BME Design-Fall 2020 - Brittany Glaeser
Complete Notebook

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KAITLIN LACY

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Table of Contents

Team contact Information

Brittany Glaeser - Sep 13, 2020, 11:15 AM CDT

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Project description

JENNA EIZADI (eizadi@wisc.edu) - Oct 07, 2020, 12:15 PM CDT

Course Number: BME 400

Project Name: Teaching Model for Ventilation and Perfusion Mismatching

Short Name: V/P Teaching Model

Project description/problem statement:

During medical school, students are taught about the importance of ventilation-perfusion (V/Q) mismatching and the effects it has on the body. Oftentimes, the students have difficulty understanding that a high V/Q ratio leads to dead space ventilation or wasted ventilation and that a low V/Q can lead to hypoxemia, which is a condition where there is a low oxygen concentration in the blood. A model representing the mechanisms underlying V/Q mismatching would help students understand this concept.

About the client:

Dr. Chris Green is a retired pediatric pulmonologist and continues to teach lectures at UW-Madison School of Medicine. During his lectures, he discusses ventilation-perfusion mismatching and understands that the concept is difficult for some students to comprehend. Therefore, he has requested a physical model to use in his classroom to help with teaching the students the concept of ventilation-perfusion mismatching.

9/9/20 Client Meeting

Brittany Glaeser - Sep 09, 2020, 8:14 PM CDT

Title: First Client Meeting

Date: 9/9/20

Content by: Kaitlin

Present: Team + Client

Goals: To discuss any questions the team has with the client to better understand the project

Content:

What aspects or ideas from the model mentioned in the project description would he like us to model/replicate in our design?

Inversely, what doesn't he like about that model that he wants us to change?

- The design is messy with the water aspect and would require too much work to set up
-

Is there a specific age group that the model and research should be oriented around? (Curious as it was mentioned that he works in pediatrics)

- The model is for teaching med. students about V/Q mismatching so the direction of research is not important

What kind of budget does he want us to stick to?

- Has leftover money, $1000, most have spent 100 to 300 bucks
- He is going to clarify on how to buy things and confirm with his department

Does this need to interface with any other equipment, or should it stand on its own?

- Stand on own

How portable should this be/what kind of size and weight is he thinking of? (any specific size or weight restrictions)

- Bigger the size of his fist
- 180 med students, room holds 225, model up 6x8 two feet deep, set up so everyone can see? Too big? Build tabletop size, 1.5-2 feet wide with camera on it

What in particular do students have trouble understanding? (he mentioned high V/Q ratios not leading to hypoxemia and leading to dead space ventilation)

- is that just because all of the extra ventilation is not helping perfusion but not hurting it?

What sort of ratios and ranges does he want the model to be able to mimic?

- Range from dead space to shunt
- Mentioned maybe buttons with about 5 settings or a dial to slowly increase/decrease ratios

Does he envision this as something that only the instructor uses to demonstrate, or would the students interact with it to learn? (aka how user friendly does this need to be)

How long of a time period would it be used for at once?

Does he want this for a purely learning tool or does he envision some sort of commercial viability he would want to pursue?

- Students to observe

Is there anything about ventilation/perfusion mismatch that he thinks are very important to this project/main ideas that we need to research

Does this model need to mimic any specific clinical conditions? (emphesema, pneumonia)

Would it be more beneficial to model a close up view of an alveoli in the lung and what happens specifically when the ratio of ventilation to perfusion changes, a system of alveoli and how a V/Q mismatch affects the system, or a whole diagram of the lung and how hypoxemia occurs? Should we include options for specific clinical applications like causes (pnemonia, COPD, PE, fibrosis, pulmonary hypertension, asthma…) and how to treat (100% O2)

- Not whole lung, single compartment lung, airway with alveolus at the end (not anatomically perfect, easy to build), one blood vessel
- Could also model a healthy V/Q ratio

<u>Overview: medical students used to use West's textbook</u>

- Trachea into bronchi branch points into alveoli
- Moving lots of wasted air in and out but no blood flow is dead space (infinity)
- 1 mL air to mL of blood 1:1, healthy ratio, most of lung
- Perfusion but no ventilation, blocked bronchus for example, lung tries to adjust, but called shunt
- Hard for medical students to grasp; hard to teach well
- Suggested dye in the airway pretended to be oxygen, colors fluid to indicate oxygenation of blood, dye and a pump but would be very messy, reservoirs, set speed
    - Instead could use LEDs to turn up or down voltage to show
    - Venous blood is darker red, arterial blood is bright red
    - bluish/bluish red, depict air coming in, color coming out indicates oxygenation
    - Ideally have a controller to show students dead space ventilation output, high V/Q ratio what do you, low V/Q what do you get, shunt output
    - Venous blood has oxygenation (mixed) 75% at rest
    - Show difference in oxygenation dead space, close to dead space, normal, low v/q, shunting
        - Slider or dial to show spectrum
        - Less desired having five switches
- If it doesn't work, we should learn a lot

He will send paper to us w/ more info

-he has lots more if we want it

Pedagogic: promoting better teaching

Get him advisors info

Pediatric pulmonology is his specialty

Hypoxemia low blood oxygen levels in the blood

- High vq
    - Dead space ventilation
    - hyperventilation
    - Blood clot, no gas exchange taking place into blood
        - Pulmonary embolism
- Low vq
    - shunting

Couple of weeks to meet again

Conclusions/action items:

After the client meeting, the team has a better understanding as to what the client is looking for in the design. The next steps would be to think of ideas to model the mixing of blood with O2 similar to the diagram he referred to which used water. The client mentioned using LEDs to model this. The team can also begin more research on V/Q mismatching and how it can lead to hypoxemia.

9/24/20 Client Meeting

Brittany Glaeser - Sep 25, 2020, 2:32 PM CDT

Title: Client Meeting

Date: 9/24/20

Content by: Britt

Present: Team + Client

Goals: To understand our clients take on our design ideas

Content:

- Beads
    - Could flow beads through a closed liquid system
    - Use the same color beads and use volume to represent amount of flow
- LED
    - Use brightness
    - Shade of colors
    - Oxygen color and oxygen flow
    - O2 and CO2 would add to the design
- He likes the idea of having a physical model because many people learn in different ways
    - He has looked into having someone create an online model, and it have been proven to be difficult, but he would like a physical model for class purposes
- The LEDs seem to be the best option
- Scatter light in a tube
    - He used the idea of glass to scatter the light
    - Clear plastics could also be used to do this

Conclusions/action items:

After meeting with the client, we all decided the best way to model V/Q ratios would be through the use of LEDs. We will begin finalizing the LED more and also think of ways that would could scatter the light so that the LEDs are less noticable.

9/11/20 Discussion of Initial Client Meeting and Overall Project

Brittany Glaeser - Sep 11, 2020, 2:00 PM CDT

Title: Advisor Meeting

Date: 9/11/20

Content by: Britt

Present: Team + Advisor

Goals: Discuss what has been accomplished for the project and what will need to be done for the semester

Content:

- Physical aspect of model
    - Lung + capillaries
    - Can 3D print at makerspace (pickup)
- Electronics aspect of model
    - LEDs, motor, microcontroller, etc.
    - Model oxygen flow and blood flow
- Can split into to team for the physical and electronics aspect
- Can easily do small scale models at home
    - Should have all the necessary tools
- PDS is due next Friday
    - Rough draft ideas included in lab archives
- Problem statement should be included in lab archives

Conclusions/action items:

The team discussed the client meeting and the ideas the client was looking for in our model. Further research will be conducted for V/Q mismatching in order to come up with some future design ideas to present to the class. Also, the team will begin creating the PDS with information provided from the client meeting and will work out any details as we move along with the project.

9/18/20 Discussion of PDS

Brittany Glaeser - Sep 18, 2020, 2:22 PM CDT

Title: Advisor Meeting

Date: 9/18/20

Content by: Britt

Present: Team

Goals: Discuss model ideas and PDS

Content:

- 6x8 feet is very large
    - Talk over again with client
- Why a physical model?
    - Easier for students to learn with a physical interactive model
- Would be good to start with a small scale model for this semester
    - Could use plumbing tubes from homedepot
        - Transparent
    - Easier than 3D printing for a small scale model
- A display with ratios
- Microsoft teams works better to share screen

Conclusions/action items:

The next steps would be to do more research so we can determine how we want to model V/Q mismatching. By the next advisor meeting it would be good to have a few sketches and a few solidworks drawings of some designs. It would also be beneficial to create have an outline of our presentation slides with some information to go over.

9/25/2020 - Discussion of Preliminary Designs

KAITLIN LACY - Oct 06, 2020, 8:13 PM CDT

Title: Discussion of Preliminary Designs Advisor Meeting

Date: 9/25/2020

Content by: Kaitlin Lacy

Present: Entire Team

Goals: Discuss initial designs and get feedback in order to proceed for preliminary presentation.

Content:

-possibility to not have actual visible LEDs but rather put them inside a tube to diffuse the light

-Initial designs were presented, but even the ones that will not be chosen need to have enough details to understand how they would work

-decided to add a second design matrix that focuses on the different presentation of the LED models

Conclusions/action items:

Create a second design matrix with the variations of the LED design. Add more details to the bead design in order to properly conclude that the LED should still be chosen. Prepare for the preliminary presentation.

2020/09/20 - Design Matrix Ideas

Brittany Glaeser - Oct 07, 2020, 10:02 AM CDT

Title: Design Matrix Criteria

Date: 9/20/20

Content by: Britt

Present: Team

Goals: Determine the criteria for the design Matrix

Content:

- Because this design is going to be used as a teaching model in a classroom setting Effectiveness would be most important.
    - This would only be how well the design can show V/Q mismatching
    - How noticable the differences are in ratios
    - The size of the device, if it can be seen in a lecture hall with 180 people (by the use of a projector)
- The device needs to be easy to set up and clean up for the professor
    - This category should also include how easy it would be for the user to change the ratios (buttons, dye, etc.)
    - Also ability to store the device, the smaller and lighter the device is the easier it would be to store
- Fabrication is important as we do have some limitations
    - Online models would be very difficult for us as we have limited knowledge with that kind of computer programming
    - How many moving parts are involved
- Viability
    - The device will likely be used in different semesters and the rest of the time will sit in storage
    - How fast the parts are likely to degrade or fall apart (LEDs would last longer than a water pump)
    - This would also depend on the parts chosen that would fall in our budget and other constraints
- The budget is large so this is less of a concern but important to consider

Conclusions/action items:

Next the team will evaluate each of the designs for the design criteria for the Model that will be used.

After further discussing the design with the advisor, we will create another design matrix that will show how we plan on incorporating the LEDs into our design (The LED model scored the highest in most categories).

2020/09/24 - Initial SolidWorks of Alveoli

KAITLIN LACY - Oct 06, 2020, 8:20 PM CDT

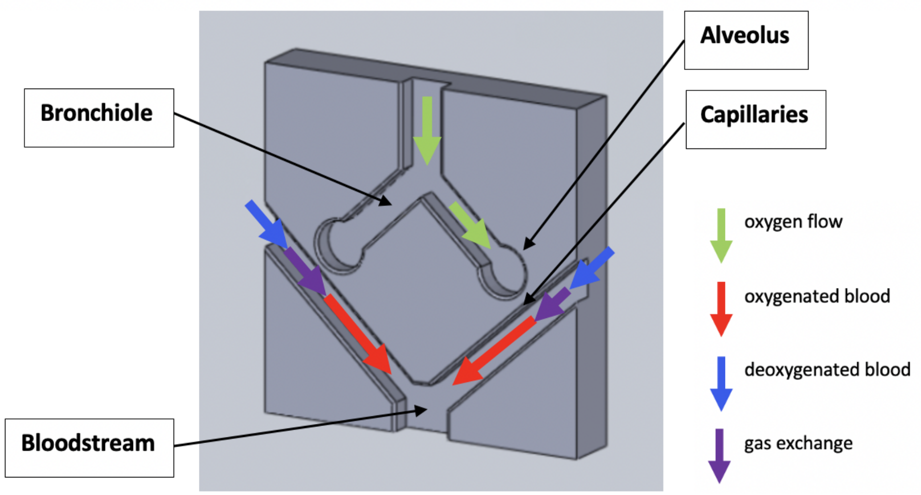
Title: Initial SolidWorks of Alveoli

Date: 9/24/2020

Content by: Kaitlin Lacy

Goals: Generate an initial idea of the layout of the alveoli and blood vessels in the model.

Content:



Conclusions/action items: Discuss dimensions and ways we can improve the model to show the passage of air and blood flow.

Ventilation-Perfusion Mismatching

Brittany Glaeser - Sep 05, 2020, 3:51 PM CDT

Title: Ventilation-Perfusion Mismatching

Date: 9/5/20

Content by: Britt

Present: Britt

Goals: Understand ventilation-perfusion mismatching and how it affects oxygen in the blood

Content:

- Ventilation: Alveolar airflow
- Perfusion: Capillary Blood flow
- Ventilation / Perfusion ratio
    - Much have a correct proportion otherwise is termed mismatching/inequality
- Major effect of inequality is to decrease PO2 of systemic arterial blood\
- In disease states, regional changes in lung compliance, airway resistance, and vascular resistance can cause marked ventilation-perfusion inequalities
    - Examples: ventilated alveoli with no blood supply at all (dead space) or blood flowing through an area with no ventilation due to collapsed aveoli
- Carbon dioxide elimination can be impaired by inequality
    - Small increases in arterial PCO2 lead to increases in alveolar ventilation, which usually prevent further increases in arterial PCO2
- There are some local homeostatic responses within the lungs that can help some cases of inequalities - these can be seen in figure 1.
    - Effects of vasoconstriction and bronchoconstriction are to supply less blood flow to poorly ventilated areas and thus diverting blood flow to well-ventilated areas and to redirect air away from diseased or damaged alveoli and toward healthy alveloli.

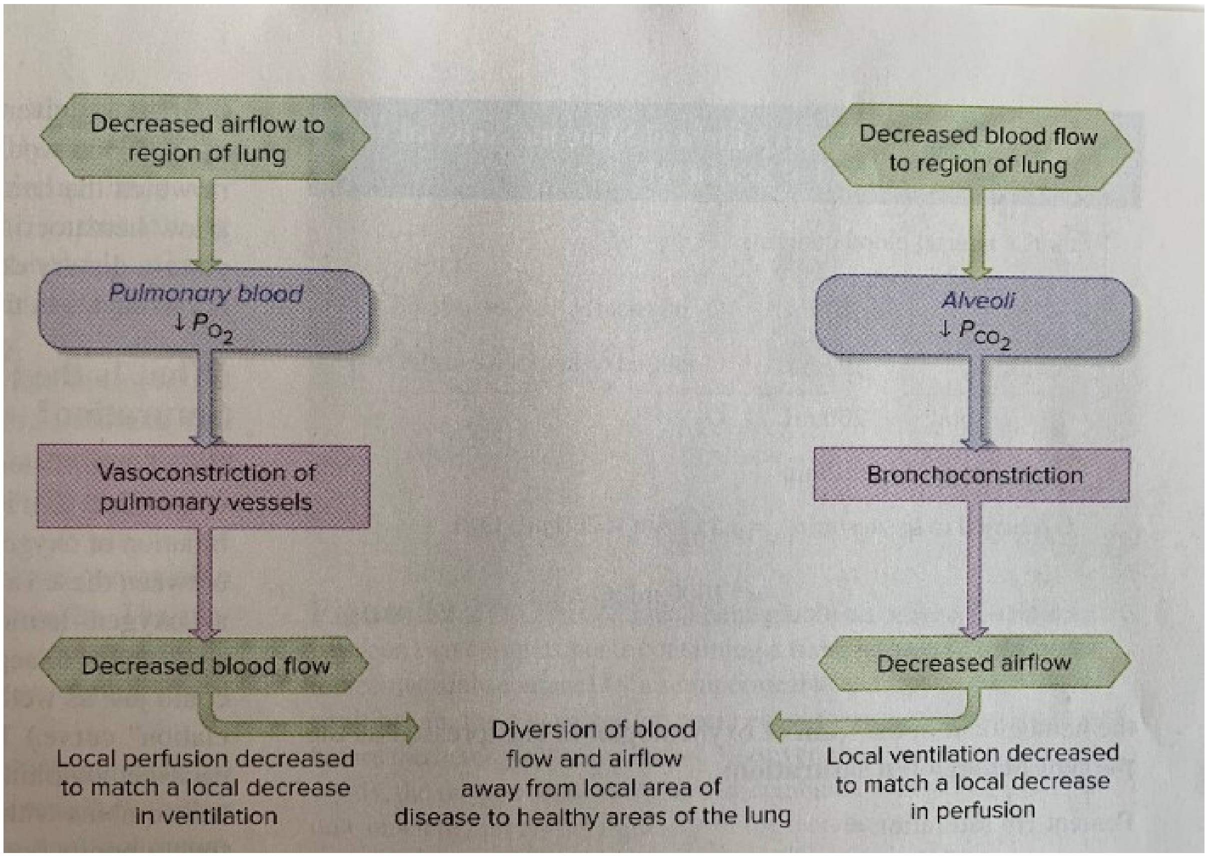


Figure 1: Local homeostatic responses to ventilation-perfusion mismatching [1]

Conclusions/action items:

The important thing to understand when making a model is what causes the events that are occurring. Ventilation-Perfusion mismatching is a common cause of hypoxia which our model will need to show. Mismatching can occur in a few different ways but some, such as decrease in PO2 of systemic arterial blood, is the major cause. It is also good to know how our body responds to the mismatching and showing how a normal lung works could also be an important aspect to our model.

CITATION: [1] E. P. Widmaier, A. J. Vander, H. Raff, and K. T. Strang, *Vanders human physiology: the mechanisms of body function*, Fifteenth. New York: McGraw-Hill Education, 2019.

Lung Anatomy

Brittany Glaeser - Sep 12, 2020, 3:45 PM CDT

Title: Lung Anatomy

Date: 9/9/2020

Content by: Britt

Present: Britt

Goals: Understand the mechanics of the lung

Content:

- Dead Space is the volume of fresh air wasted in the conducting zone with each breath
  - The space below dead space is a mix of old and new air
  - The space below that is the old air for expiration
- With a high V/Q ratio, the dead space volume is higher than normal as the air is not mixing with the blood and will be expired
- Dead space is important to the aveolar ventilation
- Normal ventilation has 150 mL of dead space volume
- Aveolar Ventilation:
  - AV = respir. Rate x (tidal vol - dead space)

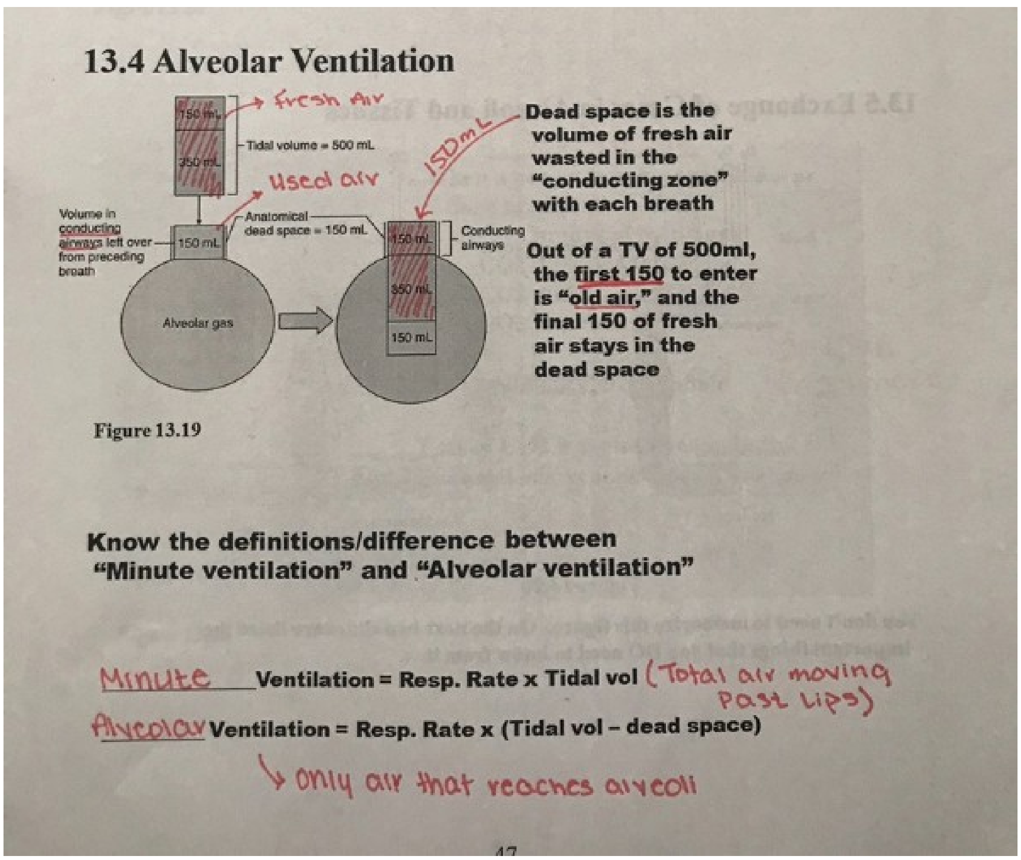


Figure 1: Process of aveolar ventilation and equations for ventilation

- The lung anatomy will not be modeled in our design but it important to understand as it contributes to ventilation/perfusion mismatching
- Air Flow: Mouth - larynx - trachea - bronchus - lung
- Diaphragm is used to change pressure to pull air into the lungs and then out of the lungs for expiration

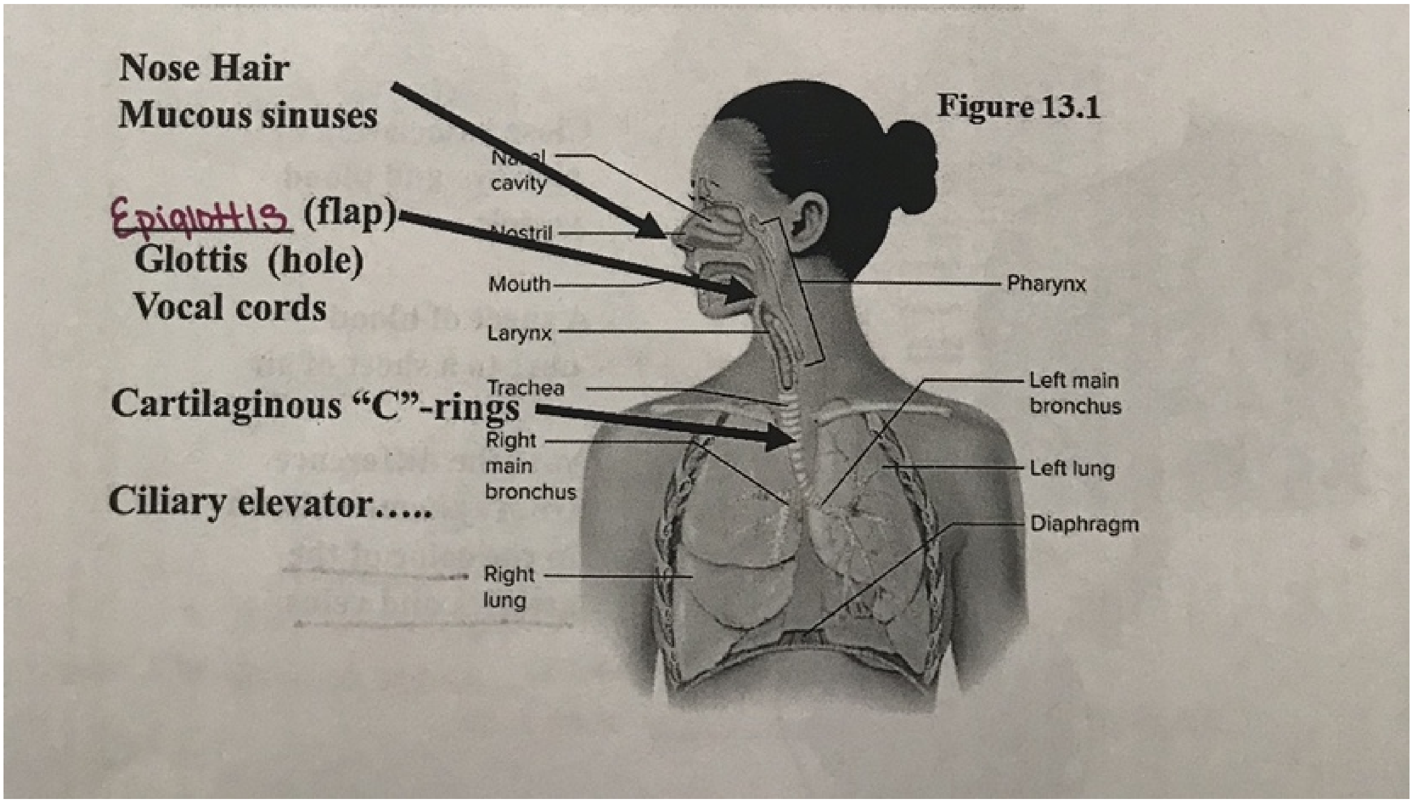


Figure 2: Lung Anatomy

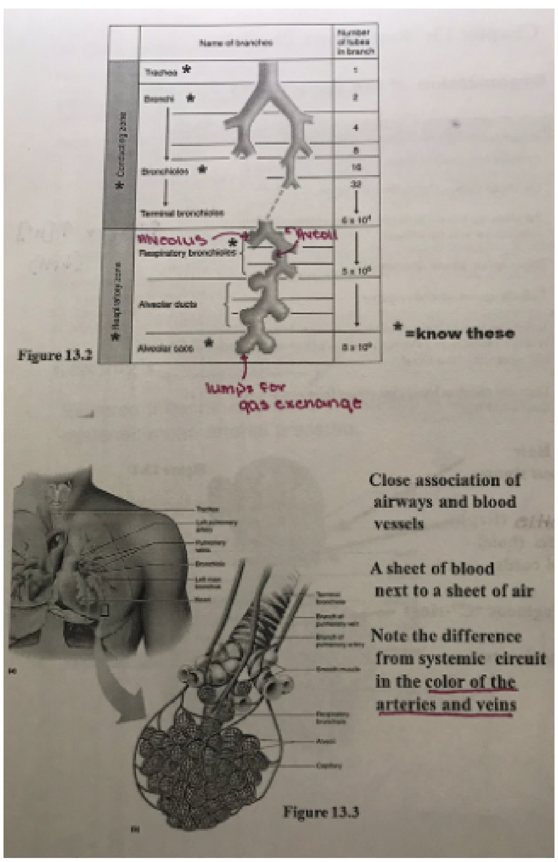


Figure 3: Aveoli Anatomy and lung hierarchy

- The capillaries surrounding the aveoli are the main aspect we will want to model in our design because this is the site of gas exchange
- The photo doesn't show the veins and the arteries (blue and red respectively), but that is something will we also want to show in our design
- Because the aveoli are so small in respect to the lung, it would not make sense to model the entire lung in our design
- The upper part of figure 3 shows the hierarchy of the parts of the lung from largest to smallest diameters

    - Air flows through each of these to the aveolar sacs

Conclusions/action items:

By understanding lung anatomy, it will help to better understand ventilation/perfusion mismatching. From this we will decide how we want to model the lung, most likely the alveoli portion where gas exchange occurs. We would also have to model the flow of air through the lungs which was stated previously. We could also use the aveolar ventilation rate to determine the ratios of air in our model, or we could use it to show the output of our model. Will will have to determine these final ideas as a team.

CITATION: Physiology Class Notes

Hypoxemia

Brittany Glaeser - Sep 09, 2020, 1:54 PM CDT

Title: Mechanism of Hypoxemia

Date: 9/9/2020

Content by: Britt

Present: Britt

Goals: To understand the disorder, hypoxemia, and how the body responds to the disorder

Content:

- Hypoxemia: decrease in the partial pressure of oxygen in the blood
- Hypoxemia can be caused by different mechanisms
  - V/Q mismatching
  - right-to-left shunt (abnormal communication between right and left sides of systemic and pulmonary vessels)
  - Diffusion impairment
  - Hypoventilation
  - Low inspired PO2
- V/Q mismatch is the most common cause
- Normal V/Q level is 0.8 (ventilation / Perfusion)
- Ventilation is responsible for gas exchange, the apical region with high ratio has low alveolar CO2 and high oxygen content and the basal region has low alveolar oxygen and high CO2
  - Only low V/Q ratio produces hypoxemia by decreasing the alveolar oxygen level and subsequently arterial oxygen level
- Body Compensatory Mechanism: the body will try to restrict perfusion in areas of the lungs with reduce ventilation
  - Done by Hypoxic pulmonary vasoconstriction (HPV)
    - Diverts blood to well-ventilated lung regions
    - Chronic HPV causes vascular structural remodeling and subsequent development of sustained pulmonary hypertension
- Common causes of mismatching
  - Asthma, COPD, bronchiectasis, cystic fibrosis, interstitial lung disease, pulmonary hypertension
  - Mismatch can be easily corrected by supplemental oxygen therapy

Conclusions/action items:

This article was a little more detailed into how hypoxemia can occur and related it to how it can cause other disorders such as hypoxia. This is important to understand why this disorder should be acknowledged. This article also mentioned how the body compensates for the changes in oxygen levels which related to the chart show on the page "ventilation-perfusion mismatching". An important thing to note is that V/Q mismatching is not the only cause of Hypoxemia, but it is the most common.

CITATION: Sarkar, M., Niranjan, N. and Banyal, P., 2017. Mechanisms of hypoxemia. *Lung India*, 34(1), p.47.

Water Model

Brittany Glaeser - Sep 12, 2020, 4:11 PM CDT

Title: Ventilation Perfusion Water Model

Date: 9/12/20

Content by: Britt

Present: Britt

Goals: To understand some existing design ideas

Content:

This model was given to the team from the client. The idea is that the water running through the bottom represents the blood and the powered dye represents the intake of oxygen. When ventilation is increased, there would be more dye and the blood would become a darker color, becoming more oxygenated. The model shows that the concentration of dye is affect by the flow of the water and the flow of the dye being poured (ventilation). The stirrer on the bottom represented the diffusion occurring between the capillaries and the aveoli.

After discussing with our client, we decided that this model may not be the best representation of V/Q mismatching. It would be difficult to show different ratios. This design could also be messy and difficult to set up for class.

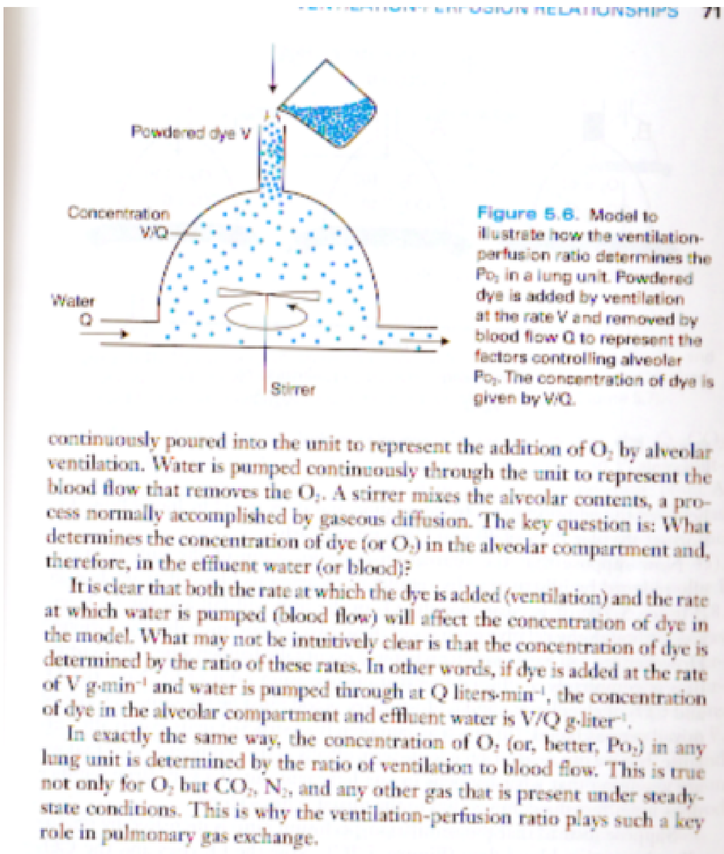


Figure 5.6. Model to illustrate how the ventilation-perfusion ratio determines the Po_2 in a lung unit. Powdered dye is added by ventilation at the rate V and removed by blood flow Q to represent the factors controlling alveolar Po_2. The concentration of dye is given by V/Q.

continuously poured into the unit to represent the addition of O_2 by alveolar ventilation. Water is pumped continuously through the unit to represent the blood flow that removes the O_2. A stirrer mixes the alveolar contents, a process normally accomplished by gaseous diffusion. The key question is: What determines the concentration of dye (or O_2) in the alveolar compartment and, therefore, in the effluent water (or blood)?

It is clear that both the rate at which the dye is added (ventilation) and the rate at which water is pumped (blood flow) will affect the concentration of dye in the model. What may not be intuitively clear is that the concentration of dye is determined by the ratio of these rates. In other words, if dye is added at the rate of V $g \cdot min^{-1}$ and water is pumped through at Q $liters \cdot min^{-1}$, the concentration of dye in the alveolar compartment and effluent water is V/Q $g \cdot liter^{-1}$.

In exactly the same way, the concentration of O_2 (or, better, Po_2) in any lung unit is determined by the ratio of ventilation to blood flow. This is true not only for O_2 but CO_2, N_2, and any other gas that is present under steady-state conditions. This is why the ventilation-perfusion ratio plays such a key role in pulmonary gas exchange.

Figure 1: Water model for ventilation and perfusion with description

Conclusions/action items:

The team is going to focus our ideas around this main concept of this design. We plan on eliminating the water aspect and using more electrical components such as LEDs. It would be beneficial to include some way of easily changing the V/Q ratios in the model without having to clean the device before the next use. We would also like to incorporate different colors to represent oxygen, deoxygenated blood, and oxygenated blood.

CITATION: Photo provided by client

Multi-Scale Computational Model

Brittany Glaeser - Oct 05, 2020, 11:36 AM CDT

Title: Multi-scale Computation Model of V/Q matching

Date: 10/4/20

Content by: Britt

Present: Britt

Goals: To find other competing designs for V/Q mismatching

Content:

- This study plans on using a computer model of the hemodynamics and gas exchange for V/Q matching
- The model serves as an in-silico (online/computer) platform to test and refine hypotheses regarding the contributions of vasoregulatory mechanisms
    - They are using their model for more research purposes rather than teaching like our model would be used for
- For an accurate model, they used a series of ordinary and partial differential equations
- Would model the whole lung vascular network model
    - Geometry is generated by a space-filling algorithm and is tested by comparing anatomical predications to existing literature
    - Mechanics are tested by comparing the model predictions to macro-scale pressure-flow relationships and pulmonary artery pressure waveforms
- From using their simulated model, they could determine that more homogenous blood flow distributions increase the bulk oxygen content entering the systemic circuit
- The model of the computer design can be seen in figure 1
- This design is far more complicated that we could model on a computer, but the idea of using a simplified online model may be more achievable, but we require much more programming knowledge

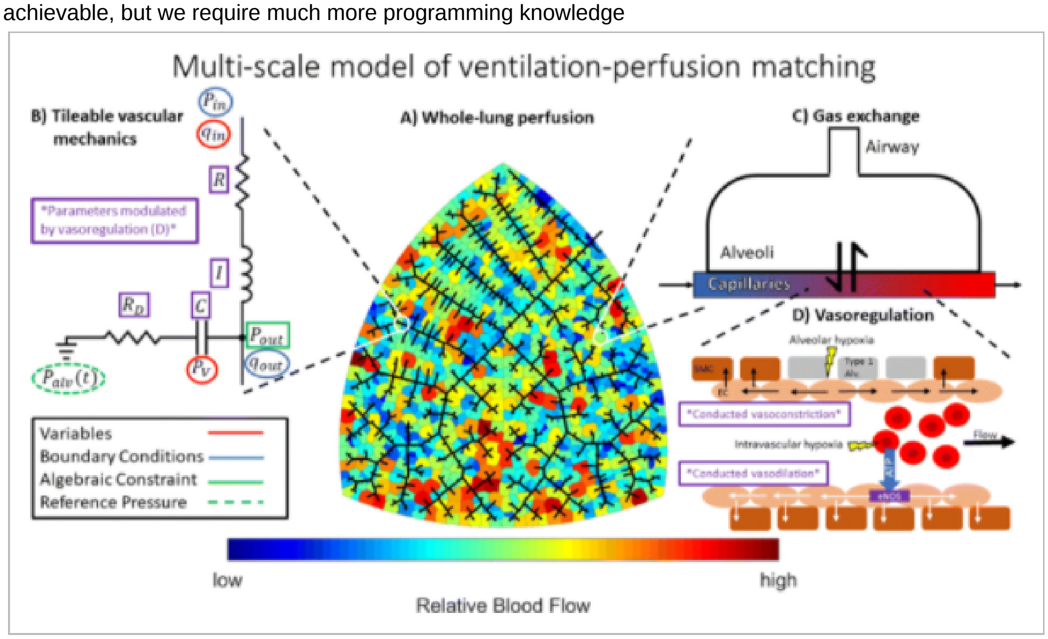


Figure 1: Online model of V/Q ratios

Conclusions/action items:

This model is used more for research purposes and helping to create a better understanding of V/Q mismatching. This model specifically, models the entire lunch, where we ideally would like to model our design on the micro-level (alveolar level). We would also like to better model the flow of blood and gas through the design, where this uses more shades of colors to model flow (we would like to do this as well as using moving pieces whether it be LED movement or water flow). There don't seem to be many resources or patents with other models for V/A models, which would be good for our design if we later decide to go further with this project.

CITATION: Marquis, A., Beard, D., and Pinsky, D., 2019. Towards a Multi-Scale Model of Ventilation-Perfusion Matching. *FASEB Journal. [Online].*

Alveolus Colored idea

Brittany Glaeser - Sep 09, 2020, 9:10 PM CDT

Title: Alveolus Colored Idea

Date: 9/9/20

Content by: Britt

Present: Britt

Goals: To come up with design ideas for the alveous to model V/Q mismatching

Content:

After the meeting with the client, I had a better understanding of what he wants to model in the design. In figure 1, it shows a model of the alveolus which we discussed would be the main part of the model, not the entire lung. The figure shows different colored blood representing the different levels of oxygenation. The idea of using different colors would be ideal for our model and we could use this using LEDs. In the figure, it shows purple as being the blood that is currently being mixed with the oxygen and the red as being oxygenated. We could easily model the how oxygenated the blood is by creating a spectrum of colors similar to the one in the figure.

One thing the figure doesn't show is the movement of air flow to the capillaries, so this is something we will have to add. Also a shunt, which could potentially be shown by LEDs not being lit or dimming the LEDs to show less ventilation is occurring while the brightness of the blood remains constant.

If LEDs were to be used, I have used Adafruit Neopixels that had a wide range of colors and brightness levels and were easy to program. There are also a wide array of LEDs that could be used for the project.

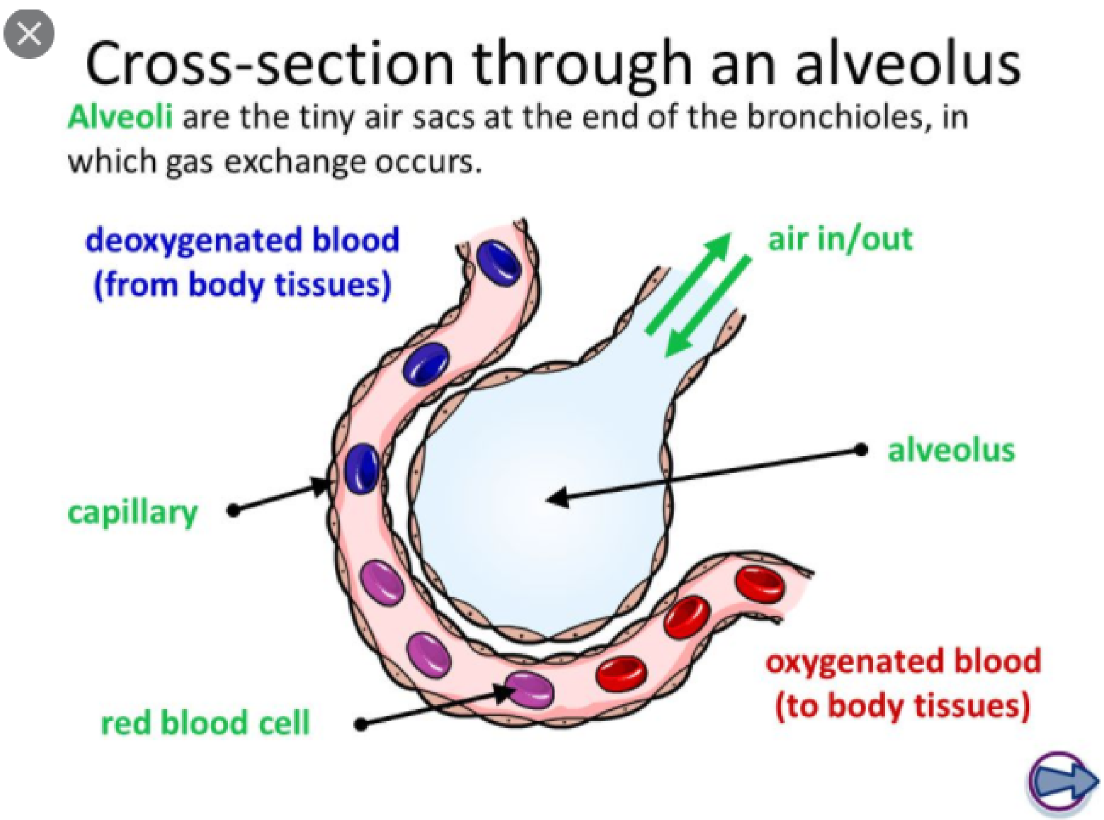


Figure 1: Cross-Section of the alveolus using different colors to represent oxygenated blood [1]

Conclusions/action items:

The next steps would be to further develop this model as potentially use it as a preliminary design for the design matrix.

CITATION: [1] Sarkar, M., Niranjan, N. and Banyal, P., 2017. Mechanisms of hypoxemia. *Lung India*, 34(1), p.47.

Alveolus LEDs

Brittany Glaeser - Sep 27, 2020, 4:29 PM CDT

Title: Aveolus LED design

Date: 9/20

Content by: Britt

Present: Britt

Goals: To present an LED idea

Content:

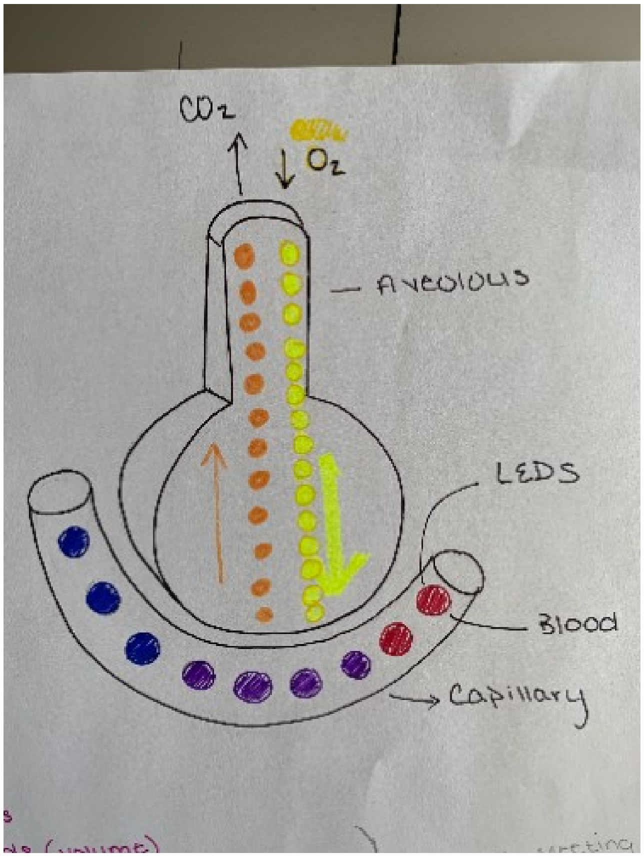


Figure 1: A single 3D aveolus with LEDs to represent oxygen and carbon dioxide as well as blood flow

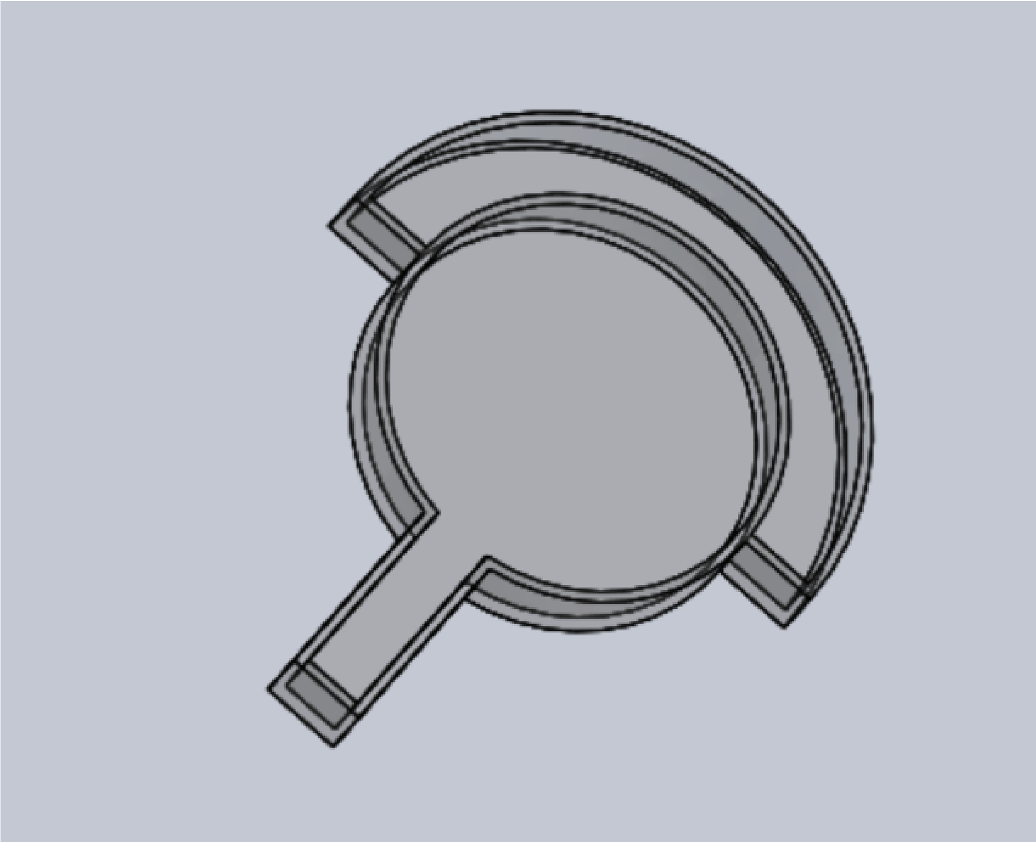


Figure 2: Solidworks drawing of alveolus design

The idea with this design was to use a single alveolus to model perfusion, even though it happens at more than one at a given time. The LEDs would be color coded to represent O2, CO2, deoxygenated blood and oxygenated blood. Ideally, both the brightness and the shade of color would change based on how much perfusion is occurring. The O2 and CO2 would also change based on how much ventilation is occurring. The LEDs would "move" to show the direction of flow through the capillary and show the CO2 moving out and the O2 moving into the alveolus.

The solidworks drawing is shown slightly differently than the drawing. I modeled this design as if it would be carved from a laser cutter machine. This idea came to me from user the laser cutter at work to encase my LEDs. The LEDs would be held within the carved middle sections of the design. The front of the design would actually be the back side of the drawing consisting of a flat surface. This would allow the light to diffuse through the plastic material (the plastic would have to be almost clear, but not clear enough that each individual LED can be seen.

Conclusions/action items:

To move forward with this design, it would be beneficial to create a CAD drawing to further explain my thought process. I would also begin looking into LEDs that could be used for this design (specifically RGB LEDs).

Diffused LEDs

Brittany Glaeser - Sep 30, 2020, 11:58 AM CDT

Title: Diffused LEDs

Date: 9/29/20

Content by: Britt

Present: Britt

Goals: To come up with ideas for diffusing the light of LEDs so that the LEDs are less noticeable

Content:

https://www.instructables.com/id/13-Ideas-for-Diffusing-LEDs/

The website listed above has some really cool ideas for how to diffuse light through a bunch of different materials

- The one that first caught my eye is ping pong balls
  - Ping pong balls wouldn't not actually be ideal for this project but using a thin plastic cover around the LED capillaries would work
- In one of there other ideas, they used white 3D printed materials over the LEDs
  - This would be great for our project as it could give us a lot of options as to how we want the design to look
  - The only worry is that it may diffuse too much and color change or brightness shade would be less noticeable
- Crinoline tubing was also used in one
  - This may not be ideal as it is form fitting to the LED strip and the LED strip would still be seen through the design and won't have as clean as a look
- Laser-Cute Acrylics
  - This is similar to what I did in my lab that allowed the light to diffuse through and also provide some "holes" for the light to flow out of
  - This is a more complicated idea, but could also give us some more ideas for the design
  - Would only allow for a 2D like object as laser cutting won't allow 3D prints
- Glass
  - Our client mentioned using glass
  - This would be a lot harder as we would need outside help to do this
  - It would also increase the overall weight of our design but it gives it a nice clean finish

Conclusions/action items:

Using these ideas, it would probably be best to combine a few ideas or test a few of them out before making a decision on what would work best for our design. Using some form of plastic that we can design/shape ourselves would most likely be preferred as it will give us a design with the look we intend.

CITATION: Stern, B., 2020. *13 Ideas For Diffusing Leds*. [online] Instructables. [Accessed 30 September 2020].

Water Model Circuit

Brittany Glaeser - Oct 05, 2020, 11:49 AM CDT

Title: Water Model + Closed Circuit Design

Date: 10/1

Content by: Britt

Present: Britt

Goals: To combine the water idea with a full system for a design

Content:

The design seen in Figure 1 is also mentioned in the Competing design portion of my notebook. This model was given to us by the client as an example of what he was looking for. The model given was only a brief overview of what a model could look like using water and dye and an explanation in the book, but we would need to complete the design into a full physical model. To do this, we would need to use a close water circuit to circulate the water through the system to create flow. An idea of this system can be seen in Figure 2. This design would need to include a clean water reservoir to and a water pump to move the water through the system, it will also need a waste reservoir at the end to hold the water mixed with the dye. This will cause the design to become heavy and would require clean up and set up time. The design would have the similar ideas as the author suggested in his book, just with the incorporation of a water pump system.

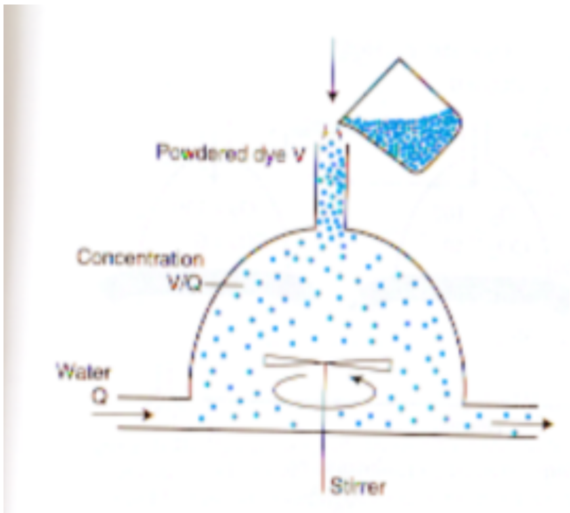


Figure 1: Initial water model from client using water and dye circulation [1]

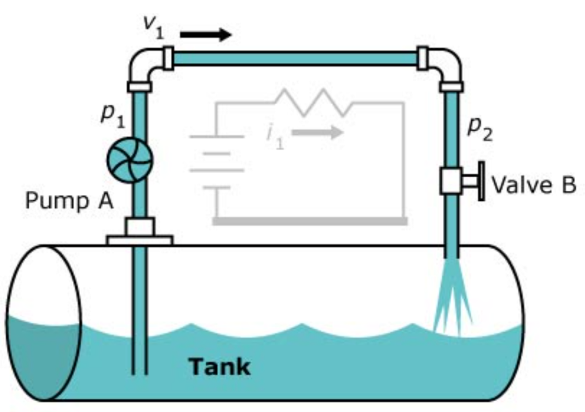


Figure 2: Closed water system [2]

Conclusions/action items:

This design, when added with a water pump system, is a viable design for our design matrix. This would require a lot of fabrication in order to create a water reservoir and pump system, but is doable. The dye for this design would only allow for one color, therefore, the ratios would only be shown by the dye and flow is simply shown by water through the system. If this were to be the design we chose from our design matrix, more research would need to go into specific water pumps for this circuit (there seems to be many viable options, it would just be a matter of picking the right one for our design).

CITATION: [1] *West's Pulmonary Physiology, Tenth Edition, John B. West and Andrew Luks, Wolters Kluwer, 2016, pp 70-71.*

[2] Johnson, H., 2010. Water Analogy. [online] Sigcon.com.

2020/09/09 - Dead Space in Lungs

KAITLIN LACY - Sep 09, 2020, 12:40 PM CDT

Title: Lung Dead Space

Date: 9/9/2020

Content by: Kaitlin Lacy

Goals: Learn more about dead space in the lungs as it was mentioned in the description of our projects with medical students sometimes struggling to understand how high V/Q ratios lead to dead space ventilation.

Content:

-Dead space is the volume of air involved in ventilation that does not directly engage in gas exchange.

Anatomic dead space: air volume in the nose, trachea, and bronchi (conducting zone); 30% of normal tidal volume; approximately 150 mL

Physiologic/total dead space: sum of anatomic and alveolar dead space; volume in respiratory zone not involved in gas exchange (respiratory bronchioles, alveolar duct, alveolar sac, alveoli; negligible in healthy adults

Ventilation: process in which air enters the lungs

Minute ventilation (VE) = tidal volume (VT) * respiratory rate (RR)

Alveolar ventilation (VA) = (VT - physiologic dead space (VD)) * RR

VD = VT*[(PaCO2-PeCO2)/PaCO2

Amount of dead space increases when the alveoli have lost some functioning, decreased cardiac output, hypotension, pulmonary embolism, vasoconstriction

-increased by emphysema, pneumonia, acute respiratory distress syndrome

Conclusions/action items:

Dead space is a critical idea to this model, and these equations may be helpful for modeling ventilation in the lungs.

Work with the client to determine how dead space will be modeled in the device and the importance of it in the model.

S. Intagliata, W. G. Gossman, and A. Rizzo, “Physiology, Lung Dead Space.” 15-May-2019.

2020/09/09 - Ventilation and Perfusion Overview

KAITLIN LACY - Sep 09, 2020, 1:09 PM CDT

Title: Ventilation and Perfusion Overview

Date: 09/09/2020

Content by: Kaitlin Lacy

Goals: Review the concepts of Ventilation and Perfusion in order to have an informed discussion with our client.

Content:

Gas exchange occurs between alveolar air and blood of pulmonary capillaries; alveoli must be ventilated and perfused adequately; in respiratory zone of the lungs (respiratory bronchioles, alveolar ducts, alveolar sacs, alveoli)

-alveoli are opened and closed by alveolar cusps which are smooth muscle projections

-operates through diffusion

-increases as surface area increases, alveolar pressure difference increases, solubility of gas increases, membrane thickness decreases

Alveolar septa separate adjacent alveoli, and these septum have capillaries and thin walls to permit gas exchange

DPPT surfactant lowers the alveolar surface tension

V/Q ratio measures matching of ventilation to perfusion

-varies within regions of the lung (ventilation greater at the base of lung than the apex due to gravity pulling blood down and the eight of the fluid in pleural cavity increases intrapleural pressure to a less negative value)

-high V/Q results in increased PO2 and decreased PCO2 (alveolar air matches the larger volume of air more than perfused blood

Bronchial circulation drains into the pulmonary vein; PaO2 drops slightly from 100 mmHg to 95 mmHg in this vein

Conclusions/action items:

Ventilation varies depending on the part of the lung, so inquire about whether this device needs to mimic a specific area of the lung, the lung as a whole, or just specific V/Q ratios set by the user.

K. A. Powers and A. S. Dhamoon, “Physiology, Pulmonary, Ventilation and Perfusion.” Jan-2020.

2020/09/17 - Teaching Ventilation/Perfusion Relationships

KAITLIN LACY - Sep 18, 2020, 9:56 AM CDT

Title: Teaching Ventilation/Perfusion Relationships in the Lung

Date: 9/17/2020

Content by: Kaitlin Lacy

Goals: Learn more about how medical school professors teach this concept in order to get a better idea of how our model can fit into their teaching.

Content:

-bathtub analogy: level of water represents level of O2 in alveolus (P_{AO2}), ventilation is like water poring into the tub, O2 leaving through blood flow is like water leaving the tub like a drain

-level of Co2 has inverse relationship

-high V/Q ratio will produce increased P_AO2 and decreased alveolar PCO2, low V/Q will decrease PAO2 and increase PCO2

Oxygen consumption = Ventilation(fraction of inspired oxygen*fraction of alveolar O2)

PAO2=inspired PO2 - (VO2/VA)(barometric pressure-47mmHg)

PACO2 low when V/Q is high and vice verse (marker of hypoventilation)

Decrease in the inspired O2 (like high altitude) will lead to hypoxemia unless minute ventilation increases (Fraction of inspired oxygen does not change with altitude) (from decreasing barometric pressure)

-shunt is where V/Q=0 and dead space is where V/Q = infinity

-students must understand gas partial pressures, contents of blood, and shape of hemoglobin dissociation curve

Heterogeneity of V/Q Distributions:

-should not be difference between PO2 in postveolar capillaries and PaO2

-low V/Q regions will cause PO2 to be lower in the capillary arterial blood than average alveolar value

-alveolar to arterial difference = delta(A-aO2), widened with V/Q mismatch

-hypoventilation and low pressure of inspired oxygen have normal difference

-shunt is fourth cause of hypoxemia

-fraction of shunt = $Q_{s/}Q_t$=(Cc_{O2}-Ca_{O2})/(Cc_{O2}-Cv_{O2})

-different than low V/Q as its hypoxemia does not improve with increased P_{IO2} as shunted blood does not come in contact with alveoli

-clinical example of diagnosing a narcotic overdose (normal delta(A-aO2)) versus asthma (widened delta(A-aO2))

Conclusions/action items:

The equations presented in this article will most likely be very useful in designing the model in order to create an accurate representation of V/Q ratios. This is a challenging concept and the reading raised several questions for me. Meeting with the client to ask questions about this article would help to really solidify the idea of V/Q mismatching.

Glenny, R., 2008. Teaching ventilation/perfusion relationships in the lung. *Advances in Physiology Education*, 32(3), pp.192-195.

09/17/2020 - Hemoglobin Dissociation Curve

KAITLIN LACY - Sep 18, 2020, 10:10 AM CDT

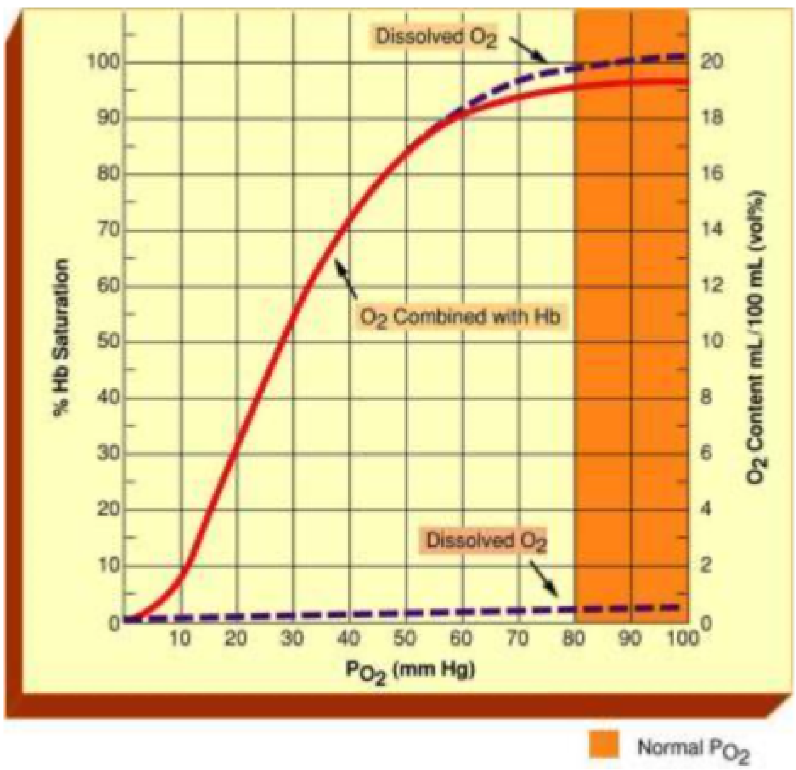
Title: Kaitlin Lacy

Date: 09/17/2020

Content by: Kaitlin Lacy

Goals: Remember the important parts of the hemoglobin dissociation curve as it was referenced in previous articles

Content:



The partial pressure of oxygen can decrease from 100 to 60 mmHg and hemoglobin will remain about 90% saturated with oxygen. However, decreasing below 60 mmHg causes a rapid decrease in amount of O2 bound to hemoglobin. Physiologically this is important to allow proper oxygenation of the tissues. Once the blood reaches areas with lower partial pressures of oxygen, this indicates an area in need of oxygen, and the hemoglobin lets go of the oxygen rather easily.

Conclusions/action items:

Knowing some of the values from the figure above will be useful in creating an accurate representation of the transfer of oxygen from the alveoli to the blood.

Oxygen Dissociation Curve, 2010. [Online]. Available: https://media.lanecc.edu/users/driscolln/RT127/Softchalk/Oxygen_transport_softchalk/Oxygen_Transport_Lesson4.html. [Accessed: 17-Sep-2020].

2020/09/18 - Beads and Water Pump

KAITLIN LACY - Sep 18, 2020, 9:51 AM CDT

Title: Bead Idea

Date: 9/18/2020

Content by: Kaitlin Lacy

Goals: Brainstorm new ideas for representing V/Q mismatch

Content:

Originally, our client shared West's proposed model for representing V/Q mismatch which utilized dye and water. The color of the water leaving the lung would show the oxygenation of the blood. However, he thought the dye and water would be too messy and require too much effort on the part of the lecturer to set up and reset in between showing the different magnitudes of mismatch. One way to resolve some of these problems would be to use colored beads instead of dye. If there was some way to cycle the beads and water back through to be reused, there would be no need for reservoirs to collect the water and would eliminate some of the mess. Some other material other than beads could be used as well. I'm thinking of something like a lava lamp where the color remains separate from the water (as opposed to dye) and does not need to be reloaded like water and dye would. If there would be some way to utilize that process, the idea of using water (or another liquid) would not need to be abandoned like the dye idea.

Conclusions/action items:

Since our client already has thought of several reasons for abandoning the water/dye model since he proposed the device, it would need to be modified in order to be viable. Cycling the water repeatedly through the model and using beads could be a way to prevent issues related to reloading and mess that the pump model had. Discuss this model with the group at the next meeting when we discuss ideas for design matrix.

2020/09/30 - Updated Beads Design

KAITLIN LACY - Oct 07, 2020, 12:27 PM CDT

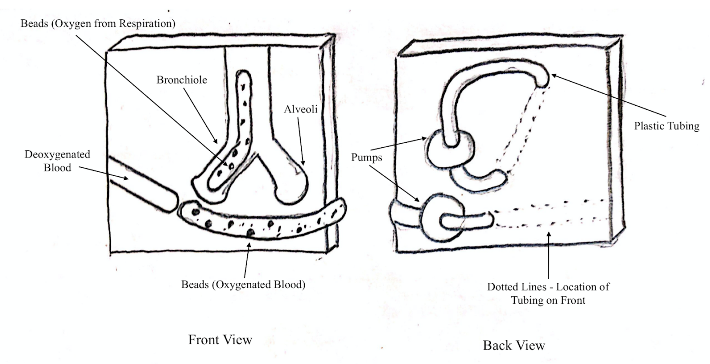
Title: Updated Beads Design

Date: 9/30/2020

Content by: Kaitlin Lacy

Goals: Fill in the details about how exactly the beads design will work and come up with a sketch of the design.

Content:



Water pumps are used to simulate the flow of air and blood while circulating beads show the oxygenation of the blood and the flow of air in the lungs. The circulation of these beads can be controlled through pinching the tubes at the back of the device. However, this would require more effort on the part of the user, and would not be as ideal as some of the other designs. This device could be designed to be more interactive where the ventilation and perfusion rates are adjusted and the V/Q ratio is displayed somehow.

Conclusions/action items:

Discuss this design in the preliminary presentation, and adjust the design as necessary. Discuss with team to decide whether or not this device could be made more user friendly.

2020/09/10 - Ventilation/Perfusion

ZOE SCHMANSKI - Oct 06, 2020, 7:56 PM CDT

Title: Ventilation/Perfusion Ratio Matching

Date: 9/10/2020

Content by: Zoe

Present: n/a

Goals: Further my understanding of V/Q ratios and what happens when they vary

Content:

V - Ventilation, air we breath in

- oxygen goes into the alveoli
    - small sacs at the end of the bronchioles (smallest air tubes)
- carbon dioxide exits

Q - perfusion, blood flow

- deoxygenated blood from your heart goes to the pulmonary capillaries (tiny blood vessels)
- oxygen is absorbed
    - through the alveoli
- carbon dioxide exits your blood
    - through the alveoli

<u>V/Q ratio</u>

- amount of air that reaches your alveoli divided by the amount of blood flow in the capillaries in your lungs
- 4 liters of air
- 5 liters of blood
- Anything other than a 1:1 ratio is a mismatch

Normal --> 1:1 ratio

<u>Measuring V/Q</u>

- using test called pulmonary ventilation/perfusion scan
- involves a series of two scans
    1. measure how air flows through the lungs
    2. show where blood is flowing in your lungs
- involves an injection of radioactive substance that gathers in areas of abnormal airflow and blood flow
    - images taken in scanner to show these areas

<u>Notation</u>

$\dot{V}A/\dot{Q}$ with the “A’ as a subscript.

V dot is measured in liter per minute and Q dot in liters per minute.

The “A” signifies alveolar.

So Vdot subscript A is alveolar ventilation in L/min. Obviously one could use mL/sec the point is that both are flows.

<u>Treatment</u>

- oxygen therapy
- oral steroids
- antibiotics
- pulmonary rehabilitation
- blood thinners
- surgery

Conclusions/action items:

Consider when developing designs for the teaching model.

https://www.healthline.com/health/v-q-mismatch#what-it-means

2020/09/10 - V/Q Mismatching

ZOE SCHMANSKI - Oct 06, 2020, 7:56 PM CDT

Title: V/Q ratio mismatching

Date: 09/10/2020

Content by: Zoe

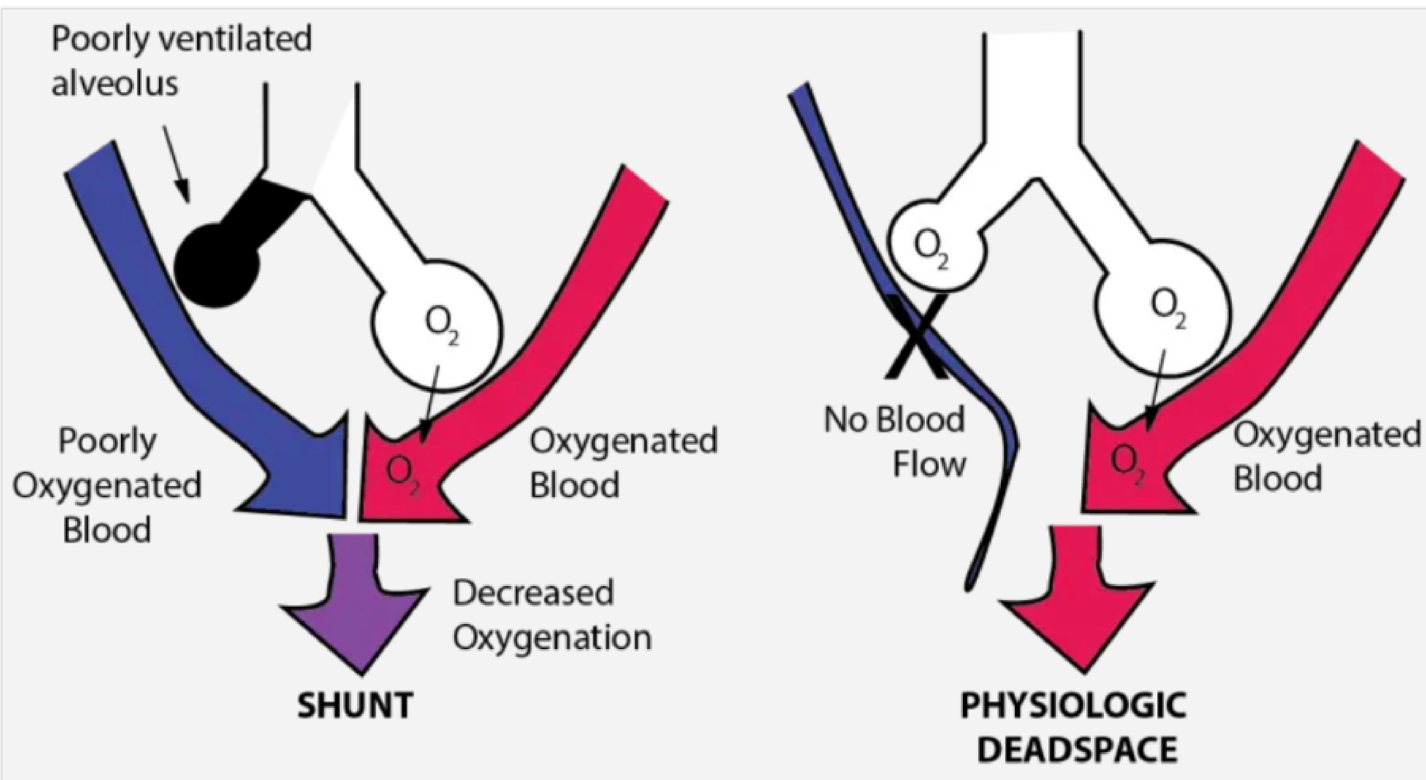
Present: n/a

Goals: Understand the outcomes of different V/Q ratio mismatches

Content:

Any V/Q ratio that differs from 1:1 is a mismatch

1. High V/Q ratio (> 1)
    - low blood oxygen level
    - dead space ventilation
        - ventilation of poorly infused alveoli
        - alveoli are ventilated, but not perfused
    - hyperventilation
    - blood clot, no gas exchange taking place into blood
        - pulmonary embolism
2. Low V/Q ratio (<1)
    - decreased oxygenation of blood
        - due to poorly ventilation alveoli
    - blood doesn't pick up enough oxygen
    - this poorly oxygenated blood mixes with other blood at the heart and lowers the blood oxygen level
        - causes hypoxemia
    - Shunting
        - perfusion of poorly ventilated alveoli
        - alveoli are perfused, but not ventilated



V/Q Mismatch Causes

- Chromic Obstructive Pulmonary Disease (COPD)
    - obstructs airflow in your lungs

  - emphysema
  - chronic bronchitis
- Asthma
- Pneumonia
  - lung infection
- Pulmonary edema
  - lung congestion
- pulmonary embolism
  - blood clot in lungs

Conclusions/action items:

Consider when developing designs for the teaching model.

https://airwayjedi.com/2017/01/06/ventilation-perfusion-mismatch/

2020/09/12 - Teaching Ventilation/Perfusion Relationships

ZOE SCHMANSKI - Oct 06, 2020, 7:57 PM CD

Title: Teaching Ventilation/Perfusion in the Lungs

Date: 9/12/2020

Content by: Zoe

Present: n/a

Goals: Published work sent to us by Dr. Green used for teaching topic in medical school to better understand ventilation/perfusion

Content:

Concept

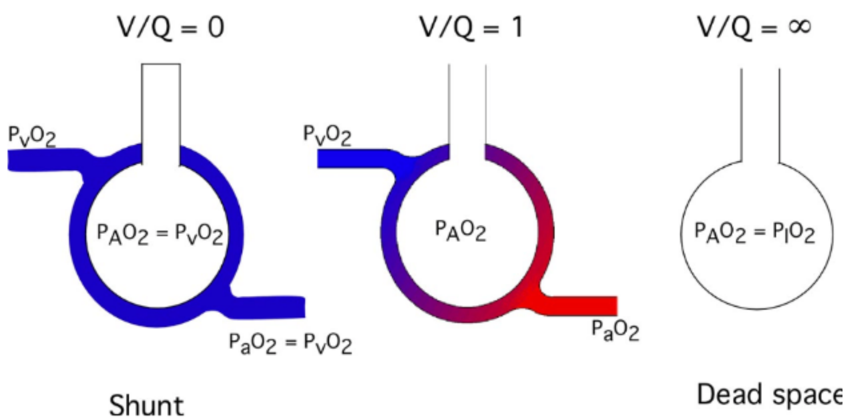
- one of the hardest topics for medical students to understand
- key building blocks for understanding pathophysiology in the lung
- hypoventilation - low V/Q
    - increased PaCO2
    - decreased PaO2
- hyperventilation - high V/Q
    - increased PaO2
    - decreased PaCO2
- lung is more complicated than the simplified model of the alveolus to blood exchange
    - asymmetries in the airway
    - vascular geometries
    - differences in ventilation perfusion between the top and bottom of the lung

hypoxemia - PaO2 less than normal for subject's age, 5 causes

1. Low PiO2 if not enough compensatory ventilation
2. Decrease in Va (hypoventilation)

** V/Q mismatches contribute to gas exchange inefficiencies, but only low V/Q ratios cause hypoxemia

Fig. 5. Three different lung regions with ventilation-to-perfusion ratios (V/Q ratios) of 0 (*left*), 1 (*middle*), and ∞ (*right*). The expected Po_2s are shown for each region. Pv_{O_2}, venous Po_2.



Equations

PaO2 - alveolar O2

PiO2 - inspired oxygen

Pb - barametric pressure

Va - ventilation

Notation

V̇A/Q̇ with the “A' as a subscript.

V dot is measured in liter per minute and Q dot in liters per minute.

The “A” signifies alveolar.

So Vdot subscript A is alveolar ventilation in L/min. Obviously one could use mL/sec. the point is that both are flows.

Teaching keys

1. build from simple to complex
2. use simplified analogies to allow students to visualize the relationship between regional ventilation and perfusion
3. integrate the concepts of alveolar-arterial O2 differences

4. use mechanisms of hypoxemia as a consistent thread to hold lecture together
5. use clinical examples to solidify topic

Conclusions/action items:

Consider when developing designs for the teaching model.

Robb W. Glenny

Departments of Medicine and of Physiology and Biophysics, University of Washington, Seattle, Washington

Submitted 27 May 2008; accepted in final form 9 July 2008

ZOE SCHMANSKI - Sep 12, 2020, 3:34 PM CDT

Refresher Course

Teaching ventilation/perfusion relationships in the lung

Robb W. Glenny

Teaching_VQ_Glenny.pdf(426.2 KB) - download

2020/09/10 - John West Pedagogic Model

ZOE SCHMANSKI - Sep 10, 2020, 11:02 AM CDT

Title: Pedagogic Model by John West

Date: 09/10/2020

Content by: Zoe

Present: n/a

Goals: Learn about the teaching model created by John West published the the textbook *Respiratory Physiology*

Content:

Dye is used to represent the oxygen levels in the alveoli and blood during exchange

Dye is added at the rate of oxygenation to show concentration in water

The concentration of the dye in water(blood) is the V/Q ratio

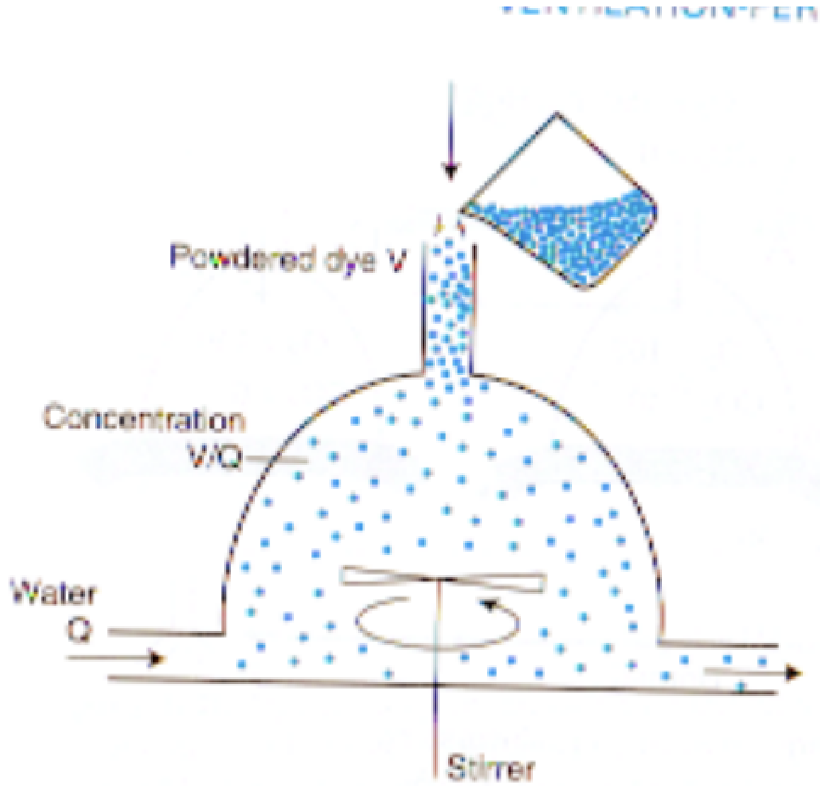


Figure 5.6. Model to illustrate how the ventilation-perfusion ratio determines the P_{O_2} in a lung unit. Powdered dye is added by ventilation at the rate V and removed by blood flow Q to represent the factors controlling alveolar P_{O_2}. The concentration of dye is given by V/Q.

Conclusions/action items:

West, John. Respiratory Physiology: The Essentials. 9th Edition. 2012

2020/09/24 - Design 1 with LEDs

ZOE SCHMANSKI - Oct 06, 2020, 7:57 PM CDT

Title: Design 1: V/Q model with LEDs

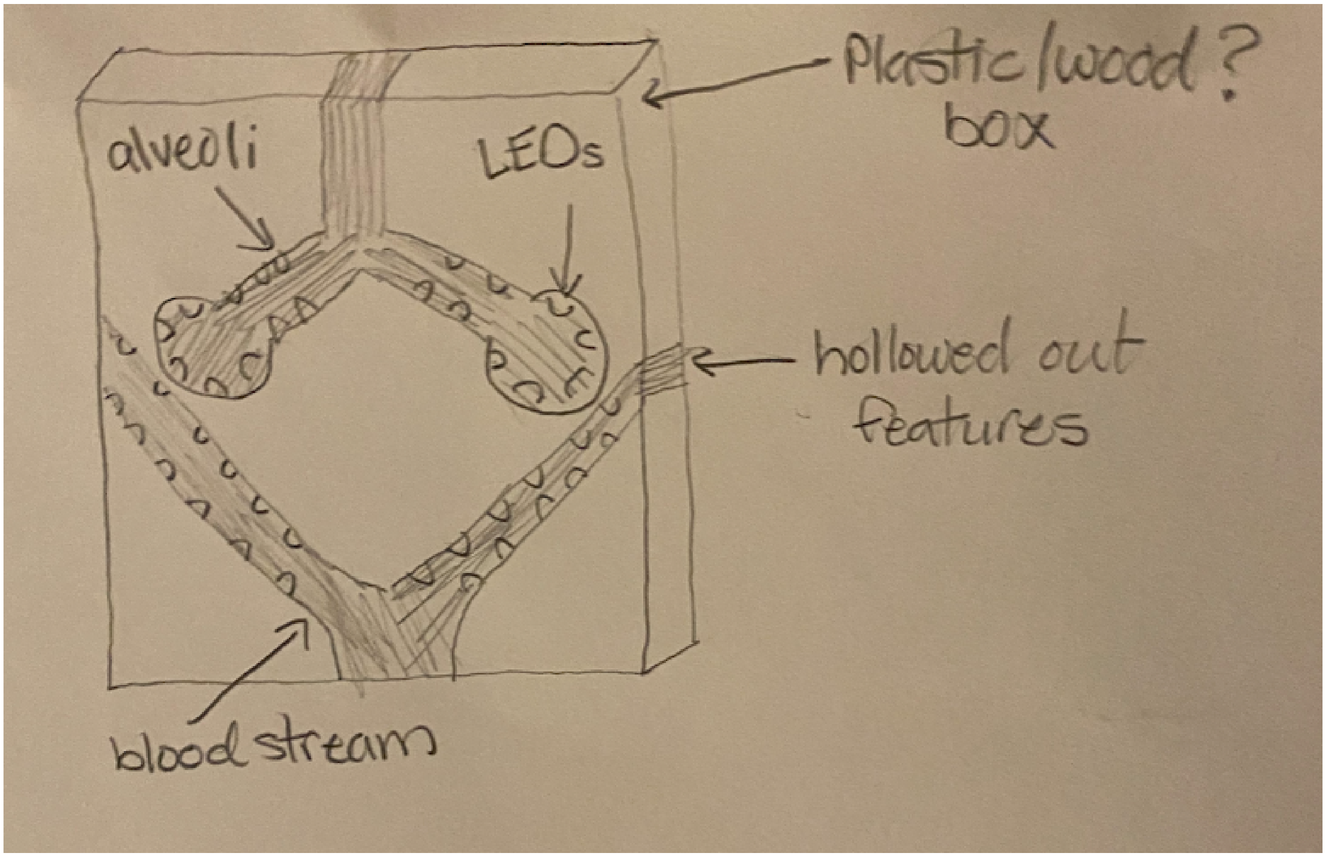
Date: 9/24/2020

Content by: Zoe

Present: n/a

Goals: Provide sketches of initial design idea

Content:



Conclusions/action items:

Bring to team meeting as an initial design idea.

2020/10/04 - Light Diffusing Plastics

ZOE SCHMANSKI - Oct 04, 2020, 7:30 PM CDT

Title: Light Diffusing Plastics

Date: 10/4/2020

Content by: Zoe

Present: n/a

Goals: Research on possible plastics to use for the base model

Content:

LEDs can be difficult because they create "hot spots" of focused light that distract from the visual appeal

Solutions

- special grades of acrylic sheet, polycarbonate sheet and polycarbonate film engineered to diffuse hot spots of light

Acrylic

- superior optical properties
- highest light transmission

Polycarbonate

- tougher/ more durable material
- high temperature resistance
- can be cold formed

Conclusions/action items:

We can use these ideas for possible materials for the base model.

https://www.curbellplastics.com/Research-Solutions/Industry-Solutions/Markets/Lighting#:~:text=Which%20plastics%20are%20the%20best,excellent%20LED%20light%20diffusing%20characteristics.

2020/10/06 - Types of LED Diffusers

ZOE SCHMANSKI - Oct 06, 2020, 7:54 PM CDT

Title: Different Types of LED Diffusers

Date: 10/06/2020

Content by: Zoe

Present: n/a

Goals: Document different types of LED diffusers for possible use in the model

Content:

Solutions

- UV stabilized polycarbonate **diffusers**.
- Tempered glass **diffusers**.
- PMMA optical **diffusers**.
- 3D three-sided **diffusers**.
- Anti-glare **diffusers**.
- Transparent **diffusers** (DT)
- Opaque **diffusers** (DO)
- Satin **diffusers** (DS)

Purpose of Using Diffusers

- Eliminates invisible hot spots
- Very good light-scattering
- Applicable in very flat, homogeneously illuminated light elements
- Diffusion breaks straight beams of light from the source, scattering them in different directions and producing a glow, rather than a sharp beam, which is soothing to the eyes.
- Diffusers mimic the soft natural light from the sun (diffused naturally by clouds and the atmosphere), eliminate harsh shadows, offer larger expanses of continuous illumination, and improve aesthetics and occupant comfort.

Applications for LED Diffusers

- Lenses
- Buttons
- Switches
- Knobs
- LED backlit signage
- Channel lettering
- Architectural accent lighting
- LED light bulb lenses

Good website: https://www.electronicsb2b.com/important-sectors/leds-led-lighting/led-diffusers-look/

Conclusions/action items:

Consider these options when deciding what LEDs and diffusers to order for the model.

2020/09/09- Ventilation/Perfusion Mismatch

JENNA EIZADI (eizadi@wisc.edu) - Sep 16, 2020, 12:27 PM CDT

Title: Research on Ventilation/Perfusion (V/Q) Mismatching

Date: 2020/09/03

Content by: Jenna

Present: Jenna

Goals: To accumulate background knowledge on the problem know as ventilation/perfusion mismatching in the lungs and understand the challenges behind teaching this concept.

Content:

VQ Mismatch Video Notes [1]

- ventilation: the exchange of air between the lungs and atmosphere so that oxygen can be exchanged for carbon dioxide in the alveoli
- perfusion: the passage of blood, a blood substitute, or other fluid through the blood vessels or other natural channels in an organ or tissue
- hypoxemia: below-normal level of oxygen in the blood
- blood that passes through the lungs via the pulmonary artery is oxygenated and the saturation of oxygen is related to the V/Q ratio or the amount of exchange for the quantity of blood in one system (alveoli and artery)
- one problem is that it is hard to distinguish the cause of ventilation/perfusion mismatching
    - asthma, COPD, pulmonary hypertension, pulmonary embolism, pneumonia, ILDs, cystic fibrosis...
    - the most common cause of hypoxemia
- V/Q ratio in one alveoli or portion of the pulmonary artery affects the whole system because either blood flow will be redirected to other parts of the lungs changing the V/Q ratios in these areas or the cumulative effect of a decreased/increased V/Q ratio will be seen in the blood re-entering the circulatory system via the pulmonary vein

V/Q Perfusion Ratio [2]

- V/Q ratio is the ratio between the amount of air getting to the alveoli (ml/min) and the amount of blood being sent to the lungs (ml/min)
    - high V/Q means either increasing ventilation or decreasing blood flow
    - low V/Q means either decreasing ventilation or increasing blood flow
- changing V/Q rate physiologically
    - the V/Q ratio in the lungs changes as you move from the apex to the base due to changing blood flow from the effect of gravity (more blood accumulates in the base because gravity pulls it downwards)
    - highest V/Q ratio at the apex because good ventilation but poor blood flow and vice versa for the base
    - when you stand up, V/Q mismatch occurs because more blood flows to the base of the lungs

Conclusions/action items:

Ventilation/Perfusion mismatching occurs

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

[2] https://courses.kcumb.edu/physio/adaptations/vq.htm

2020/09/16 - Teaching VQ Relationships in the lungs

JENNA EIZADI (eizadi@wisc.edu) - Oct 07, 2020, 11:31 AM CDT

Title: Teaching V/Q Relationships in the Lungs

Date: 2020/09/16

Content by: Jenna

Present:

Goals: Paper sent to us by the client, Dr. Green on teaching the ventilation/perfusion relationship in the lungs.

Content:

- Ventilation and perfusion matching form the basic foundation for lung function
- Suggestions for a teaching model
  - want to build from simple to complex
  - use simple analogies for visualization
  - integrate the concept of alveolar-arterial O_2 differences
  - use hypoxemia as a consistent example
  - use clinical examples to solidify concepts
- Simple: lung is one large unit where gas exchange occurs, bathtub analogy
  - relationship between ventilation and perfusion determines the level of O_2 or CO_2 in the alveolar space
- Bathtub: level of water in the bathtub is the level of O_2 in the alveolus, ventilation bringing air with O_2 into the alveolus is pouring water into the tub and O_2 leaving into the blood is the drain
  - if the amount of water coming into the tub is greater than that leaving the drain, the water level (PAO_2) rises
  - high V/Q ratio in the above example

Conclusions/action items:

Identify the key concepts of V/Q that we need to model and consider most probably an LED approach to demonstrating these teaching models in physical form.

JENNA EIZADI (eizadi@wisc.edu) - Oct 07, 2020, 12:34 PM CDT

Teaching_VQ_Glenny.pdf(426.2 KB) - download

2020/09/16 - Cardiovascular Computer Model for Undergraduate Teaching

JENNA EIZADI (eizadi@wisc.edu) - Sep 16, 2020, 11:04 AM CDT

Title: A computer model for the cardiovascular system: development of an e-learning tool for teaching of medical students

Date: 2020/09/16

Content by: Jenna

Present:

Goals: To gain insight into the types of teaching models already existing.

Content:

- Incorporated a Lumped Parameter Model (LPM) into an e-learning environment to create a tool to help students, undergraduate medical students, in particular, understand cardiovascular physiology, map disease progression, and classify the severity of a disease [1]

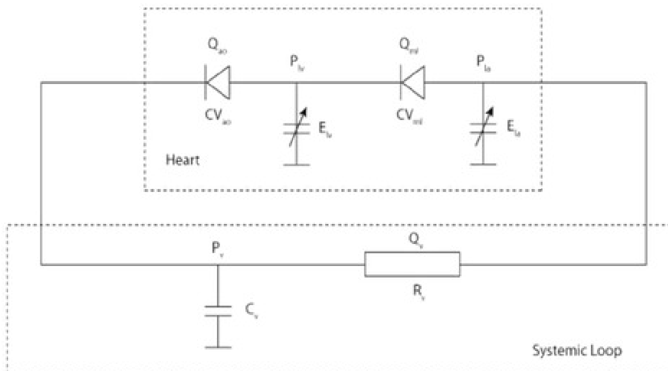


Figure 1. Lumped parameter model of the left heart as an electrical analog.

- Components modeled in circuitry above as related to cardiovascular physiology [1]
    - capacitor (C): elastic property of the large arteries (total arterial compliance)
    - resistor (R): frictional loss in the smaller vessels (systemic vascular resistance)
    - variable capacitors: pumping chambers (Ela=left atrium, Elv=left ventricle)
    - diodes: valves (CVao=aortic valve, CVmi=mitral valve)
- Can create more advanced LPM models to mimic various other complexities including coronary circulation to facilitate clinical diagnosis [2]
- Normal, hypertension, heart failure, and hemorrhage pathological processes were modeled with various severities [1]

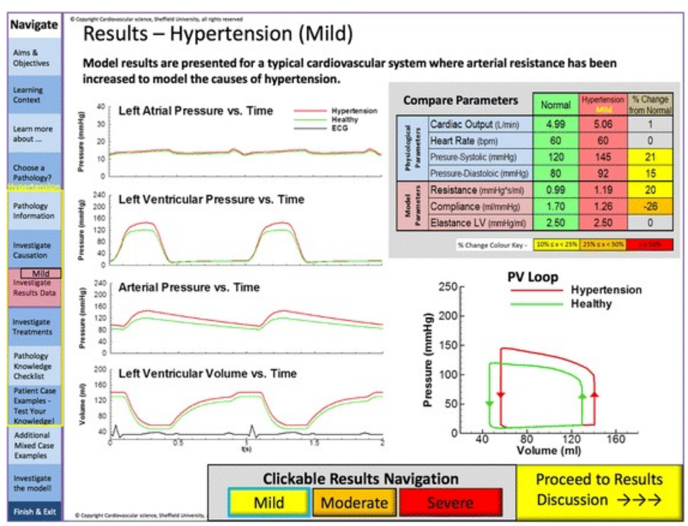


Figure 2. Screenshot from the lumped parameter results in mild hypertension.

- E-learning environment allows students to repeatedly go through simulations to become familiar with different pathologies and introduces opportunities to include relevant information for each including posing questions for a more interactive learning experience

[1]

- Found from a study completed within the paper that improvement was found in student's knowledge and understanding after e-learning environment exposure [1]
- As related to V/P Mismatching
  - Create an e-learning model to add on lung visual to a model of the heart as well
  - Could easily identify concentrations of oxygen and V/P ratios with different colors
  - Allow for easy incorporation of many different pathologies and clinical cases
  - Downside is that it is all online and would be better suited to individual learning

Conclusions/action items:

The model created in this paper is more readily focused on coronary diseases as compared to our goal of modeling the cardiovascular topic of V/P mismatch, however it demonstrates that ability to create an e-learning environment with certain characteristics that allow students to interact with various pathologies. We might want to consider a similar e-learning environment as a possible design idea as it would be easy to incorporate into a classroom and would allow for not only an integration of various diseases, but clear modeling of the concentration gradients in the extremities as a result. The difficulty we would encounter is needing to have a strong computer programming background to create such a platform.

[1] Warriner Dr, Bayley M, Shi Y, Lawford PV, Narracott A, Fenner J (2017) Computer model for the cardiovascular system: development of an e-learning tool for teaching of medical students. BMC Med Educ 17: 017-1058.

[2] Duanmu Z, Yin M, Fan X, Yang X, Luo X. A patient-specific lumped-parameter model of coronary circulation. *Sci Rep*. 2018;8(1):874. Published 2018 Jan 17. doi:10.1038/s41598-018-19164-w.

2020/09/16 - The Application of Complex Research Simulation Models in Education

JENNA EIZADI (eizadi@wisc.edu) - Sep 16, 2020, 12:14 PM CDT

Title: The Application of Complex Research Simulation Models in Education; a Generic Approach

Date: 2020/09/16

Content by: Jenna

Present:

Goals: Research into the category of research simulation model designs as it pertains to education.

Content:

- Circ-Adapt is a computational model of the heart and circulation that is used to investigate clinical aspects [1]
  - a schematic overview which we should strive to mimic in our own diagram
  - transferred to an educational application
- Circ-Adapt incorporates mechanical and hemodynamic interactions [1]
- parameters can be apated to obtain needed physiological behavior of heart and vessel walls [1]
  - volume can also be adapted
- Circ-Adapt is written in C++ and developed in Matlab [1]
- Can simulate a number of different cardiac diseases and produce pressure and volume graphs for different parts of the heart [1]

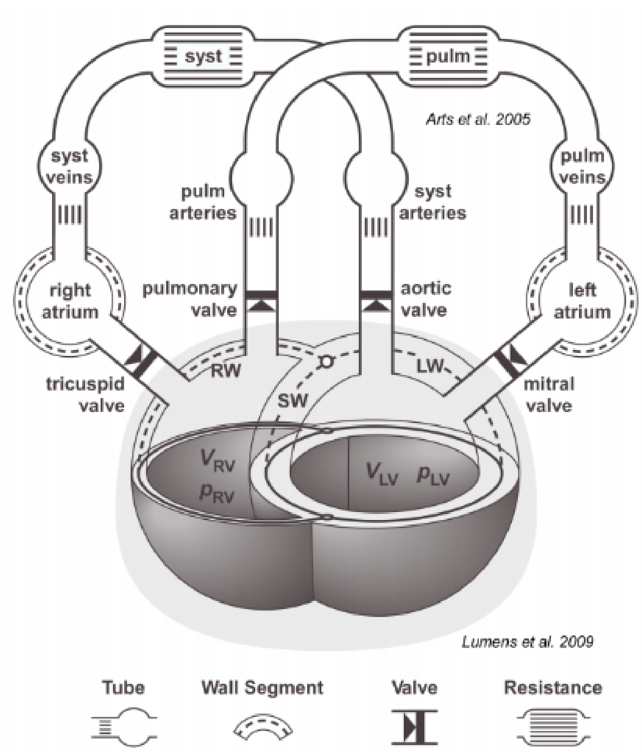


Figure 1. Schematic overview of the CircAdapt model [1].

- How this pertains to our model
  - Would be a good idea to include a schematic overview of the design similar to the one in Figure 1
    - Could include the alveoli and capillary bed as the major structures but also identify the other parts of the system
  - I like the set-up of having each part of the cardiovascular system identified but focusing in on the most relevant parts
  - Another example of an e-learning type tool that has been developed for teaching

Conclusions/action items:

The CircApapt model is yet another example of an e-learning tool that has been developed to facilitate the teaching of cardiovascular pathologies in a more interactive manner. Again, it would be difficult to develop a tool such as this one with limited computer programming knowledge, but seeing as this is built in Matlab and written in C++, the idea is more promising. We should consider adding an e-learning design idea to our matrix.

[1] W.Dassen *et al.,* "The application of complex research simulation models in education; A generic approach," *2011 Computing in Cardiology*, Hangzhou, pp.465-468.

2020/09/10 - Liquid Flow and Dye Model

JENNA EIZADI (eizadi@wisc.edu) - Sep 16, 2020, 10:13 AM CDT

Title: Liquid Flow and Dye Concentration Model for V/P Mismatching

Date: 2020/09/10

Content by: Jenna

Present:

Goals: To identify one potential design idea that was introduced by the client, Dr. Christopher Green.

Content:

- The model illustrates how the ventilation-perfusion (V/P) ratio determines the partial pressure of oxygen gas in a lung unit [1]
- The powdered dye is continuously added at a rate V to mimic the addition of O2 by alveolar ventilation and removed by water pumped through the unit to simulate the blood flow Q that removes the O2 [1]
    - The concentration of the dye is given by V/Q
- Represents the factors controlling alveolar PO2 [1]

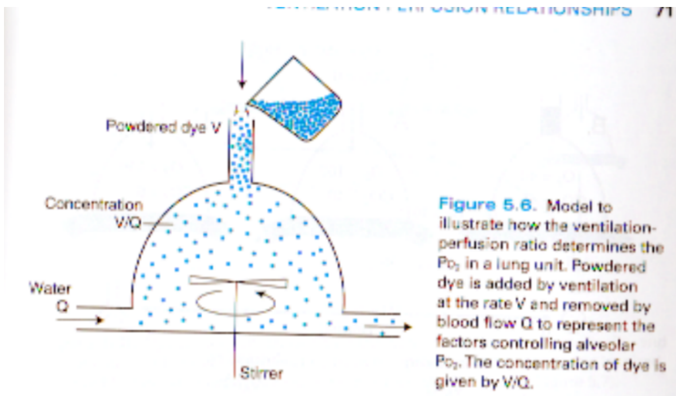


Figure 1. Model to illustrate how the V/P ratio determines the partial pressure of oxygen in a lung unit.

- Components of the model as shown in Figure 1
    - Powdered dye: represents addition of O2 by ventilation at a rate V
    - Water: blood flow, removes O2 at a rate Q
    - Stirrer: mixes the contents of the lung unit, mimics gas diffusion
    - Lung unit: casing for the rest of the components, would need to be clear as to see the dye and water mixture
- Other critical components not shown in Figure 1
    - Pumping and filtration system for recycling and filtering water mixed with dye
    - Waste bin if water is to not be reused
    - Housing for water and dye
    - Electronics to run pumps and stirrer
    - Tubing

Conclusions/action items:

While this model would be visual and easy to understand, the mechanics behind the model are not trivial. Not only would it be difficult to run such a model multiple times in a session without having to refill a water resouvoir, it would be challenging to store and manipulate. I think our team should consider other possible designs before returning to this one in particular.

[1] West's Pulmonary Physiology, Tenth Edition, John B. West and Andrew Luks, Wolters Kluwer, 2016, pp 70-71. I

2020/09/21 - Online E-learning model

JENNA EIZADI (eizadi@wisc.edu) - Sep 24, 2020, 10:50 PM CDT

Title: Online E-Learning Model

Date: 2020/09/21

Content by: Jenna

Present:

Goals: Brainstorm design ideas for the V/P mismatching teaching model.

Content:

One idea for the V/P mismatch teaching model is an online e-learning model similar to those used for teaching cardiac diseases from my research on competing designs. In this way, we would be able to model the correct anatomy and individualize learning by having each student have access to the model from their laptop. We would need to develop a web or computer application capable of being programmed with a few, or unlimited, settings of ratios for ventilation and perfusion. From these ratios, we could identify the different pathologies they correspond to as well as posing questions and providing more insight into the diagnosis, prognosis, and treatment of the different clinical situations. In the Cardiovascular Computer Model previously mentioned in Competing Designs, the designers of the model created different clinical cases in which students were then able to identify the corresponding pathologies.

Conclusions/action items:

Being that many of us have little computer programming experience, this would be a very difficult project to realize and most likely not the best option at this moment. Also, it seemed that the client would like to have a physical model representing the V/P mismatching problem so that it can be used during class time and projected to the lecture. As an action item, we should propose an e-learning model to the client to make sure that this is not the best option for his purposes before moving on to physical models.

2020/09/23 - Combination Model of LED and Fluid

JENNA EIZADI (eizadi@wisc.edu) - Sep 25, 2020, 1:39 PM CDT

Title: Combination Model with both LEDs and Fluidics

Date: 2020/09/23

Content by: Jenna

Present:

Goals: Brainstorm a design for the V/P mismatch teaching model to propose to the client.

Content:

A combination model adapted both from our own design idea of an electronic LED model and the liquid flow model from the paper received from our client. This design would encompass principles of both being that the "dye" that is contained in the liquid flow model would instead be varying colors and brightnesses of LEDs. The main issue our client had with the liquid flow model was that it would be messy and difficult to clean up, store, and reset, due to the dye that would need to be filtered out. My idea for this combination design model is to expand on that point and create a system that is easily reset but also can be modeled with a fluid that potentially can amplify the LEDs and portray different settings of V/P mismatch ratios. The main difficulties we would run into in this model would be identifying a fluid that serves as an amplifier for light and creating a system that utilizes liquid in a simple way so that the resetting of the model and storage is not difficult.

Conclusions/action items:

We should present our ideas to the client during the next meeting, 9/25, and get his opinion and preferences. Then, we will need to create a design matrix and decide on a singular preliminary design that we will want to pursue.

2020/10/05 - Proposed Designs for Design Matrix

JENNA EIZADI (eizadi@wisc.edu) - Oct 07, 2020, 12:08 PM CDT

Title: Proposed Preliminary Designs for Flow Mechanism

Date: 2020/10/05

Content by:

Present:

Goals: To outline the three preliminary designs considered for the flow mechanism.

Content:

1. LED Flow Model

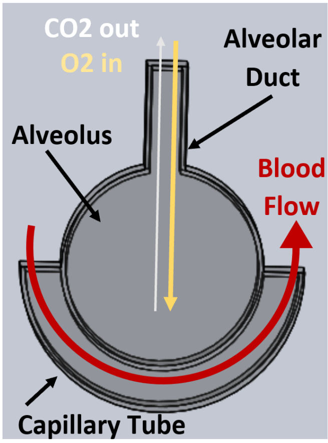
- alveolar duct leading into a single alveolus surrounded by a capillary tube
- LED lining both the capillary tube and alveolar duct to represent blood flow and gas flow
- the color change could also indicate oxygenation of the bloodstream and gas exchange
- 

Figure 1. LED flow model with arrows representing the flow of substances through the tubing.

2. Bead Flow Model

- consists of a tube representing a bronchiole connected to two alveoli surrounded by a single capillary tube
- model flow using beads in water and pumps controlling the amount of water and beads in the system
- number of beads=the amount of ventilation and the ratio of beads to water=amount of perfusion
- regulate the release of beads using a flexible tube with modifiable diameter to model different ratios of V/P

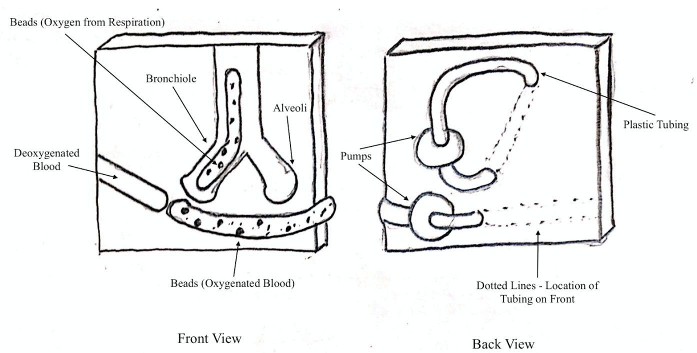


Figure 2. Bead flow model with black dots representing beads as well as tubing through the front and back of the design. Pumps also included on the back view moving water through the system.

3. Water Flow Model

- based on John West's model in the textbook entitled *Respiratory Physiology* detailed in the competing designs section of lab archives
- the model includes a closed water system and a water pump

- dye would then be inserted into the alveolar portion and flow into the capillary tubing with the amount of dye added representing different ratios of V/P
- could become messy depending on the type of design pursued

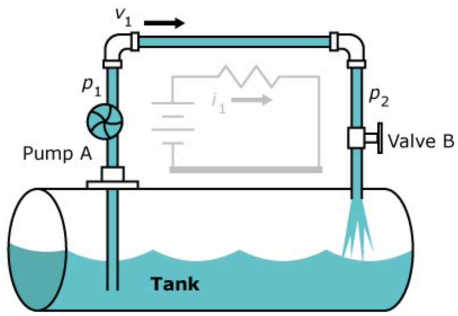


Figure 3. Closed water tank system showing a pumping mechanism as well as a storage tank.

Conclusions/action items:

We will need to create criteria and evaluate each of these proposed designs using a design matrix to decide upon a final design.

2020/10/05 - Design Matrix for Flow Mechanism

JENNA EIZADI (eizadi@wisc.edu) - Oct 07, 2020, 11:53 AM CDT

Title: Design Matrix for Flow Mechanism

Date: 2020/10/05

Content by:

Present:

Goals: To determine a final proposed design for the flow mechanism.

Content:

Table 1. *The design matrix with categories on the left, their weights in parentheses, and each design labeled on the first row. The dark green cells represent the designs that won each category as well as the design that won overall.*

Designs / **Categories**	LEDS 		BEADS 		DYE 	
Effectiveness (35) (Competency)	5/5	**35**	3/5	**21**	2/5	**14**
Ease of Use (30)	5/5	**30**	4/5	**24**	1/5	**6**
Ease of Fabrication (15)	4/5	**12**	3/5	**9**	2/5	**6**
Viability (10)	4/5	**8**	4/5	**8**	2/5	**4**
Safety (5)	3/5	**3**	4/5	**4**	4/5	**4**
Cost (5)	4/5	**4**	3/5	**3**	2/5	**2**
Total (100)	92		69		36	

- Effectiveness: accuracy of the device to portray V/Q mismatching and how well the device would appear in front of a lecture full of students
- Ease of Use: how intuitive the device would be to operate for someone without a technical background, also easiness of setup and storage of the device
- Ease of Fabrication: the ability of the team to produce the model
- Viability: the ability of the device to last for a long period of time with no decrease in performance
- Safety: electrical and other outstanding hazardous concerns
- Cost: cost of fabrication and reset of the device

Conclusions/action items:

The LEDs design won the flow mechanism design matrix because of its effectiveness in teaching the V/Q mismatching concept in addition to being easy to use and fabricate. This model also is cost-effective and will be able to be used for many years without decreases in performance. The next step for the team is to create proposed designs for LED modeling.

2020/10/05 - Proposed Designs for LED Mechanism Design Matrix

JENNA EIZADI (eizadi@wisc.edu) - Oct 07, 2020, 11:59 AM CDT

Title: Proposed Preliminary Designs for LED Mechanism

Date: 2020/10/05

Content by:

Present:

Goals: To outline the three preliminary designs considered for the LED mechanism.

Content:

1. Original LED Model

- LED Flow model lined with singular LEDs of different colors
- each individual LED linked together into a system and some component altering the colors of the system
- no gradient of colors possible, or difficult to implement

Figure 1. Individual LEDs lining LED Flow Model.

2. Diffused LED Model

- LED strip lining the LED Flow model
- strip would allow for each color gradient to be achieved and also allows for different colors to be demonstrated on the same strip
- can model a large variety of different V/Q ratios
- diffused tubing would increase the light diffraction and intensify the colors of the LEDs

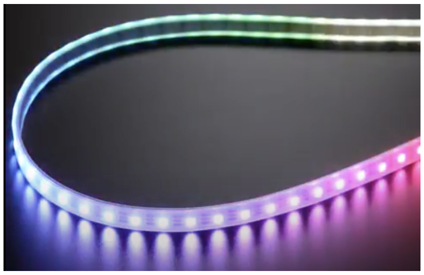


Figure 2. LED strip in diffused tubing with different color gradients.

3. Water-Submerged LED Model

- LED strip lining the LED Flow model but also submerged in water
- attempts to increase the light intensity with light diffraction in water
- the drawback is the difficulty in creating a model with water incorporated with electronic components
- could become messy depending on the type of design pursued

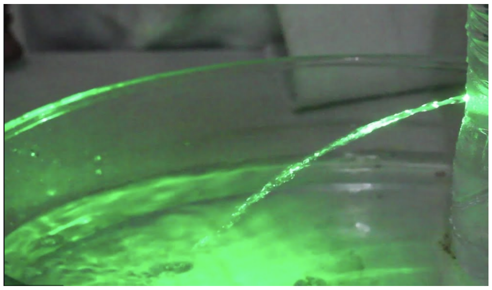


Figure 3. LED light diffraction in a stream of water.

Conclusions/action items:

We will need to create criteria and evaluate each of these proposed designs using a design matrix to decide upon a final design.

2020/10/05 - Design Matrix for LED Mechanism

JENNA EIZADI (eizadi@wisc.edu) - Oct 07, 2020, 12:04 PM CDT

Title: Design Matrix for LED Mechanism

Date: 2020/10/05

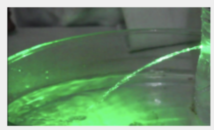
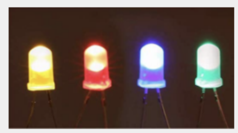
Content by:

Present:

Goals: To determine a final proposed design for the LED mechanism.

Content:

Table 1. *The design matrix with categories on the left, their weights in parentheses, and each design labeled on the first row. The dark green cells represent the designs that won each category as well as the design that won overall.*

LED Designs **Categories**	Diffused LEDs		LEDs + Water		Original LEDs	
						
Effectiveness (50) (Competency)	5/5	**50**	5/5	**50**	3/5	**30**
Ease of Fabrication (35)	4/5	**28**	3/5	**21**	5/5	**35**
Safety (10)	5/5	**10**	4/5	**8**	4/5	**8**
Cost (5)	4/5	**4**	3/5	**3**	5/5	**5**
Total (100)	92		82		78	

- Effectiveness: clarity of the device in portraying V/Q ratios and how well the device would appear in front of a lecture full of students
- Ease of Fabrication: the ability of the team to incorporate the LEDs into the LED Flow Model
- Safety: electrical and other outstanding hazardous concerns
- Cost: cost of fabrication

Conclusions/action items:

The Diffused LEDs will be used in modeling the V/Q mismatching concept in combination with the LED Flow Model from the previous design matrix. The design will include the base model representing the alveoli and bloodstream along with the visual flow representation using the color gradient of a strip of LEDs encased in diffused tubing. The team now needs to begin brainstorming the fabrication of this device including a fabrication plan and parts list.

2020/10/06 - Proposed Final Design

JENNA EIZADI (eizadi@wisc.edu) - Oct 07, 2020, 12:07 PM CDT

Title: Proposed Final Design

Date: 10/06/2020

Content by:

Present:

Goals: Demonstrate the proposed final design.

Content:

- combination of the LED Flow model along with the Diffused LED design
- tubing representing the alveoli and the bloodstream
- visual flow representation with LED strip encased in diffusive tubing to amplify light
- dial incorporated somewhere into the base to allow for different V/Q ratios to be modeled

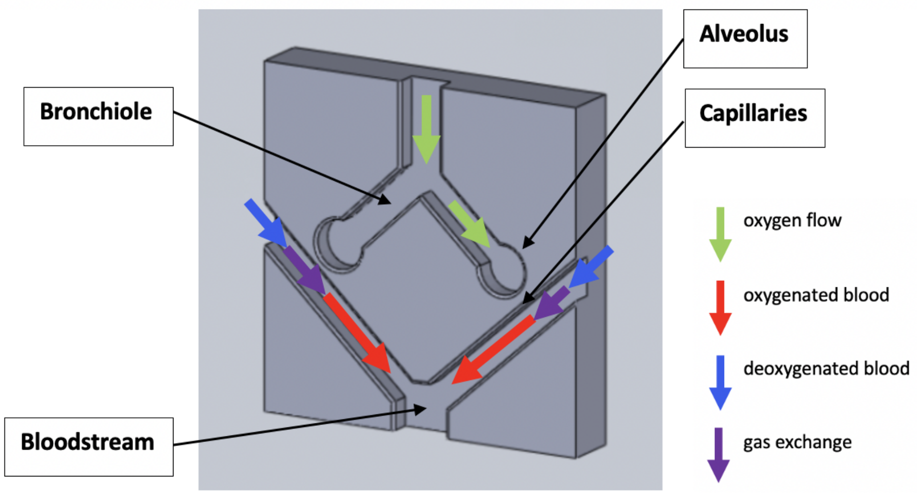


Figure 1. CAD drawing of the base modeling the alveoli and bloodstream with arrows demonstrating flow gradients represented with LEDs.

Conclusions/action items:

Create a fabrication plan and materials list for this proposed final design and begin ordering parts to create a prototype.

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.

2014/11/03-Template

John Puccinelli - Nov 03, 2014, 3:20 PM CST

Title:

Date:

Content by:

Present:

Goals:

Content:

Conclusions/action items: