR9nKuLK16ncg=/1500x0/filters:no_upscale():max_bytes(150000):strip_icc():format(webp)/what-is-vq-mismatch-in-the-lungs-914928-v1-b4d9d6af14a54347bc4cc06d2304308f.jpg

SOURCES:

1. https://www.verywellhealth.com/what-is-vq-mismatch-in-the-lungs-914928
2. https://teachmephysiology.com/respiratory-system/gas-exchange/ventilation-perfusion/

Conclusions/action items:

1. Ventilation/Perfusion mismatches can occur due to decreased ventilation or perfusion in the lungs.
2. Both a high V/Q ratio and a low V/Q ratio are detrimental
3. There are various reasons due to which this might occur.

2021/09/29 - Design of Previous Students in BME 2/300

DARSHIGAA GURUMOORTHY - Oct 20, 2021, 10:41 AM CDT

Title: Previous Designs from BME 2/300 Students

Date: 09/29/2021

Content by: Darshigaa Gurumoorthy

Present: N/A

Goals: To Describe the previous design of the students who were in this class.

Content:

External Features:

The electronics and the board is housed in a grey, 3-D printed box.

The box has a display that shows ratios and four buttons.

There are LED strips that change colour based on the ratios inputted into the system.

A round circular area is identified as the alveolus.

LED Colours and their Meanings:

1. Green: Oxygen flow
2. Blue: Deoxygenated blood
3. Red: Oxygenated blood
4. Purple: Gas exchange between capillary and alveoli

Pros:

- Design works well, does the calculations right.

- Is small enough to be displayed on a lecture board and thought on to the class.

- Electronics are sturdy enough to last a long time.

Cons:

- Not intuitive enough to use

- Electronics not housed properly within the box, needs to be concealed to withstand expected wear and tear

- Display too dim

Clients Comments:

1. Use another method to change the V/Q ratios to make the concept more obvious
2. Consider changing the design of the model completely
3. Consider using computer animations to supplement the model

Conclusions/action items:

1. Our first step is to consider how to incorporate the client's comments and needs into the project
2. We need to redesign the V/Q ratio adjusters, perhaps use sliders in our design

2021/10/13 - Group Design 1

DARSHIGAA GURUMOORTHY - Oct 20, 2021, 11:33 AM CDT

Title: Slider with LED Screen Design

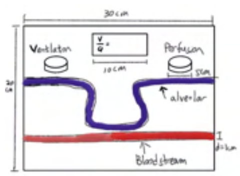
Date: 09/13/2021

Content by: Darshigaa Gurumoorthy

Present: Alex Houle, Charlie Zhu, Kendra Besser, Milica Lukic, Darshigaa Gurumoorthy

Goals: Describe the Design 1 we agreed upon as a group

Content:

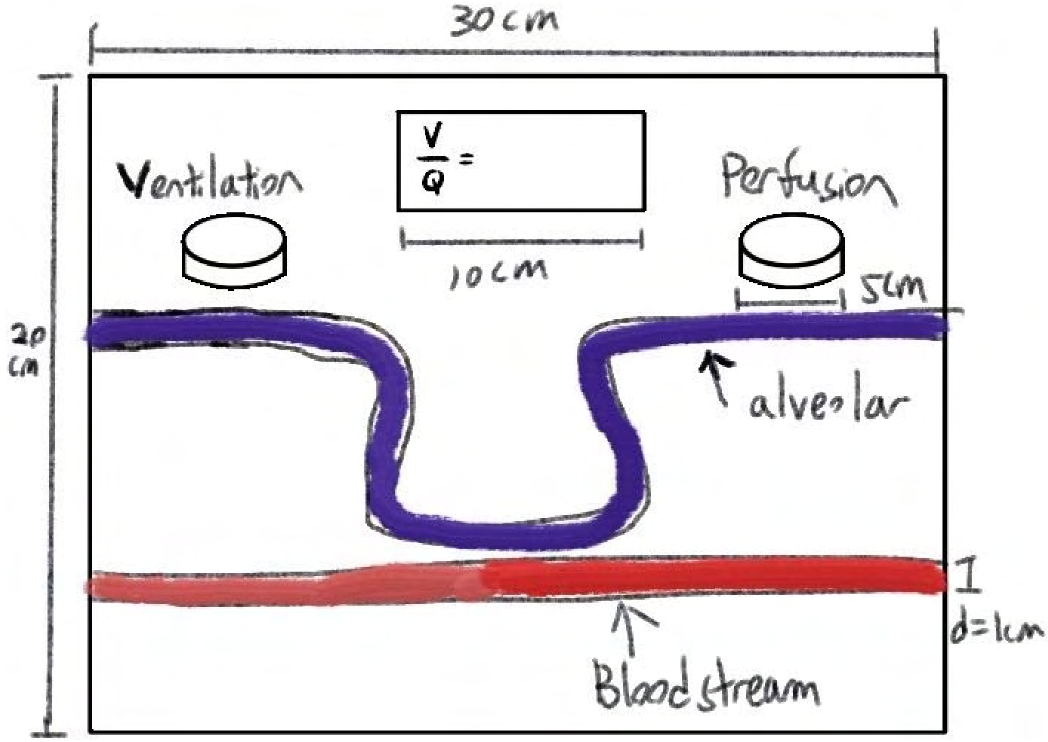


Features:

1. 3-D printed case to house the electrical components
2. Sliders for adjusting V/Q ratios
3. Display with detailed information to provide maximum information to the students
4. Simple and intuitive to make use for the students easy
5. Compact to be used in lecture
6. Speed in flashing of light used to demonstrate the change in ventilation and perfusion rates.

Conclusions/action items:

The physical model uses the most resources to fabricate, but it is the most useful in the long term. This model is highly adaptable to the needs of the students and the lecturer and hence will be highly effective in relaying the information across to the students.


30cm
V/Q =
Ventilation
Perfusion
10cm
5cm
20 cm
alveolar
I
d=1cm
Bloodstream

2021/10/13 - Group Design 2

DARSHIGAA GURUMOORTHY - Oct 20, 2021, 11:34 AM CDT

Title: Computer Animation Design

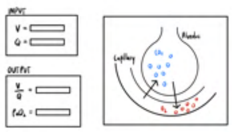
Date: 2021/09/13

Content by: Darshigaa Gurumoorthy

Present: Alex Houle, Milica Lukic, Charlie Zhu, Kendra Besser, Darshigaa Gurumoorthy

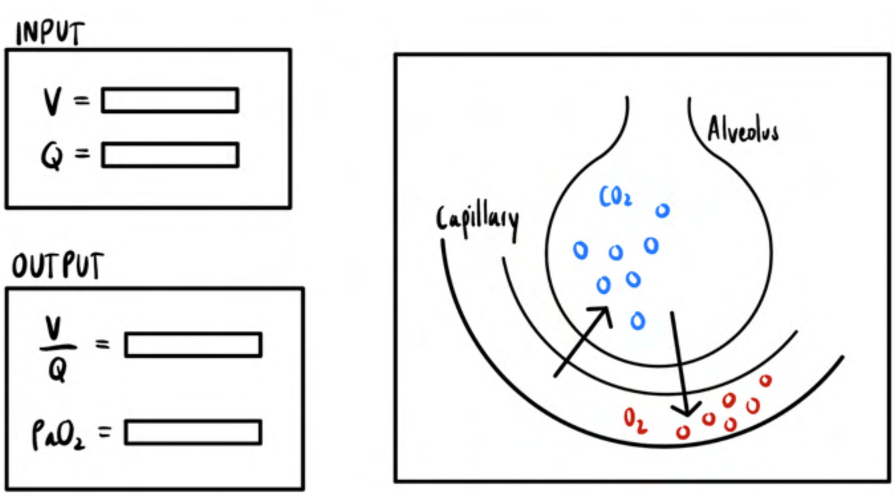
Goals: Describe the second design we came up with together as a group

Content:



The second design is a computer animation design which was much recognized by the client. It would have slidable animations to change the ratios of V and Q. It would then output all the necessary values the client would request.

It is the easiest to use and manipulate. It is highly portable and adaptable.



Conclusions/action items:

1. While this is the easiest to use and was requested by the client if possible, we do not have the skills as a team to come up with computer animation in the limited period of time that we have.

2021/10/13 - Group Design 3

DARSHIGAA GURUMOORTHY - Oct 20, 2021, 11:35 AM CDT

Title: Water/Dye Concentration Model

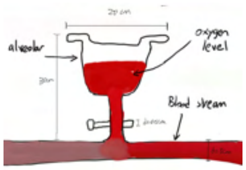
Date: 10/13/2021

Content by: Darshigaa Gurumoorthy

Present: Alex Houle, Charlie Zhu, Milica Lukic, Kendra Besser, Darshigaa Gurumoorthy

Goals: To describe the third design we came up with together as a group.

Content:

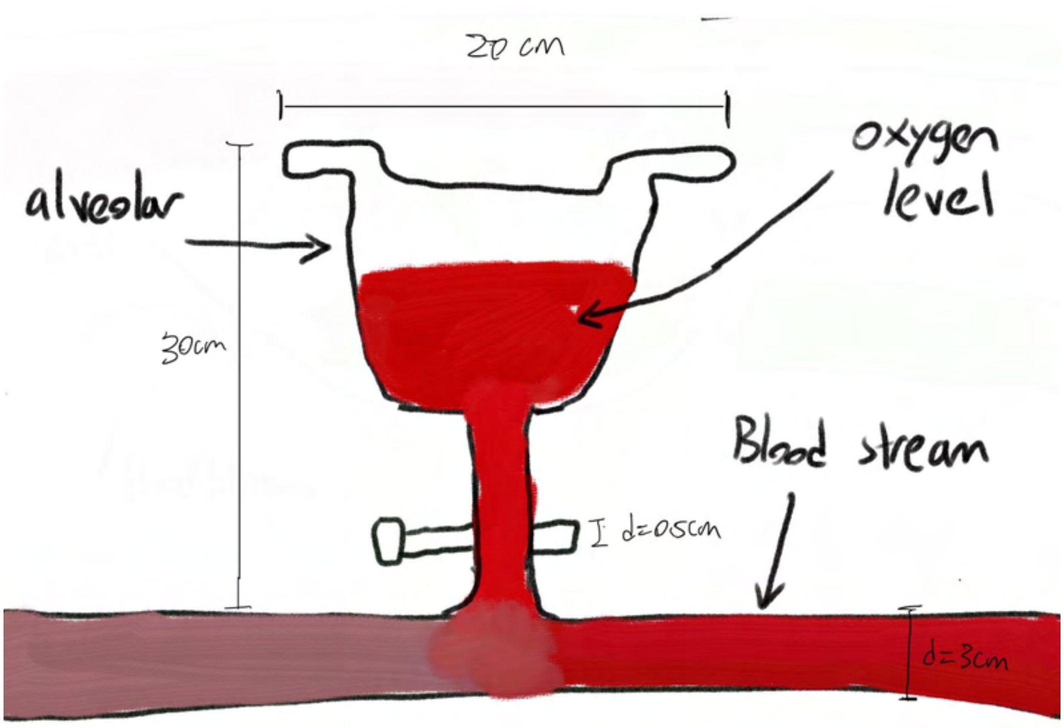


Features:

- Flexible tubing that allows to show different volumes of blood flowing through the blood vessels.

-Color dyes to represent oxygenated and deoxygenated blood.

-This model would be controlled by computer software so data can be displayed



Conclusions/action items:

- While this model is the most intuitive, it is a hassle to replace the water and dye. It also takes up a lot of space and is very inconvenient to use during lectures.

2021/10/14 - Design Matrix (Group)

DARSHIGAA GURUMOORTHY - Oct 20, 2021, 11:46 AM CDT

Title: Design Matrix

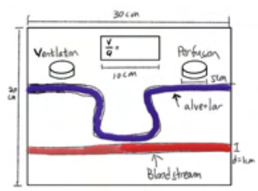
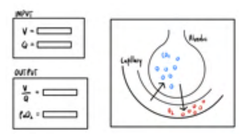
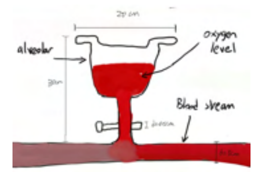
Date: 2021/10/14

Content by: Darshigaa Gurumoorthy

Present: Alex Houle, Chalie Zhu, Kendra Besser, Milica Lukic, Darshigaa Gurumoorthy

Goals: To provide our design matrix, a description of our criteria and our decision

Content:

Criteria (Weight)	**Slider with LEDs and Screen*** 		**Computer Animation*** 		**Water/Dye Concentrations** 	
Intuitive use (30%)	5/5	30%	4/5	24%	2/5	12%
Learning Outcomes (30%)	4/5	24%	2/5	12%	4/5	24%
Adjustability (20%)	4/5	16%	5/5	20%	4/5	16%
Ease of fabrication (10%)	3/5	6%	2/5	4%	1/5	2%
Cost (5%)	2/5	2%	5/5	5%	2/5	2%
Safety (5%)	4/5	4%	5/5	5%	5/5	5%
Total		**82%**		**70%**		**61%**

1. Intuitive Use: How easily a user can obtain the model and figure out its usage. Weighted 30% because it is a teaching model
2. Learning Outcomes: How effective the model is at explaining the necessary concepts.
3. Adjustability: How easily the V/Q ratios can be adjusted
4. Ease of Fabrication: How easily the product can be produced and how much the model manufacturing matches the group's skillset.
5. Cost: How much the model costs to manufacture.
6. Safety: How safe the teaching model is (Least Important)

Conclusions/action items:

The slider with the LED model despite some drawbacks is the best model.

2021/11/19 - New Design Ideas

Title: Redesigning model

Date: 2021/11/19

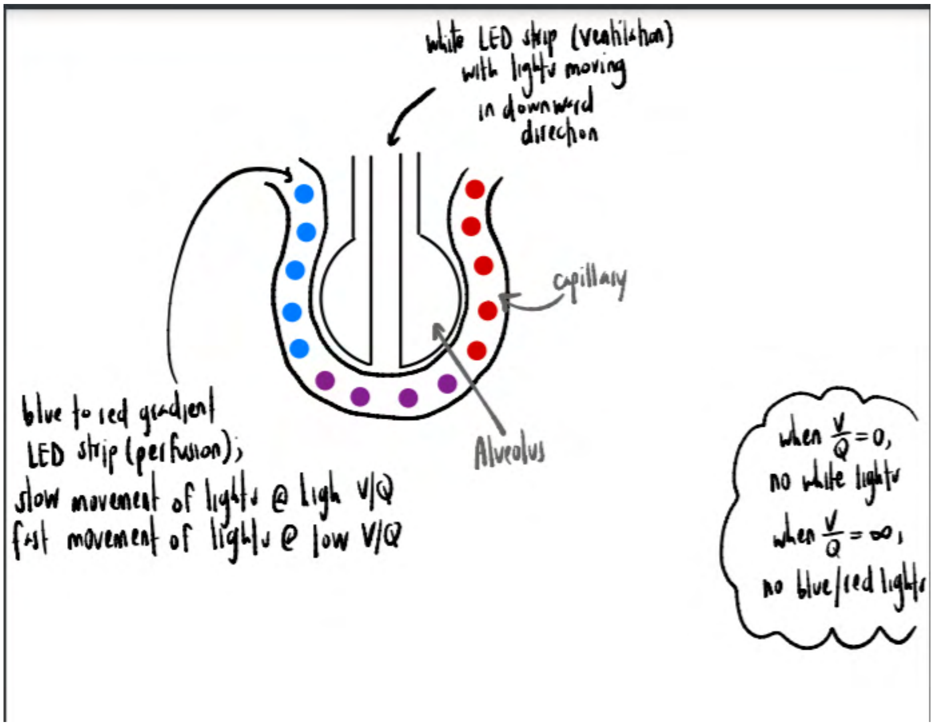
Content by: Darshigaa Gurumoorthy

Present: Alex Houle, Chalie Zhu, Kendra Besser, Milica Lukic, Darshigaa Gurumoorthy

Goals: To redesign the previous model so it accurately reflects the Lungs

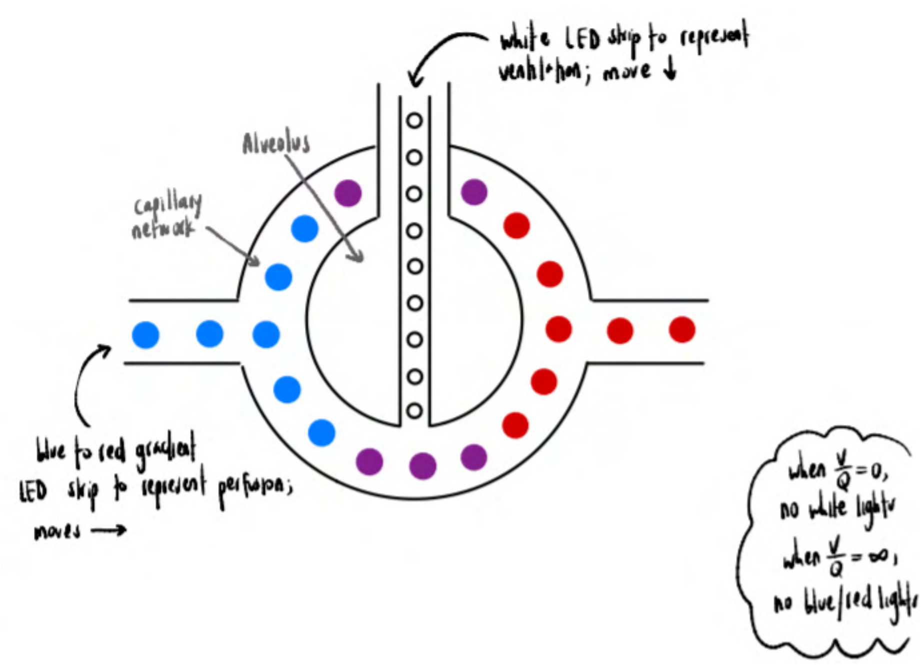
Content:

Design Idea 1:



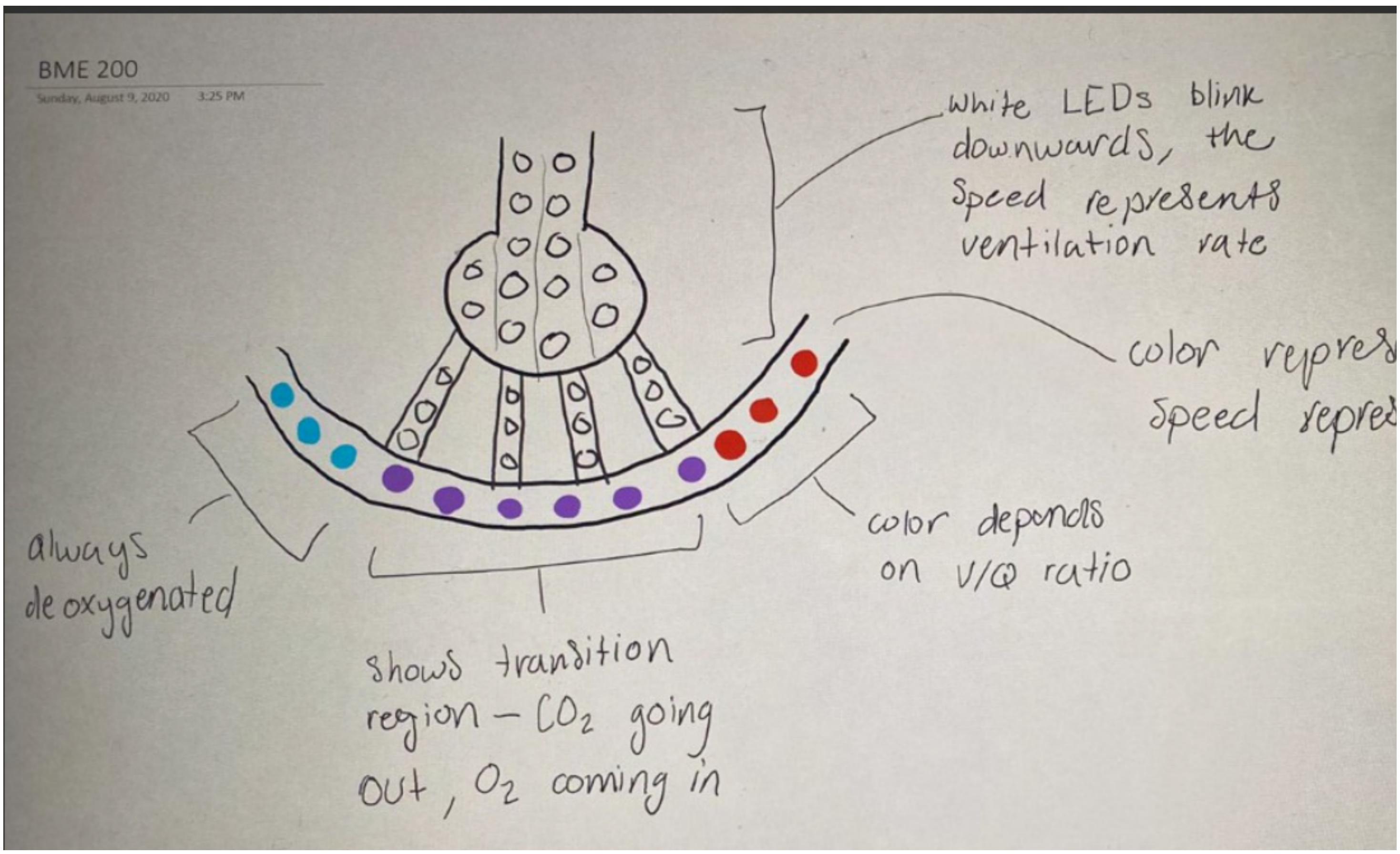
- Capillary is shown to wrap around the alveoli.
- Lights change from blue to red, with the rates of flashing of light changing as the perfusion rate increases in the capillary
- White LED strip with varying flashing rates to represent the flow of air into the lungs.

Design Idea 2:



- Capillary forms an almost circular case around the alveolus
- A white strip of LED light going down the middle of the alveolus represents the ventilation.
- Colour of lights from the capillaries changes from left to right to represent deoxygenated blood getting oxygenated.

Design Idea 3:



- Alevolus represented as a separate entity on the design with channels of white light leading into the capillary
- Capillary is an almost vertical strip
- Color scheme and working similar to the above two models.

Conclusions/action items:

- All three are very good design ideas, however client feedback is required.

2021/12/05- Final Design

Title: Client approved Design

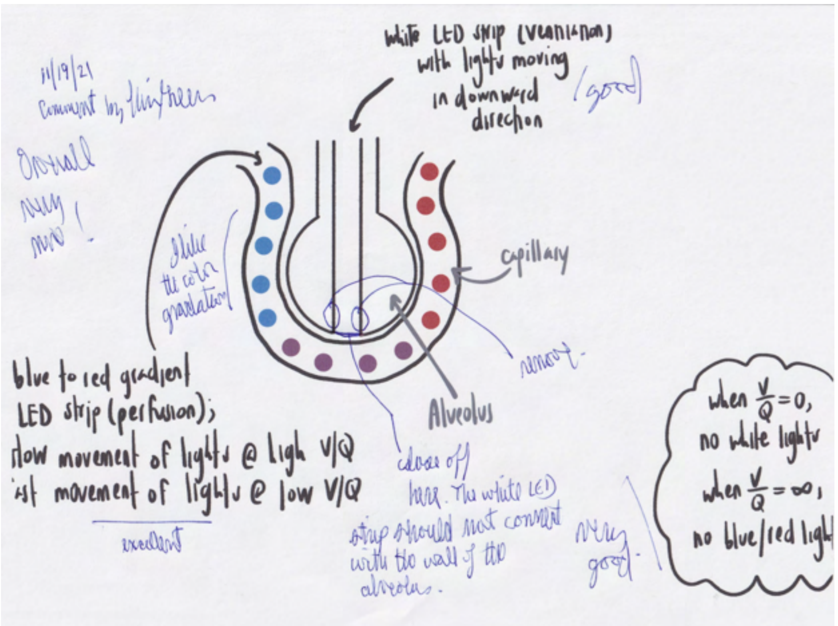
Date: 2021/12/05

Content by: Darshigaa

Present: Alex Houle, Charlie Zhu, Milica Lukic, Kendra Besser, Darshigaa Gurumoorthy

Goals: Discuss Client feedback and finalize design

Content:



General Client comments:

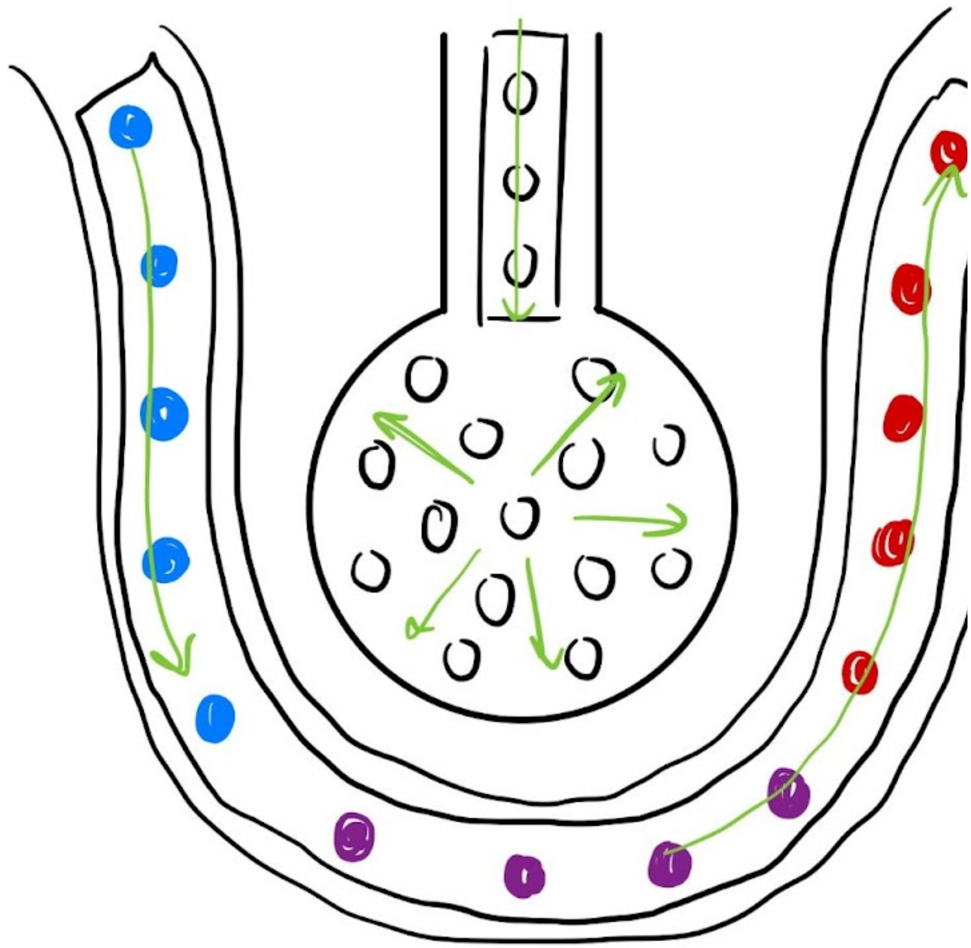
- Other models deviate too much from the textbook diagram.
- This design, although not anatomically accurate, is the closest to the textbook diagram, therefore will be the most effective.

Specific Comments:

- Remove the end of the LED strip
- Close off alveolus, separate from the bloodstream
- Good color scheme
- Values displayed are accurate

FINAL DESIGN:

green arrows show direction lights should move



In capillary:

- High V/Q - slow movement of lights = low perfusion
- Low V/Q - high perfusion = fast movement of lights

In alveolus:

- LED strip - move in the downward direction
- LED bulbs - move in the outward direction
- High V/Q = all white bulbs should be on
- Low V/Q = low ventilation - white bulbs partially on

Ends of V/Q ratios:

- When V/Q = 0, white lights should be off, only blue in the capillary
- When V/Q = infinity, blue to purple to red strip of lights should be off, alveolus lights remain on

Conclusions/action items:

- Begin fabrication
- Have first print ready by 11/25/2021

2021/11/29 - Lab Orientation Permit

DARSHIGAA GURUMOORTHY - Dec 15, 2021, 1:20 PM CST

Title: Lab Orientation Permit

Date: 2021/11/29

Content by: Darshigaa Gurumoorthy

Present: N/A

Goals: Permit

Content:

You have the following permits and upgrades:

Name	Date
Lab Orientation	09/21/2020
Laser 1	10/06/2020

Apply for a new/additional permit

Conclusions/action items:

- Need to apply for further permits and upgrade to a higher level.

2021/12/08 - Fabrication - Materials and Methods

DARSHIGAA GURUMOORTHY - Dec 15, 2021, 1:14 PM CST

Title: Fabrication of Model - Methods and Materials

Date: 2021/12/08

Content by: Darshigaa Gurumoorthy

Present: Alex Houle, Charlie Zhu, Milica Lukic, Kendra Besser, Darshigaa Gurumoorthy

Goals: List materials needed for fabrication and describe the process

Content:

Materials Required and their cost:

Item	Manufacturer	Quantity	Cost/Unit	Link
Digital Display	Adafruit	1	$24.95	https://www.adafruit.com/product/498#technical-details
Panel Mount 10K	Adafruit	2	$1.90	https://www.adafruit.com/product/562
potentiometer				
Panel Mount Right Angle 10K Linear Potentiometer	Adafruit	2	$3.00	https://www.adafruit.com/product/3395
Solid Machines Metal Knob	Adafruit	2	$7.90	https://www.adafruit.com/product/2056#description
3D printing prototype (1) fabrication cost	Ultimaker	1	$25.92	https://making.engr.wisc.edu/mini-mart/
3D printing prototype_board (2) fabrication cost	Ultimaker	1	$23.28	https://making.engr.wisc.edu/mini-mart/
3D printing prototype_lid (2) fabrication cost	Ultimaker	1	$22.96	https://making.engr.wisc.edu/mini-mart/
3D printing prototype_board (3) fabrication cost	Ultimaker	1	$37.92	https://making.engr.wisc.edu/mini-mart/
3D printing prototype_lid (3) fabrication cost	Ultimaker	1	$16.00	https://making.engr.wisc.edu/mini-mart/
Super Glue	Pacer	1	$1.15	https://making.engr.wisc.edu/mini-mart/
Arduino Mega	Elegoo	1	$22.00	https://making.engr.wisc.edu/mini-mart/
Large Breadboard	Adafruit	1	$3.00	https://making.engr.wisc.edu/mini-mart/
Led bulbs	Adafruit	16	$4.00	https://making.engr.wisc.edu/mini-mart/
Female to male Arduino wires	Adafruit	40	$2.00	https://making.engr.wisc.edu/mini-mart/

Heat Shrink	Eventronic	9	$0.90	https://making.engr.wisc.edu/mini-mart/
Epoxy	Hardman	5	$7.50	https://making.engr.wisc.edu/mini-mart/
LED Strip	Adafruit	2	$25.00	https://www.adafruit.com/product/3919?gclid=CjwKCAjww5r8BRB6EiwArcckCzEIg95MquQekbTMIV_LZ4VwndfflJ-GjxrnGvsVQTvlRloZGAF2jxoCVIoQAvD_BwE
Bright White 5mm LED (25 pack)	Adafruit	1	$6.95	https://www.adafruit.com/product/754
Total	$236.33			

Methods:

- The electrical components were ordered online
- The model shell was 3-D printed at the makerspace
  - After printing, it was discovered that a few changes have to be made and the shell did not perfectly fit the potential outlet and inlet wires The model was hence drilled to make holes so everything would fit in the model
  - All electrical components were glued with epoxy and the box was taped to the baseboard so that they don't move.
- The code was written to reflect the requirements of the model.

Conclusions/action items:

- Some dimensions of the model need changing but everything works perfectly. Only minor tweaks are necessary.

2021/10/29 - Preliminary Testing

DARSHIGAA GURUMOORTHY - Dec 15, 2021, 12:10 PM CST

Title: Preliminary testing of previous model

Date: 2021/10/29

Content by: Darshigaa Gurumoorthy

Present: Alex Houle, Charlie Zhu, Milica Lukic, Kendra Besser, Darshigaa Gurumoorthy

Goals: To test model from previous years and see how to improve the design

Content:

Results and Conclusions from testing:

The current model does not fit well under the doc-cam - Max dimensions should be 22.86 x 22.86 mm

The prototype needs to be connected to a laptop for use (power supply)

Gray PLA does not reflect the lights under the doc-cam well

Need a bigger display to ensure that the ratios are displayed properly on the screen

Green LEDs for alveolus do not show up on the screen

Scratches and other damages visible evidently under the doc-cam

Alveolus representation must be simplified

Sliders and knobs need labels

Conclusions/action items:

- Come up with design solutions to the issues presented above.

2021/12/09 - Final V/Q ratio testing

DARSHIGAA GURUMOORTHY - Dec 15, 2021, 12:26 PM CST

Title: Final V/Q ratio testing (Code reliability)

Date: 2021/12/09

Content by: Darshigaa Gurumoorthy

Present: Alex Houle, Milica Lukic, Charlie Zhu, Kendra Besser, Darshigaa Gurumoorthy

Goals: Test the code and the reliability of the model to produce accurate V/Q ratios

Content:

Procedure:

- Decide arbitrary values for V and Q with a good amount of variation in the numbers
- Enter the numbers in the model and record the V/Q ratios and P_aO_2 values displayed
- Separately calculate the V/Q ratios and P_aO_2 for each of the chosen sets of numbers
- Compare the obtained values from the manual calculation and the model

Results:

V Value (L/min)	Q Value (L/min)	V/Q Ratio Displayed	P_aO_2 Displayed (mmHg)	V/Q Ratio Calculated	P_aO_2 Calculated (mmHg)
90.00	100.00	0.90	101.84	0.9000	101.8412
6.00	37.00	0.16	50.42	0.1622	50.4199
29.00	56.00	0.52	82.14	0.5179	82.1384
59.00	100.00	0.59	86.86	0.5900	86.8567
6.00	74.00	0.08	43.33	0.0811	43.3342

- The values calculated from the model and the manually calculated values were the same when rounded to 2 significant digits

Conclusions:

- The model works effectively and the required values calculated are accurate

Confidence in method:

- The formulae used for both the model and the manual calculation were provided by the client
- The values used for calculation were varied widely and were repeated multiple times to obtain a result.

Conclusions/action items:

- The model is accurate for the calculation of the values.

2021/12/09 - Final Usability Testing

DARSHIGAA GURUMOORTHY - Dec 15, 2021, 12:48 PM CST

Title: Final Usability Testing

Date: 2021/12/09

Content by: Darshigaa Gurumoorthy

Present: Alex Houle, Charlie Zhu, Milica Lukic, Kendra Besser, Darshigaa Gurumoorthy

Goals: Test the usability and the function of the model

Content:

The model was tested for visibility under the doc-cam, usability, accessibility and intuitiveness.

- Black PLA provided a good contrast to the lights and they showed up better under the doc-cam
- White lights to represent airflow over green lights made it less confusing for the users
- Knobs instead of sliders made the model more intuitive to use and provided the opportunity to allow for more V values and Q values to be set allowing for a wider range of V/Q ratios.
- The display was large enough to display all the numbers clearly. The lack of coloured text in the display made it more pleasing to the eye
- LED lights and LED flex strips were visible. The colours were intuitive.
- Labelling of the components on the model made it self-explanatory.
- The model fits well under the doc-cam

Conclusions/actions:

- Although there are potential improvements that can be made to the model, the current model is efficient and is a good improvement over the first model.

2021/09/28 - Preliminary Research

MILICA LUKIC - Oct 20, 2021, 2:51 PM CDT

Title: Preliminary Research
Date: 9/28/2021
Content by: Milica Lukic
Goals: Discuss the concept with Dr. Green as well as read the resources he has provided

Content:
5 causes of hypoxemia; not infectious causes but mechanistic causes:

1. Breathing lower partial pressure of oxygen or running out of oxygen if no external supply
2. Diffusion block or decreased diffusion across the alveolar capillary membrane - CO2 goes out O2 goes in
    a. fibrosis for example causes it to be thicker and then transport does not work as well
3. Hypoventilation - not breathing enough liters per minute to keep oxygen up
    a. when respiratory muscles are exhausted; bad asthma, bronchiolitis in babies; drug overdose
4. Shunt - non oxygenated blood goes into wrong ventricle because of holes
    a. extra oxygen does not help the shunt
5. V/Q Mismatching - Ventilation and perfusion mismatching is the most common
    a. blockage right below the larynx; oxygen going into alveoli
    b. Low ventilation = not enough oxygen getting into that area to oxygenate the blood = low V/Q ratio = cause for hypoxemia
    c. Example: a little bit of blood getting through a blood clot and air still going in and out of that area of the lung results in a high V/Q ratio
    d. The blood get oxygenated, wastes air bc extra ventilation
    e. High V/Q does not cause hypoxemia causes wasted ventilation

Conclusions/action items:

Continue reading resources provided by Dr. Green and compile any questions for him.

2021/10/04 - Gas Exchange Article

MILICA LUKIC - Oct 20, 2021, 3:00 PM CDT

Title: Gas exchange and ventilation–perfusion relationships in the lung
Date: 10/4/2021
Content by: Milica Lukic
Goals: Read and take notes on the gas exchange article by Robb W. Glenny that Dr. Green provided for us
Content:

1. There are five causes of hypoxemia. Decreased PaO_2 can be caused by hypoventilation, low PIO_2, diffusion limitation, low V/Q regions or shunt.
    a. In contrast with other causes, hypoxemia due to shunt characteristically responds poorly to increased FIO_2.
    b. Low V/Q regions and shunt are by far the most common causes of clinically encountered hypoxemia.
2. Hypoventilation and low V/Q ratios also impair CO_2 removal, but the magnitude of the effect on $PaCO_2$ is less
3. High V/Q ratios and alveolar dead space cause increased wasted ventilation and impaired CO_2 elimination
    a. The primary response to increased wasted ventilation is increased minute ventilation and work of breathing, not increased $PaCO_2$.
4. The effect of V/Q mismatch on gas exchange efficiency can be quantified using calculations of $PA–aO_2$ (venous admixture and wasted ventilation)
5. Low and high V/Q ratios cause hypoxemia, impaired CO_2 elimination and increased work to breath
6. Shunt is the most important cause of hypoxemia in patients with ARDS and pneumonia.

Conclusions/action items:

Discuss findings with group members to solidify understanding.

Compile some questions to ask Dr. Green at our next meeting.

2021/10/07 - Ventilation-Perfusion Relationships

MILICA LUKIC - Oct 20, 2021, 11:37 AM CDT

Title: Ventilation-Perfusion Relationships (West Chapter 5)
Date: 10/7/2021
Content by: Milica Lukic
Goals: Read and take notes on the ventilation-perfusion relationships chapter that Dr. Green provided for us
Content:
Primary function of the lungs is gas exchange.

There are three mechanisms of hypoxemia:

1. Hypoventilation
2. Diffusion limitation
3. Shunt

Oxygen transport from air to tissues:

- PO2 of alveolar gas determined by
    - Removal of O2 by pulmonary capillary blood
    - Continuous replenishment of O2 by alveolar ventilation
- Fluctuation of alveolar PO2 with each breath only ~3 mmHg
    - Can be regarded as continuous bc breath much smaller than total lung volume

Hypoventilation:

- Occurs when alveolar ventilation is abnormally low; alveolar PO2 falls and PCO2 rises
- Causes include
    - Drugs such as morphine and barbiturates
    - Damage to chest wall or paralysis of respiratory muscles
    - High resistance to breathing such as deep underwater
    - Some diseases such as obesity
- Relationship between alveolar ventilation and PO2
    - VCO2 is CO2 production
    - VA is alveolar ventilation
    - K is a constant
    - If alveolar ventilation is halved, PCO2 is doubled

$$P_{CO_2} = \frac{\dot{V}_{CO_2}}{\dot{V}_A} \times K$$

- Relationship between fall in PO2 and PCO2
    - F is a small correction factor
    - R is respiratory exchange ratio

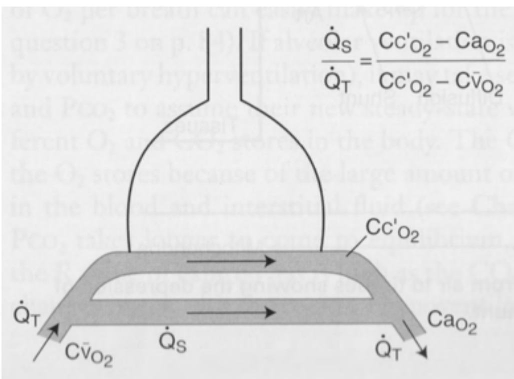
$$P_{A_{O_2}} = P_{I_{O_2}} - \frac{P_{A_{CO_2}}}{R} + F$$

Diffusion Limitation:

- Rarely causes hypoxemia at rest at sea level bc red blood cells spend enough time in the pulmonary capillary

Shunt:

- Blood that enters the arterial system without going through ventilated areas of the lung
- Measurement of shunt flow equation in image below
    - Oxygen carried in the arterial blood equals the sum of the oxygen carried in the capillary blood and that in the shunted blood
- Hypoxemia responds poorly to added O2
- When 100% O2 is inspired, arterial PO2 does not rise to the expected level
- If shunt is caused by mixed venous blood, its size can be calculated from the shunt equation



Ventilation-Perfusion Ratio:

- Most common and most difficult to understand cause of hypoxemia
- If ventilation and blood flow are mismatched in various regions of the lung, impairment of both O2 and CO2 transfer results
- PO2, PCO2, PN2 (and any other gas) is determined by V/Q ratio
- Model for understanding ventilation and perfusion

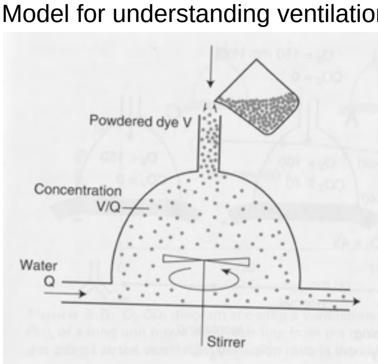
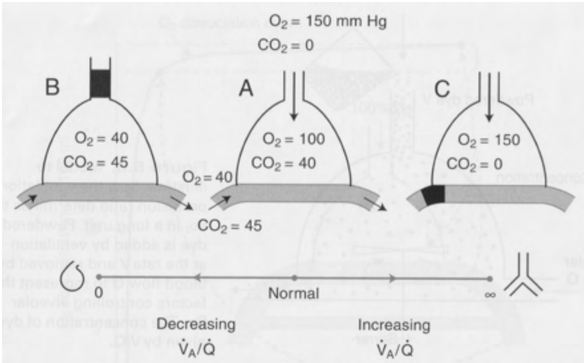


Figure 5.6. Model to illustrate how the ventilation-perfusion ratio determines the P_{O_2} in a lung unit. Powdered dye is added by ventilation at the rate V and removed by blood flow Q to represent the factors controlling alveolar P_{O_2}. The concentration of dye is given by V/Q.

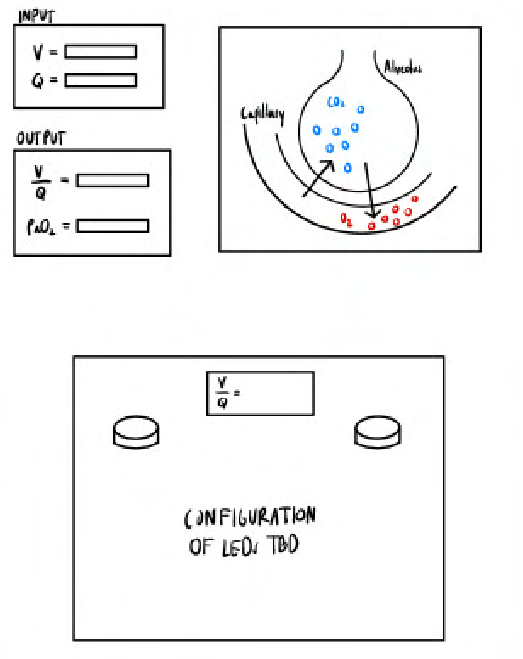
- Effect of altering the V/Q ratio on PO2 and PCO2



Conclusions/action items:
Re-read chapter to understand effects of different V/Q ratios.
Discuss findings with group members to solidify understanding.
Compile some questions to ask Dr. Green at our next meeting to ensure that we understand the relationship between ventilation and perfusion.

2021/10/01 - Initial Design Matrix Drawings

MILICA LUKIC - Oct 20, 2021, 11:38 AM CDT



Design_Matrix_Diagrams.pdf(235.5 KB) - download

2021/11/15 - LED Design Possibilities

MILICA LUKIC - Dec 15, 2021, 2:10 PM CST

Title: LED Design Possibilities

Date: 11/15/21

Content by: Milica Lukic

Present: N/A

Goals: Come up with potential LED designs and discuss with Dr. Green to decide on the most intuitive and clear option.

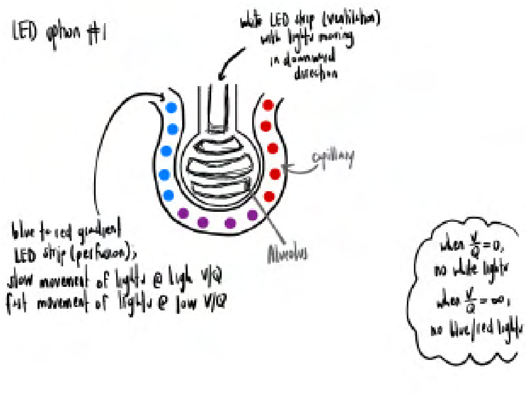
Content:

PDF with design ideas attached.

Conclusions/action items:

Dr. Green likes the design of the capillary and alvelous in options 1, 2, and 3. Team must discuss the different options for alveolus lights and confirm final design with Dr. Green.

MILICA LUKIC - Dec 15, 2021, 2:08 PM CST



LED_Design_Ideas.pdf(2.7 MB) - download

2021/12/03 - Updated Design Matrix Drawings

MILICA LUKIC - Dec 15, 2021, 2:22 PM CST

Title: Updated Design Matrix Drawings

Date: 12/03/21

Content by: Milica Lukic

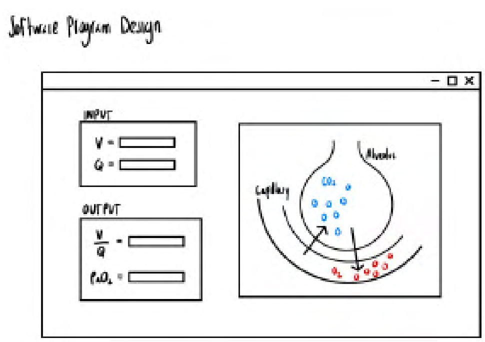
Present: N/A

Goals: Update sketches for design matrix with clearer sketches, labels, and dimensions

Content:

PDF with drawings attached

MILICA LUKIC - Dec 15, 2021, 2:06 PM CST



Design_Matrix_Drawings.pdf(3 MB) - download

2021/12/03 - Final Design Drawings

MILICA LUKIC - Dec 15, 2021, 2:13 PM CST

Title: Final Design Drawings

Date: 12/03/21

Content by: Milica Lukic

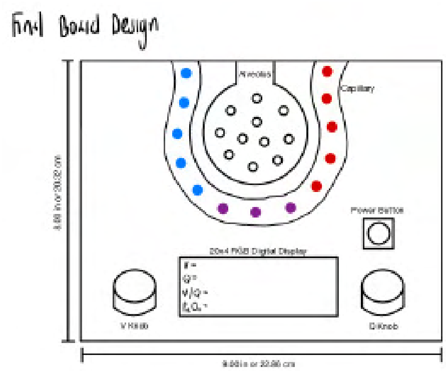
Present: N/A

Goals: Make a clear sketch of the final design including lables and dimensions.

Content:

PDF with final design attached.

MILICA LUKIC - Dec 15, 2021, 2:13 PM CST



Final_Design.pdf(1 MB) - download

2021/12/09 - Text for Poster Presentation

MILICA LUKIC - Dec 15, 2021, 2:43 PM CST

Title: Text for Poster Presentation

Date: 12/10/21

Content by: Milica Lukic

Goals: Write out all text and find diagrams that will be going on the poster presentation

Content:

Abstract

The concept of ventilation (V, air flow) and perfusion (Q, blood flow) in the lungs and the effect of ventilation and perfusion mismatch on the body is of great clinical significance. V/Q mismatching leads to a variety of problems, the most serious of which is hypoxemia which can cause respiratory failure. There is currently no effective teaching model for learning this concept, which is why the client, Dr. Christopher Green has commissioned BME design students to create an intuitive and visually helpful teaching model. The model uses a 3D printed board designed in the image of an alveolus and capillary in the lungs, with LED lights to demonstrate movement of air and blood at different V/Q ratios. Knobs allow the users to visualize a wide range of V/Q ratios, and a digital display shows the V/Q ratio and partial pressure of oxygen.

Problem Definition: Motivation and Background

Motivation

The concept of V/Q mismatching can be very difficult to understand and visualize. It is very important for medical students to understand V/Q mismatching as it is the cause of many issues in the lungs, such as hypoxemia or dead space ventilation. Currently, students rely on models in textbooks to visualize the effects of V/Q mismatching on the lungs. This teaching model is necessary as it provides students with an interactive, visual tool to understand what occurs in the alveolus and capillary during mismatching.

Background

- The lungs contain alveoli, which are the main sites of gaseous exchange. [1]
- V/Q ratio refers to the ratio of air entering and leaving the alveoli to flow of blood to and from the alveolar capillaries. [2]
- Both V and Q are measured in liters/minute, making V/Q a unitless value.
- A healthy individual would have an average V/Q ratio of 1. [1]
    - Asthma, cyctic fibrosis, COPD, and other lung diseases alter the normal V/Q ratio
- Alveolar dead space refers to lack of ventilation, resulting in some alveoli not being ventilated, lowering V/Q, causing hypoxemia. [2]
- Hypoxemia occurs when there is a low level of oxygen in the blood, and it can lead to respiratory failure. [3]
- Partial pressure of oxygen (P_aO_2) is the measure of the pressure of oxygen dissolved in the blood [4]

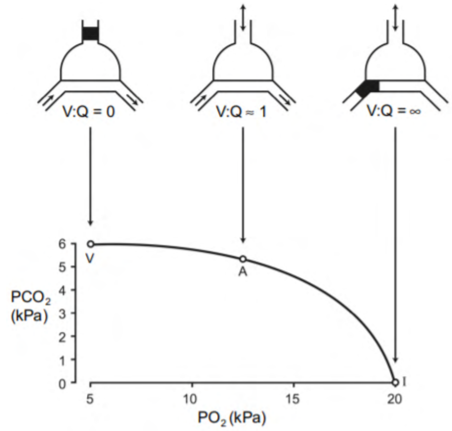


Figure 1. Effects of V:Q mismatch on gas exchange [5]

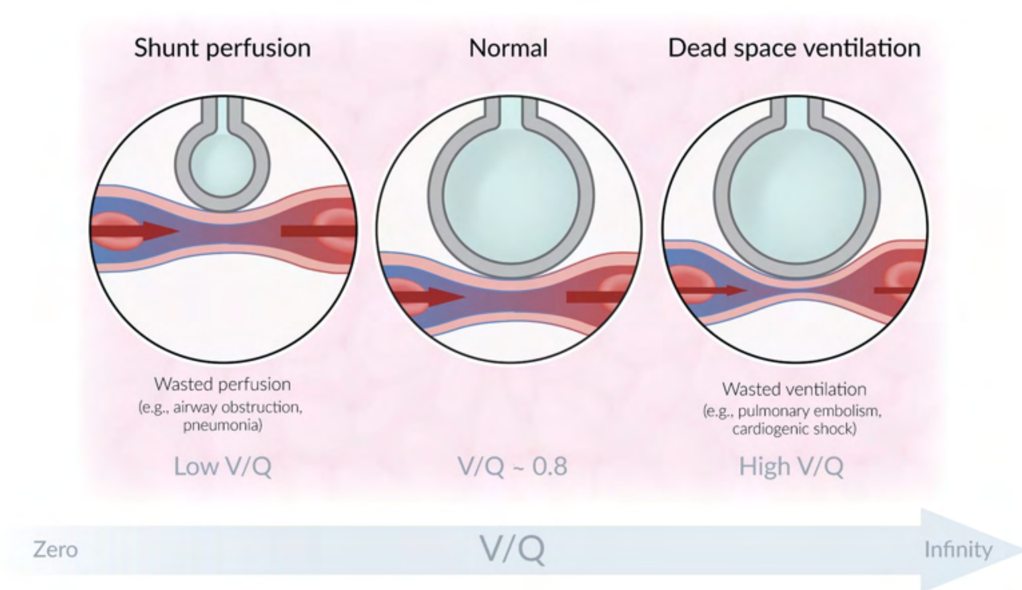


Figure 2. Obstrution of capillary at different V/Q ratios. [6]

Design Criteria

- Intuitive use for students and teachers
- Knobs that control V and Q to allow the user to view a wide range of V/Q ratios
- Digital display that shows the V/Q ratio and partial pressure of oxygen (P_aO_2)
- Visibility under a document camera in a lecture hall setting
- No larger than 27.90 cm x 27.90 cm
- No heavier than 6.8 kg
- Easily storable with a service life of at least 5 years
- Not necessarily anatomically realistic, but good visual representation of the alveolus and capillary at different V/Q ratios

Materials

- PLA for 3D printing
- Arduino
- Adafruit potentiometers
- Adafruit knobs
- Adafruit Neopixel LED strips
- LED bulbs
- Adafruit RGB LCD 20x4

Final Design: Progress and Results

Progress

In order to improve upon the previous model, the buttons have been replaced with knobs and the preset ratios have been removed. This allows the user to view a much larger range of V/Q ratios and visualize the corresponding flow rates. Along with this, another improvement made was the addition of partial pressure of oxygen (P_aO_2) as a value on the display. P_aO_2 changes depending on ventilation and perfusion and is an important diagnostic tool. In order to address the client's desires, make a variety of improvements, and create an intuitive and helpful teaching model, the team went through the following steps and more:

- Redesign the board for knobs rather than buttons
- Alter the shape of the capillary on the board in order to better represent the capillary network present in the lungs
- Change the color of the PLA board in order to improve visibility under the document camera and increase the contrast of the lights against the board
- Change the shape of the LEDs in the alveolus to better show the movement of air down and dispersing throughout the alveolus
- Calibrate and program the potentiometer knobs
- Program the LEDs in the alveolus and the capillary to respond accurately to different V/Q ratios
- Program the display to show the V/Q ratio as well as P_aO_2

Results

The team was able to create a final model with the following features:

- One knob to control V values and another to control Q values
- Larger display for clearer and more visible text
- P_aO_2 calculated based on V/Q ratios and included on display
- Power button
- Yellow 3D printed board
- More accurate capillary and alveolus design
- More accurate alveolus light movement

Initial test of the original model:

In order to create the most effective fabrication plans, we tested the previous model in a classroom setting under a document camera. The findings were as follows:

- Model has to be connected to personal laptop through USB to obtain power
- Black PLA would increase visibility of the LEDs
- Electronic display needs to be larger than the previous model
- No red or dark colored text; green and white text are visible
- Green LEDs do not display well under the document camera
- Scratches on the PLA are very apparent under the document camera
- Previous model alveolus is too complex and difficult to understand
- Parts of the model need to be labeled

Show and tell feedback:

During a project show and tell, we presented the original model and a draft of our intended model to roughly 40 students and asked for feedback specifically on how we could make our model more intuitive for use and a neater appearance. It was important to us to reflect on our peers' feedback, but with the knowledge that medical students will have previous knowledge on the concept and medical terminology so they will be able to understand the model's intentions better than our BME 200/300 peers.

Results and notes:

- Display should be larger than the original display
- Labeling components would be helpful to understand what is being modeled, labeling can be done with laser cutting or engraving tools
- It was not clear what the colors of the lights means (especially the green alveolus lights)
- Capillary LEDs should be purple because it is a mix of oxygenated and deoxygenated blood
- Capillary light intensity can represent the diameter of the capillary at that point
  - Brighter light when capillary has a larger diameter
  - Dimmer light when capillary has a smaller diameter
- An arrow showing the direction in which the knobs should be turned to increase the V or Q components of the ratio
- Aveouls would benefit from being a plain white color that represents air
- The model potentially has too many lights and negatively impacts the intuitive use for students

Table 1. Comparing the displayed values from the code to the calculated values

V Value	Q Value	V/Q Ratio Displayed	P_aO_2 Displayed	V/Q Ratio Calculated	P_aO_2 Calculated
90.00	100.00	0.90	101.84	0.9000	101.8412
6.00	37.00	0.16	50.42	0.1622	50.4199

29.00	56.00	0.52	82.14	0.5179	82.1384
59.00	100.00	0.59	86.86	0.5900	86.8567
6.00	74.00	0.08	43.33	0.0811	43.3342

Future Work

- Testing the model in a lecture hall to examine the LEDs and screen under a document camera
- Testing the model with the client and a small group of his medical students to receive feedback on criteria such as intuitive use and helpful visual representation
- Later testing with a larger population of medical students to determine the impact of this teaching model on a larger scale
- Continuing with programming and circuitry to ensure the code runs smoothly
    - Specifically, working on the speed and accuracy with which the LEDs respond to the potentiometer knobs
- Addition of another alveolus to better mimic the lung

Acknowledgements

We would like to thank our client, Dr. Chris Green, our advisor, Professor Chris Brace, and the BME faculty and staff for their help and guidance throughout this project. We would also like to thank Professor Amit Nimunkar and Brittany Glaeser for their assistance with the programming and circuitry involved in our project.

References

[1] J. B. West and A. Luks, West's respiratory physiology: The essentials. Philadelphia: Wolters Kluwer, 2016.

[2] K. A. Powers, “Physiology, pulmonary ventilation and perfusion,” StatPearls [Internet]., 20-Aug-2021. [Online]. Available: https://www.ncbi.nlm.nih.gov/books/NBK539907/. [Accessed: 05-Dec-2021].

[3] “Hypoxemia (low blood oxygen),” Mayo Clinic, 2018. https://www.mayoclinic.org/symptoms/hypoxemia/basics/definition/sym-20050930#:~:text=Hypoxemia%20is%20a%20below%2Dnormal,such%20as%20shortness%20of%20breath. (accessed Dec. 09, 2021).

[4] “Arterial Blood Gases (ABG) Test | Michigan Medicine,” *Uofmhealth.org*, 2020. https://www.uofmhealth.org/health-library/hw2343 (accessed Dec. 09, 2021).

[5] N. Lees and N. Soni, “Respiratory physiology,” *Introductory Series in Medicine*, pp. 41–69, 2014.

Conclusions/action items:

Finish formatting poster, submit for printing to college library, pick up before the

2014/11/03-Template

John Puccinelli - Nov 03, 2014, 3:20 PM CST

Title:

Date:

Content by:

Present:

Goals:

Content:

Conclusions/action items:

2014/11/03-Entry guidelines

John Puccinelli - Sep 05, 2016, 1:18 PM CDT

Use this as a guide for every entry

- Every text entry of your notebook should have the **bold titles** below.
- Every page/entry should be **named starting with the date** of the entry's first creation/activity, subsequent material from future dates can be added later.

You can create a copy of the blank template by first opening the desired folder, clicking on "New", selecting "Copy Existing Page...", and then select "2014/11/03-Template")

Title: Descriptive title (i.e. Client Meeting)

Date: 9/5/2016

Content by: The one person who wrote the content

Present: Names of those present if more than just you (not necessary for individual work)

Goals: Establish clear goals for all text entries (meetings, individual work, etc.).

Content:

Contains clear and organized notes (also includes any references used)

Conclusions/action items:

Recap only the most significant findings and/or action items resulting from the entry.