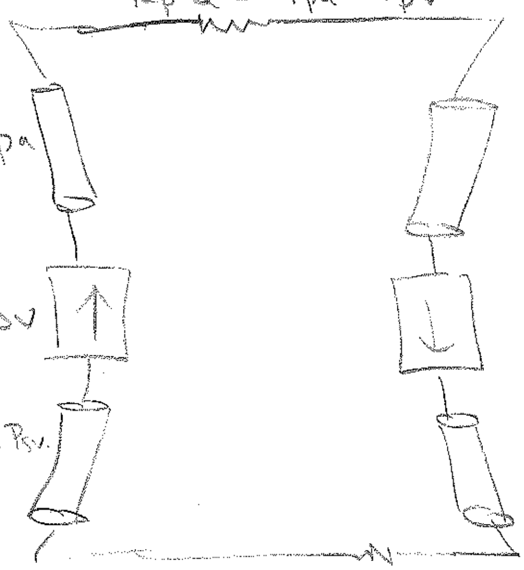
09/22/2022

model of controlled circulation

this gives $Q = F C_R P_{sv}$
$= F C_L P_{pv}$

New model of <u>controlled</u> circulation ($P_{sa} = P^*$)

$R_p Q = P_{pa} - P_{pv}$



$[V_{p}]a = C_{pa} P_{pa}$ $\quad$ $V_{pv} = C_{pv} P_{pv}$

$[Q] = F C_R P_{sv}$ $\quad$ $Q = F C_L P_{pv}$

$[V]_{sv} = C_{sv} P_{sv}$ $\quad$ $V_{sa} = C_{sa} P_{sa} = C_{sa} P^*$

$R_s Q = P_{sa} - P_{sv} = P^* - P_{sv}$

$V_0 = V_{sa} + V_{sv} + V_{pa} + V_{pv}$

Unknowns: $V_{sa}, V_{sv}, V_{pa}, V_{pv}, P_{sv}, P_{pa}, P_{pv}, F, Q$.

Harder to solve the model because we can't find V_{sa} in terms of Q.

Instead approximate $P_{sv} \ll P^*$, so

$$Q R_s = P^* \quad (\text{i.e., } \sigma_{QR_s} = -1)$$

and use $V_{sa} + V_{sv} \gg V_{pa} + V_{pv}$.
[90%] [10%].

which gives $V_{sa} + V_{sv} = V_0$.

$$C_{sa} P^* + C_{sv} P_{sv} = V_0$$

So $$P_{sv} = \frac{V_0 - C_{sa} P^*}{C_{sv}}$$

Thus $Q = F C_R P_{sv}$

$$\Longrightarrow \frac{P^*}{R_s} = F C_R \left(\frac{V_0 - C_{sa} P^*}{C_{sv}} \right)$$

$$\boxed{F = \frac{P^* C_{sv}}{R_s C_R (V_0 - C_{sa} P^*)}}$$

New model: change in R_S → change in Q → P_{sa} const
(through change in F)

In the uncontrolled circulation, Q dependent on all model parameters. For controlled circulation, Q depends only on P^* and R_S. (not on V_0! Protected against blood loss as well).

Autoregulation

Another variation on the model: what if the body controls the resistance of the tissue?
Why? Goal is to receive more O_2. Tissue consumes O_2 for cellular respiration. Let $[O_2]_a$ = arterial O_2 conc and $[O_2]_v$ = venous O_2 conc. then

$$Q[O_2]_a - Q[O_2]_v = M = \text{metabolic rate}$$

Thus

$$\boxed{[O_2]_v = [O_2]_a - M/Q.}$$

When blood supply is just enough, $[O_2]_v = 0$,

$$Q = M/[O_2]_a := Q^*.$$

As $Q \to \infty$, $[O_2]_v = [O_2]_a$. Thus, venous O_2 concentration is a good proxy for if we should increase or decrease Q (vice versa for R).

Simple model

$$R = R_0[O_2]_v.$$

So

$$R = \frac{\Delta P}{Q} = R_0([O_2]_a - M/Q).$$

$$Q = \frac{\Delta P + MR_0}{R_0[O_2]_a} = \frac{\Delta P}{R_0[O_2]_a} + \frac{M}{[O_2]_a}$$

$$\boxed{Q = Q^* + \frac{\Delta P}{R_0[O_2]_a}}$$

Consequences of this:

☆ 1) σ_{QP} is less than when $R = const.$ (and $\sigma_{QP} = 1$).

☆ 2) Tissue always receives flow Q^* required for metabolism

3) If P is constant, changes in M give

$$\Delta Q = \Delta Q^* = \Delta M / [O_2]a$$

Extra change in Q just what is needed.

4) If P is constant, increase in $M \to$ decrease in R.

☆ (5) If $[O_2]a$ changes, Q automatically adjusts so $Q[O_2]a = const.$ Rate is the same!