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Beng 189
23 April 2023

Lung Lab

Task1

Setup_lung.m plots normally distributed randomly generated ventilation-perfusion ratios using a correlation determined by beta. Each point represents a separate alveolus. If there is a perfect correlation they will all fall on the same line as they will have the same slope. If they are not a good correlation they will have ventilation-perfusion mismatch and have differing slopes not falling on the same line.

Cvsolve.m uses the bisection method to find the concentration of oxygen in the pulmonary arteries arriving at the lungs. It uses given values of r and cv to perform its calculations.

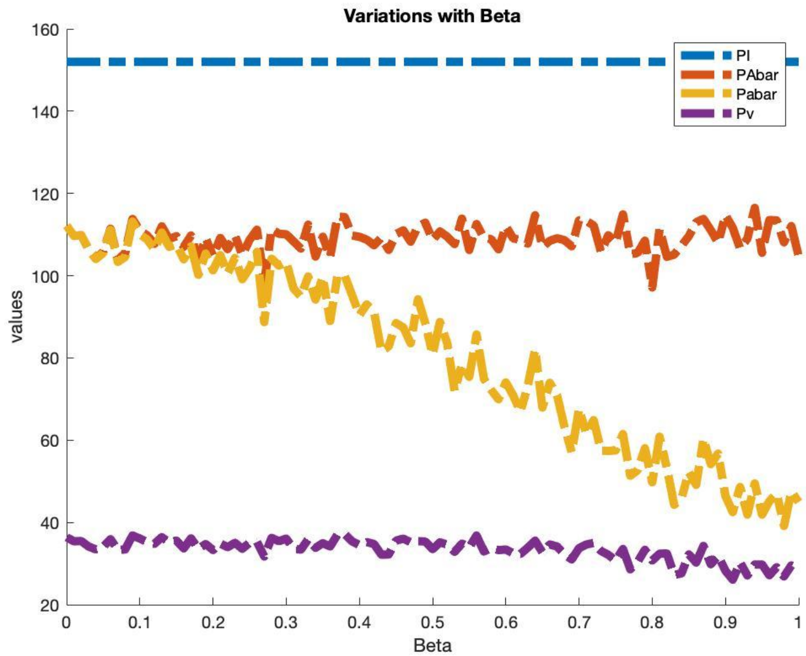
Carterial uses the bisection method to cut and find the concentration of oxygen in the pulmonary veins leaving the lungs to the heart, finding all values of r at once. The difference between this and cvsolve is that carterial assumes cv is known and defined in phi. Furthermore, cvsolve uses bisection to solve for cv using the determined carterial rather than how carterial uses a given value of cv to solve for carterial.

Task 2

Beta = 1 represents fully uncorrelated, ventilation-perfusion mismatching with random values being chosen at each alveolus around the negative log of a normal distribution. This is the most inefficient use of the lungs. Beta = 0 represents perfect ventilation perfusion matching with all values falling on the same slope. This is the most efficient use of the lungs.

Task 3

In order to plot over differing beta values I added a for loop with conditions that change the value of beta each iteration. This is done in the main lung.m script because this allows for beta to pass through every calculation, and allows for resetting of variables after. Using this change the following plot was graphed including the inspired partial pressure of oxygen, mean alveolar partial pressure of oxygen, the mean arterial partial pressure of oxygen, and the venous partial pressure of oxygen as functions of beta.

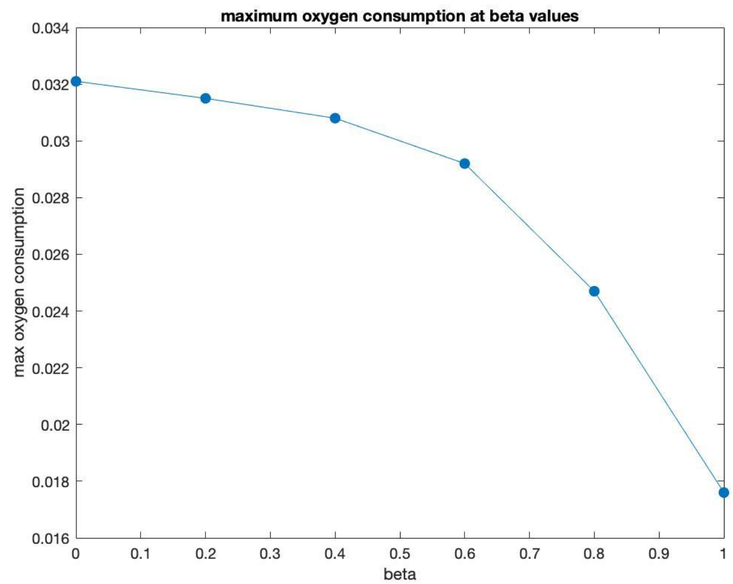


PI represents the partial pressure of oxygen in the inspired air. PAbar represents the average value of alveolar oxygen partial pressure. Pabar represents the average value of the arterial oxygen partial pressure. Pv represents the oxygen partial pressure in the venous blood. Because this represents the lungs, arterial represents post lungs while venous represents pre-lungs.

The graph shows that the inspired air stays constant. This makes sense assuming we are not in a closed area or using a small portion of the air as the air will equilibrate and remain at the same concentration of oxygen. Furthermore the alveolar partial pressure stays constant. This also makes sense because this air is equilibrating with the outside air. This is an assumption made, that the inspired air is the same as the expired. The blood coming out of the lungs is shown to decrease with beta. This makes sense as the lungs become less efficient if there is ventilation-perfusion mismatch which is described by a higher beta. The venous blood remains constant which makes sense as this is the blood returning to the lungs after the body has taken the needed oxygen.

Task 4

In order to determine the maximum rate of oxygen consumption the code was manually adjusted to have a specific beta value, and toggled with the oxygen consumption rate. If the consumption of oxygen was too great the code would return an error and the consumption rate would be lowered until the max for that beta value was determined. The results are as follows;

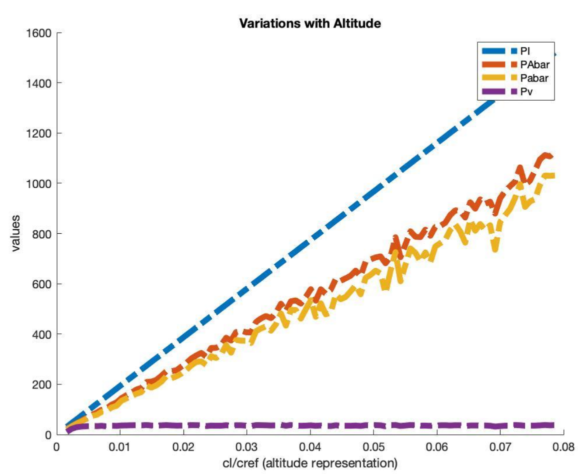


This graph shows the relationship between the maximum oxygen consumption rate and the amount of ventilation-perfusion mismatch. As mismatch increases along with beta, the maximum oxygen the modeled lungs can support lowers.

Task 5

Altitude also can affect the ability of your lungs to provide your body oxygen. This is why oxygen tanks are required on the top of mt. Everest or at altitude airplanes fly. The reason for this is because the partial pressure of oxygen decreases as altitude increases. This effectively means that there is less oxygen to interact with and grab with the body's hemoglobin.

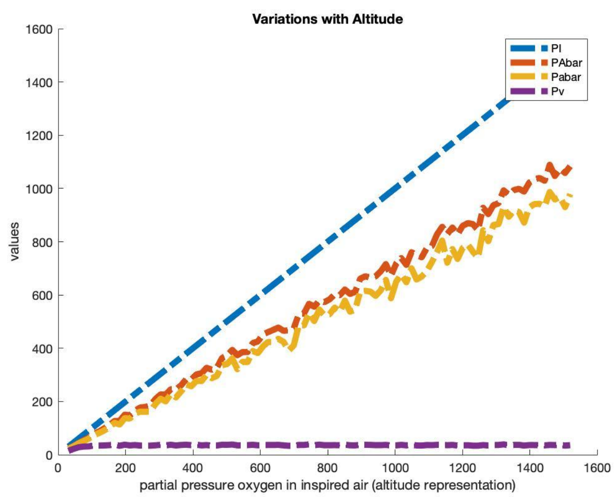
In order to represent this with the code a coefficient was added to the inspired air to allow for changes representing altitude change. The same for loop introduced for beta values was repurposed for alternating coefficients of inspired oxygen concentration. This was performed over a range of inspired concentrations which gave the following graph.



This graph is slightly misleading in that the x axis does not represent altitude directly but instead represents the concentration of oxygen in the air. The confusion with this is that the greater the concentration of oxygen, the lower the altitude giving an inverse relationship rather than the proportional one shown here. A beta value of 0.3 was used in this graph.

What this graph shows is that while venous blood has a maximum concentration, the alveolar and arterial blood scale linearly with increase of oxygen concentration, decreasing with altitude increase.

Task 6
This part of the code was easy to complete as to alternate from concentration of oxygen to partial pressure of oxygen the only needed step was to multiply by RT. Below the values of the shown variables are graphed over a large range of oxygen partial pressures. The scale goes greatly above 160 which is around pressure at sea level.



The graph shown here has been converted from oxygen concentration to partial pressure of oxygen. The partial pressure of oxygen is used to represent the elevation. However, this follows the same trend where the higher the partial pressure, the lower the altitude. In this case the change is still linear, but likely altitude is nonlinear with respect to partial pressure of oxygen, and so the resulting graph would be nonlinear as well.

In this case the maximum altitude that a person could be at can be found by trial and error finding when the code finds that the oxygen consumption is too great given the circumstances. In this case with a beta value of three the maximum pressure was around 24.32 mmHg. This is the partial pressure of oxygen at which corresponds to 77800 ft. This result is not an exact value however but is an estimate, as the random variations can alter the point at which a maximum exists.

Task 7

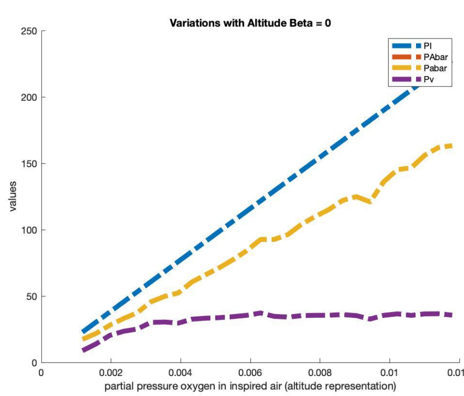
In order to complete this aspect of the code I added a coefficient variable in the main lung.m script which can be altered to change the number of hemoglobin molecules in the blood. It was determined that when hemoglobin concentration in the blood increased by 150% from 40% to 60%, the maximum elevation also increased. In this case the partial pressure of oxygen at the point where the code reported maximum oxygen consumption compared to absorption was at 19.76 mmHg. This is a greater elevation than the 24.32 mmHg found in a person who has not adapted for high altitudes. Specifically this corresponds to an elevation of around 82000 ft compared to the previously calculated 77800 ft.

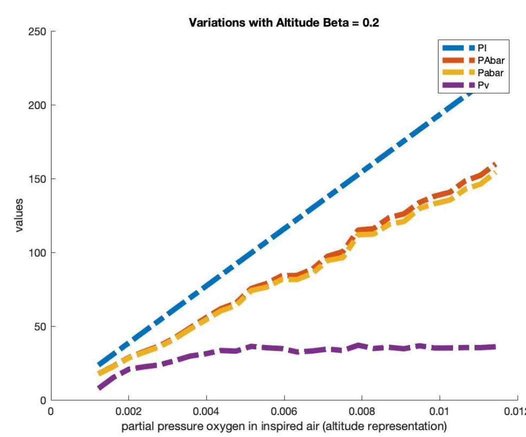
Task 8

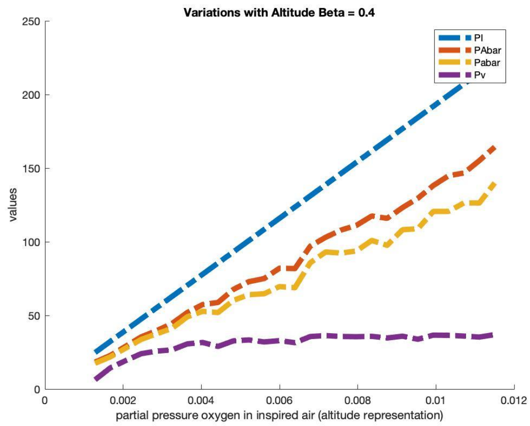
In this portion of the code manual changes were made to produce certain graphs but these did not create any significant changes rather than different values of variables.

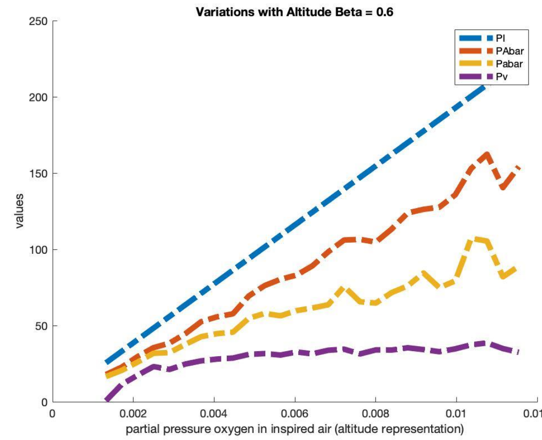
A pulmonary embolism is a blood clot that can block a certain area of blood flow in the lungs. When this happens this area experiences hypoperfusion which describes a lack of blood flow. In terms of ventilation-perfusion ratio, this would increase the value of the ratio. Compared to the rest of the lungs this would provide a significant mismatch between the ratios. It has been determined that the lung performs with greater efficiency when the ventilation-perfusion ratios are constant. In this case we can represent this phenomenon by increasing the value of beta, which refers to the amount of VQ mismatch. A pulmonary embolism would increase VQ mismatch, and so if we know the overall trend of what increasing VQ mismatch does, even if we do not know the extent of the effect this has on efficiency, we can get a general idea of what will occur.

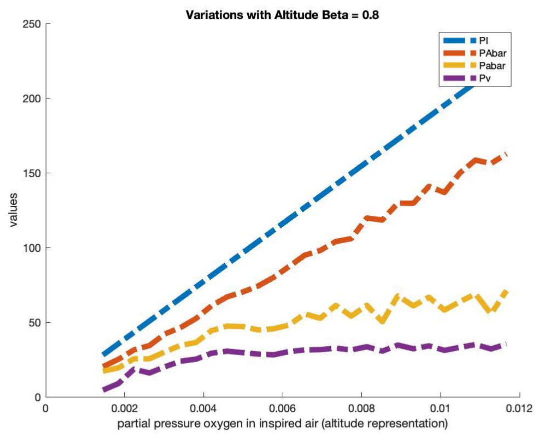
To answer this question the following graphs were produced at beta values of 0-1 at intervals of 0.2. They represent the effect of altitude for a certain beta value.

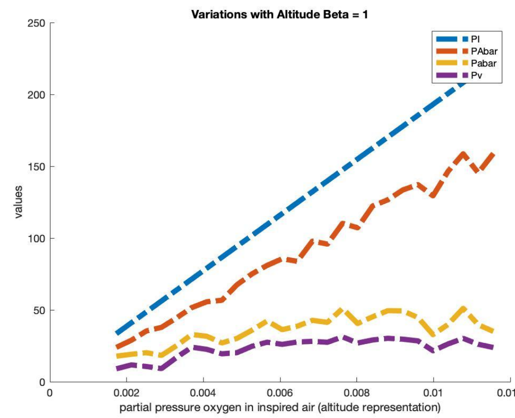










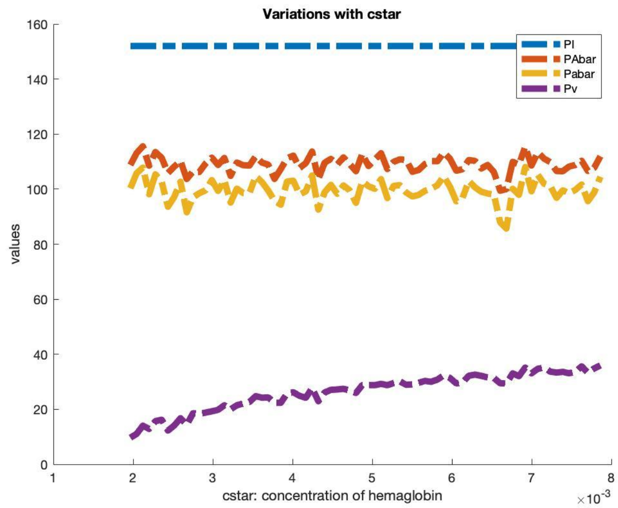


Furthermore, a chart of the maximum altitudes are presented below where altitude is represented by the partial pressure of oxygen at that point.

%Beta: 0 |0.2 |0.4 |0.6 |0.8 |1.0
%pi :22.8000|23.5600|24.7760|25.5360|27.9680|33.4400 (mmHg)

These results show that beta dramatically affects the partial pressure of oxygen in the blood leaving the heart but does not greatly affect any other parameter. Furthermore, this impact greatly reduces the maximum elevation which can be sustained with no cardiological or respiratory changes. Also, when beta equals zero, the partial pressure of oxygen was the same in the blood leaving the heart and the inspired air.

Task 9
Anemia is another factor which could influence our model. This can be represented in the code by simply adjusting the coefficient of cstar, which effectively changes the amount of hemoglobin in the blood. In the code this coefficient was put into the for loop described above. The shown variables were determined at each of the cstar values determined by the coefficients put into the for loop. The cstar value was then recalculated and input into the graph below.



What this graph shows is that all variables are relatively constant except for the partial pressure of oxygen in the blood entering the lungs, which increases with hemoglobin. This makes sense as the greater the amount of hemoglobin in the blood, the better it is able to hold onto oxygen. Furthermore the air concentrations shouldn't change by a change of blood composition.

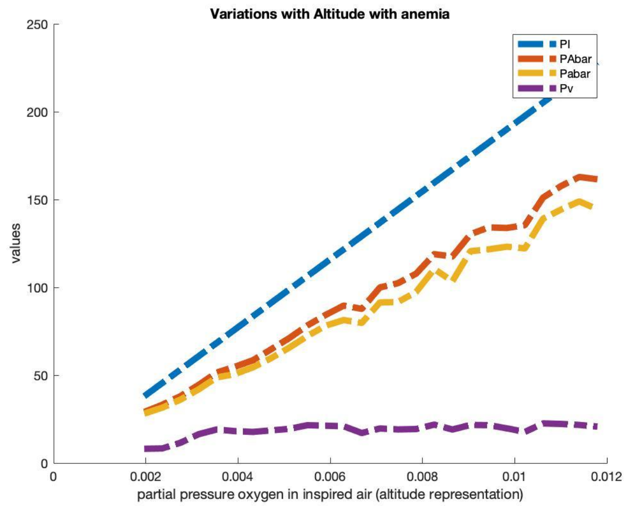
The minimum value of cstar was also determined at varying beta values as shown in the chart below. This was performed manually using trial and error when varying the value of cstar over different beta values.

%Beta 0 |0.2 |0.4 |0.6 |0.8 |1.0
%Cstar:1.9657|2.0444|2.0679|2.1230|2.4375|3.1452 (*10^-3)

Cstar essentially changes the reference air inspired concentration in a roundabout way, and so it can be viewed similarly to that of increasing altitude. Intuitively this makes sense as having less receptors for oxygen due to lack of hemoglobin is similar to having less oxygen to stick onto receptors which happens at increasing altitude. The chart above agrees with this trend as the minimum Cstar increases along with Beta, showing that the less efficient the lungs, the more hemoglobin is required to compensate.

Task 10

A person who has less hemoglobin will not be able to carry oxygen in their blood as well as a person with more hemoglobin. Below is a graph produced by altering altitude and monitoring the shown variables.



The major result of this graph is that the blood returning to the lungs have less partial pressure of oxygen that that of blood that would have more hemoglobin. Largely the graphs are similar shapes however.

Below is a chart describing the minimum Cstar corresponding to beta values. It is shown that a person with anemia needs higher Cstar values to maintain oxygen saturation.

%Beta: 0 |0.2 |0.4 |0.6 |0.8 |1.0

%Cstar:2.1230|2.2016|2.3589|2.5161|3.2238|6.2903 (*10^-3)