Problem 1: Calculate the average blood pressure level in the heart according to the circulation cycle

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Introduction

This is a project to represent the blood flow with linear algebra.

During this project, we expect to learn to structure blood flow and study the application of network problems.

-this is the average blood pressure of a person-

Veins	Average blood pressure(mmHg)
Aorta	120~ 80
Artery	100 ~ 40
Capillaries	60 ~ 40
Vein	10~ 2
Vena cava	2 ~ -5
Pulmonary artery	18~ 15
Pulmonary veins	10~ 8

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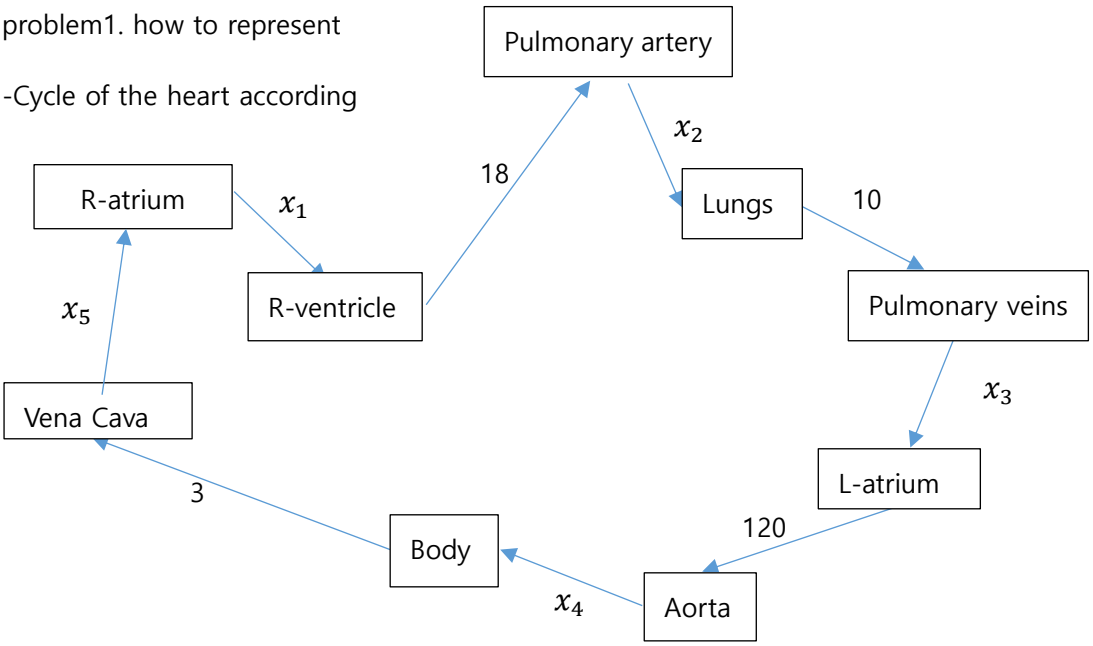
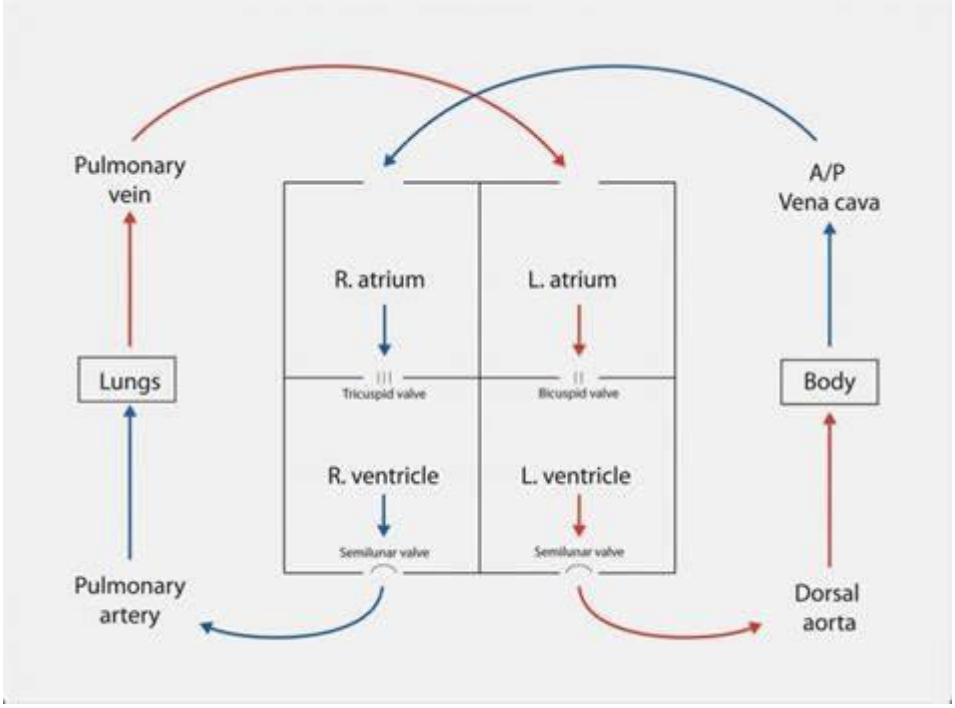
problem1. how to represent

-Cycle of the heart according





2. represent as matrix and equation[ii]

We are using a network problem to see the changes in blood pressure at parts of the range.

If blood pressure increases, then blood flow also increases, so based on this system [iii]

(Enter blood flow == out blood flow) also, blood pressure has the same logic.

-Maximum range of blood pressure-

Q1) what is the Maximum blood pressure range from the R-atrium to the Pulmonary veins?

$x_1 + x_2 = 18 + 10 \rightarrow 28$

Q2) what is the Maximum blood pressure range from the Pulmonary artery to the L-atrium?

$x_2 + x_3 = 10 + 120 = 130$

Q3) what is the Maximum blood pressure range from the Pulmonary veins to the Aorta?

$x_3 + x_4 = 120 + 3 = 123$

Q4) what is the Maximum blood pressure range from the Aorta to the R-atrium?

$x_4 + x_5 = \ 3 + x_1$

-solutions for each unknown blood pressure-

$\therefore \quad x_1 = 28 - \ x_2$

$x_2 = 130 - x_3$

$x_3 = 123 - x_4$

$x_4 = 3+x_1-x_5$

$x_5 = 3 + x_1 - x_4$

$\therefore$ $28<x_2<130$

$123<x_3<130$

$123<x_4<3+x_1-x_5$

-Matrix of maximum range-

	x_1	x_2	x_3	x_4	x_5	
R_1	1	1	0	0	0	28
R_2	0	1	1	0	0	130
R_3	0	0	1	1	0	123
R_4	1	0	0	1	1	$3+x_1$

-Minimum range of blood pressure-

Q1) what is the minimum range of blood pressure from the R-atrium to the Pulmonary veins

$x_1 - x_2 = 18 - 10 = 8$

Q2) what is the minimum range of the blood pressure from the Pulmonary artery to the L-atrium

$x_3 - x_2 = 120 - 10 = 110$

Q3) what is the minimum range of blood pressure from the Pulmonary veins to the Aorta

$x_3 - x_4 = 120 - 3 = 117$

Q4) what is the minimum range of blood pressure from the Aorta to the R-atrium

$x_4 - x_5 = \ 3 - x_1$

$\therefore \ x_1 = 8 + x_2$

$x_2 = x_3 - 110$

$x_3 = x_4 + 117$

$x_4 = 3 - x_1 + x_5$

-Matrix of minimum range

	x_1	x_2	x_3	x_4	x_5	
R_1	1	-1	0	0	0	8
R_2	0	-1	1	0	0	110
R_3	0	0	1	-1	0	117
R_4	1	0	0	1	-1	3-x_1

Solution by python

```
import numpy as np
import pandas as pd
import sympy as sp

#Matrix A = Linear equation of the Maximum Blood presure
A= np.array([[1,1,0,0,0],
             [0,1,1,0,0],
             [0,0,1,1,0],
             [1,0,0,1,1]])

X1, X2, X3, X4, X5 = sp.symbols('X1 X2 X3 X4 X5')

#MA = Maximum Blood presure
MA= np.array([[28],
              [130],
              [123],
              [3+X1]])

#Matrix B = Minimum Blood presure
B= np.array([[1,-1,0,0,0],
             [0,-1,1,0,0],
             [0,0,1,-1,0],
             [1,0,0,1,-1]])

MB= np.array([[8],
              [110],
              [117],
              [3-X1]])

print("Matrix of the Maximum Blood presure")
print(A,"\n")
print(MA,"\n")

print("Matrix of the Minimum Blood presure")
print(B,"\n")
print(MB,"\n")
```

```
Matrix of the Maximum Blood presure
[[1 1 0 0 0]
 [0 1 1 0 0]
 [0 0 1 1 0]
 [1 0 0 1 1]]

[[28]
 [130]
 [123]
 [X1 + 3]]

Matrix of the Minimum Blood presure
[[ 1 -1  0  0  0]
 [ 0 -1  1  0  0]
 [ 0  0  1 -1  0]
 [ 1  0  0  1 -1]]

[[8]
 [110]
 [117]
 [3 - X1]]
```

[2]:
```
print("Extraction equation from Matrix\n")
print("when the range in Max")

#Max N= equation N of maximum range

 #Define the equations
Max1 = sp.Eq(X1 + X2, 28)
Max2 = sp.Eq(X2 + X3, 130)
Max3 = sp.Eq(X3 + X4, 123)
Max4 = sp.Eq(X4 + X5, 3 + X1)

# Display equations
print(Max1)
print(Max2)
print(Max3)
print(Max4)

# MaxE soultion of maximum range equations
MaxE= sp.solve([Max1,Max2,Max3,Max4],
               (X1,X2,X3,X4,X5))

print("\nSolution in Maximum range in X1, X2, X3, X4, X5:")
print(MaxE,"\n")
```

```
Extraction equation from Matrix

when the range in Max
Eq(X1 + X2, 28)
Eq(X2 + X3, 130)
Eq(X3 + X4, 123)
Eq(X4 + X5, X1 + 3)

Solution in Maximum range in X1, X2, X3, X4, X5:
{X1: X5/2 + 9, X2: 19 - X5/2, X3: X5/2 + 111, X4: 12 - X5/2}
```

[ ]:

[3]:
```
print("Extraction equation from Matrix\n")
print("when the range in Min")

#min N= equation N of minimum range

 #Define the equations
min1 = sp.Eq(-X2+X1, 8)
min2 = sp.Eq(-X3+X2, 110)
min3 = sp.Eq(-X4+X3, 117)
min4 = sp.Eq(-X5+X4, 3 - X1)

# Display equations
print(min1)
print(min2)
print(min3)
print(min4)

# MaxE soultion of maximum range equations
minE= sp.solve([min1,min2,min3,min4],
             (X1,X2,X3,X4,X5))

print("\nSolution in minimum range in X1, X2, X3, X4, X5:")
print(minE,"\n")
```

```
Extraction equation from Matrix

when the range in Min
Eq(X1 - X2, 8)
Eq(X2 - X3, 110)
Eq(X3 - X4, 117)
Eq(X4 - X5, 3 - X1)

Solution in minimum range in X1, X2, X3, X4, X5:
{X1: X5/2 + 119, X2: X5/2 + 111, X3: X5/2 + 1, X4: X5/2 - 116}
```

[ ]:

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[i] Guyton, Arthur C. (2006).《Textbook of medical physiology》11판. Philadelphia: Elsevier Saunders. 162 page. ISBN 0-7216-0240-1.

[ii] 0321947622.pdf (pearsonhighered.com)

[iii] Hemodynamics - PMC (nih.gov) <Basic concepts of hemodynamics> Compr Physiol. Author manuscript; available in PMC 2017 Mar 15. Published in final edited form as: Compr Physiol. 2016;

6(2): 975–1003. Published online 2016 Mar 15. doi: 10.1002/cphy.c150038