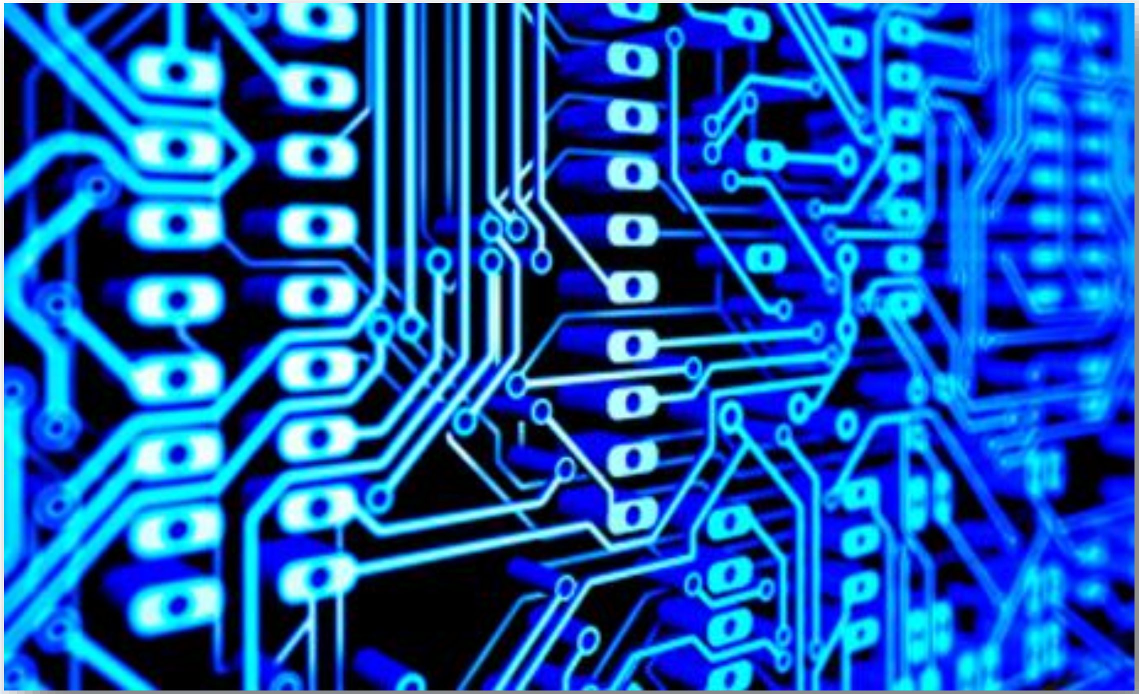


Phys 102 – Lecture 7

Series and parallel circuits

Today we will...

- Learn about <u>*electric circuits*</u>

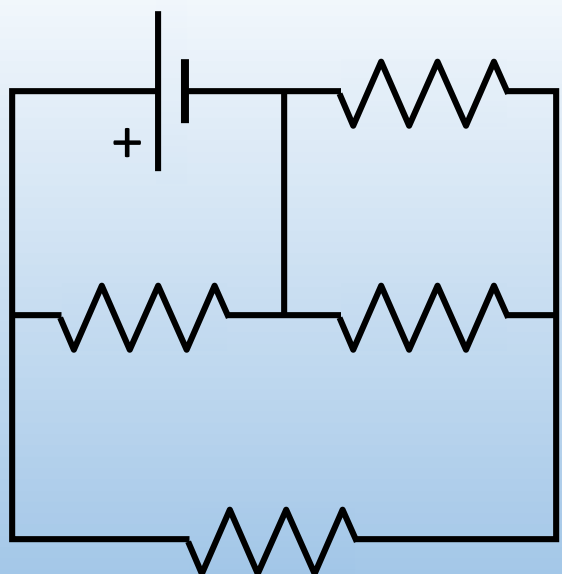
  Circuits with a battery, wires, and resistors

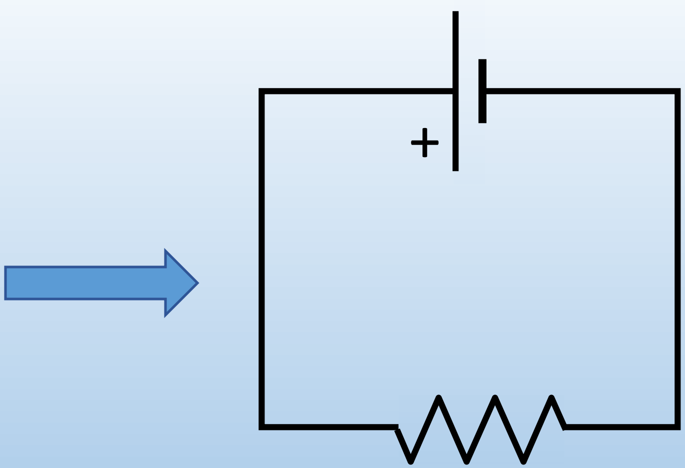
  Circuits with a battery, wires, and capacitors

- Analyze circuits

  Take a complex-looking circuit like...

  ...and turn into a simple-looking circuit like

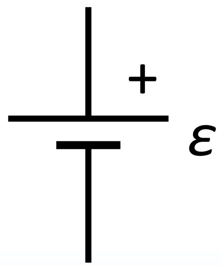


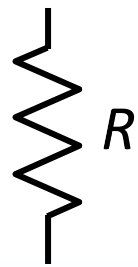


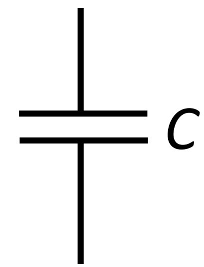
Recall from last time...

Electric potential difference across circuit element is its "voltage"

$V_{element}$ Should be "ΔV", but we'll usually drop the "Δ"







Batteries – pump charges
Provide emf for charges

$$V_{battery} = \varepsilon$$

Resistors – regulate current
Dissipate power

$$V_R = IR$$

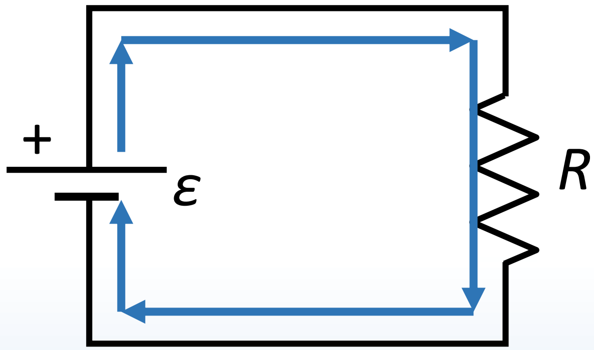
Capacitors – store charge
Store energy

$$V_C = \frac{Q}{C}$$

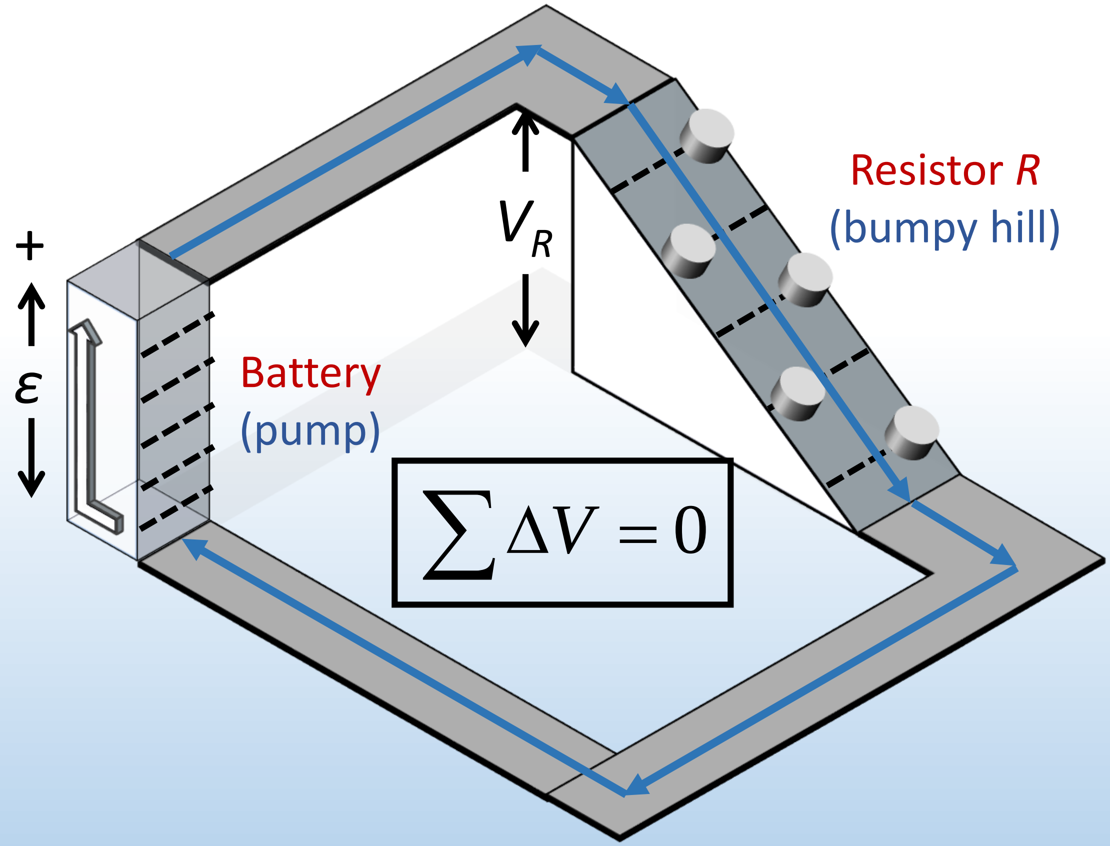
Circuits connect elements with wires, which we treat as *ideal conductors*

Kirchhoff loop rule

A charge making a complete loop around a circuit must return to the same electric potential ("height") at which it started



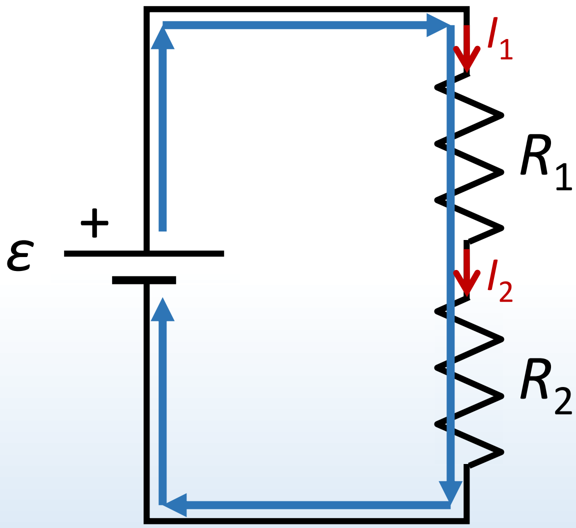
Sum of electric potential differences (voltages) around circuit loop is zero

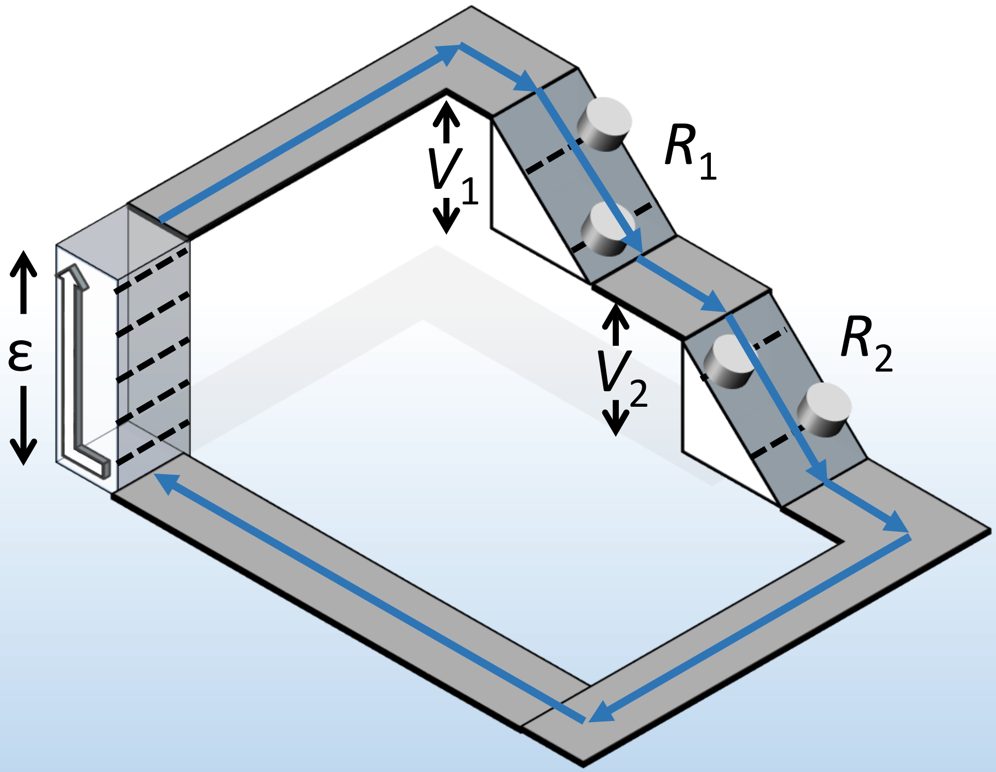


$$\sum \Delta V = 0$$

Series components

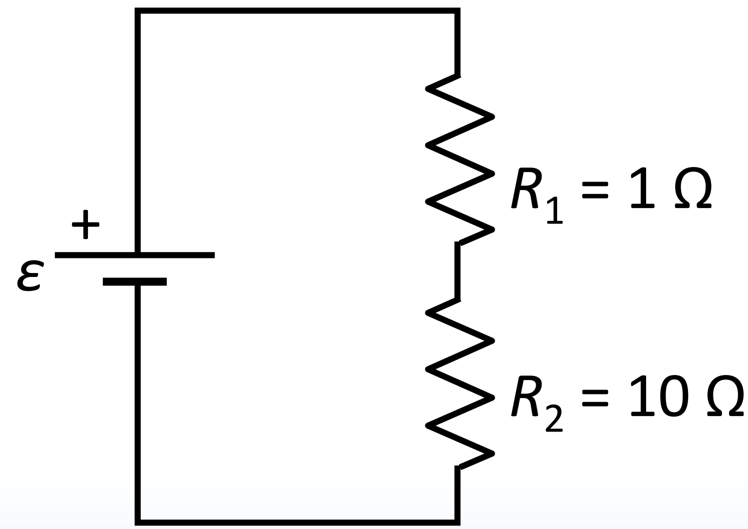
Two components are said to be *in series* when they are connected end-to-end by a *single* wire





ACT: CheckPoint 1.2

Consider a circuit with two resistors R_1 and R_2 in series. Compare the voltages across the resistors:



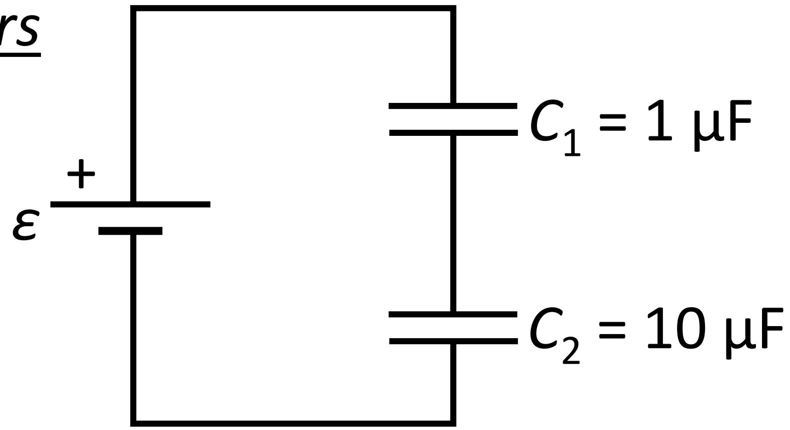
A. $V_1 > V_2$

B. $V_1 = V_2$

C. $V_1 < V_2$

ACT: Capacitors in series

Consider a circuit with two *capacitors* C_1 and C_2 in series. Compare the voltages across the capacitors:



A. $V_1 > V_2$

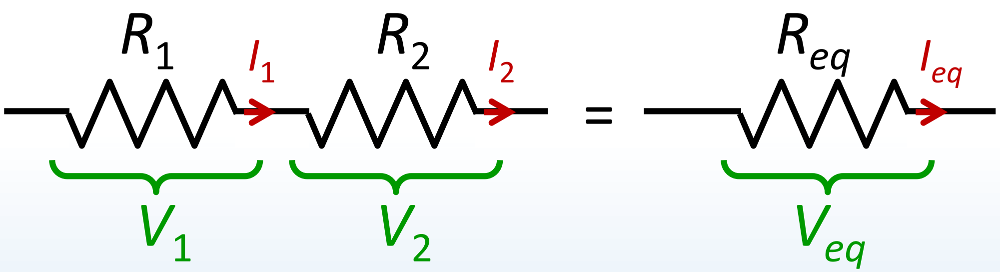
B. $V_1 = V_2$

C. $V_1 < V_2$

Equivalent resistance & capacitance

Circuit behaves the same as if *series* components were replaced by a *single, equivalent* component

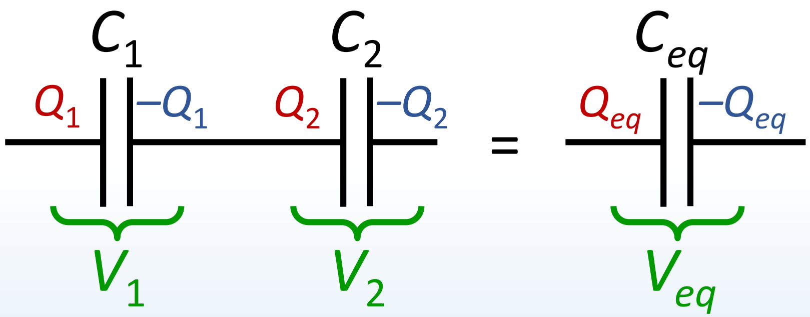
Resistors



$$I_1 = I_2 = I_{eq} \qquad V_1 + V_2 = V_{eq}$$

$$\boxed{R_{eq} = R_1 + R_2}$$

Capacitors



$$Q_{eq} = Q_1 = Q_2 \qquad V_{eq} = V_1 + V_2$$

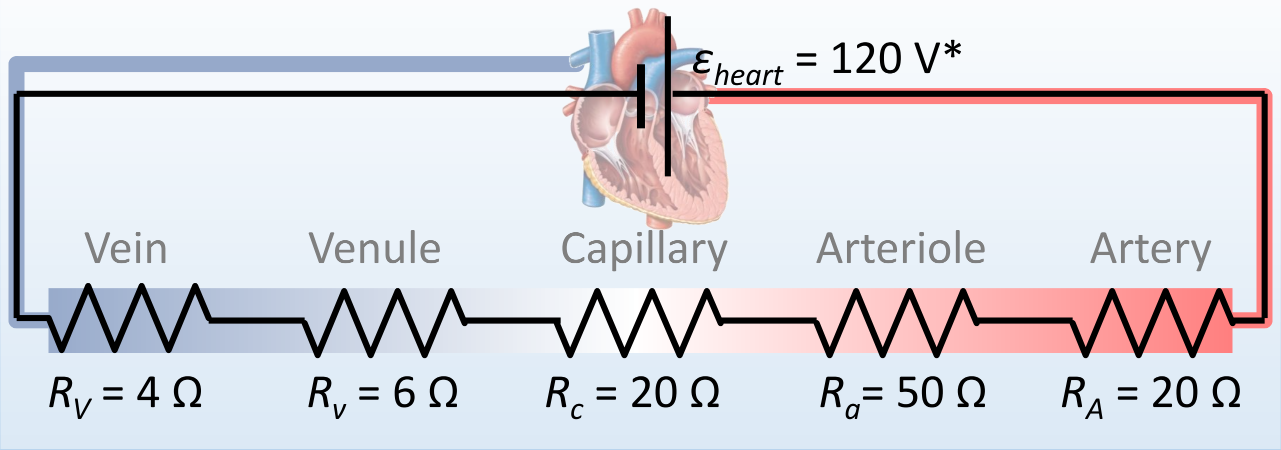
$$\boxed{\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}}$$

Calculation: vascular resistance

The circulatory system is analogous to an electric circuit

Pressure difference	⟷	emf
Blood flow	⟷	Electric current
Vascular resistance	⟷	Electrical resistance

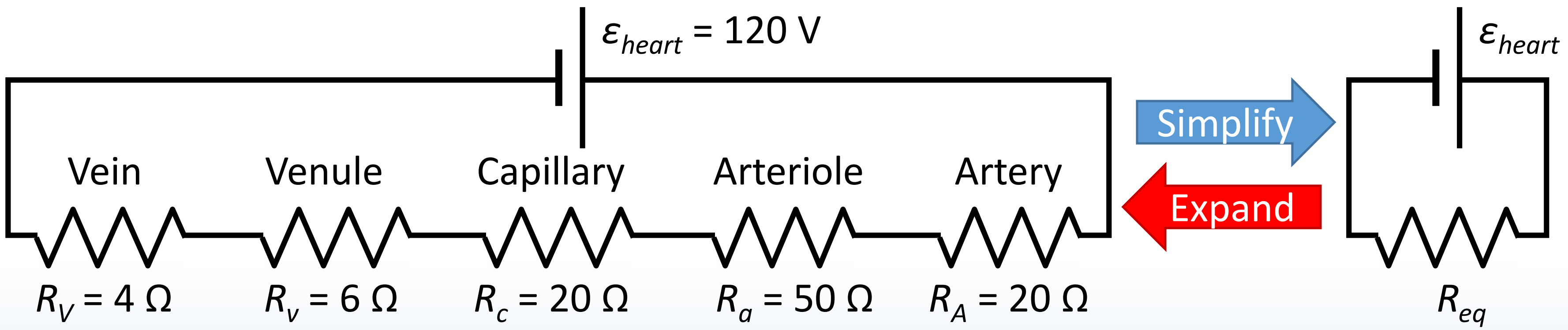
The circulatory system consists of different types of vessels in series with different resistances to flow



*Numbers represent accurate relative values

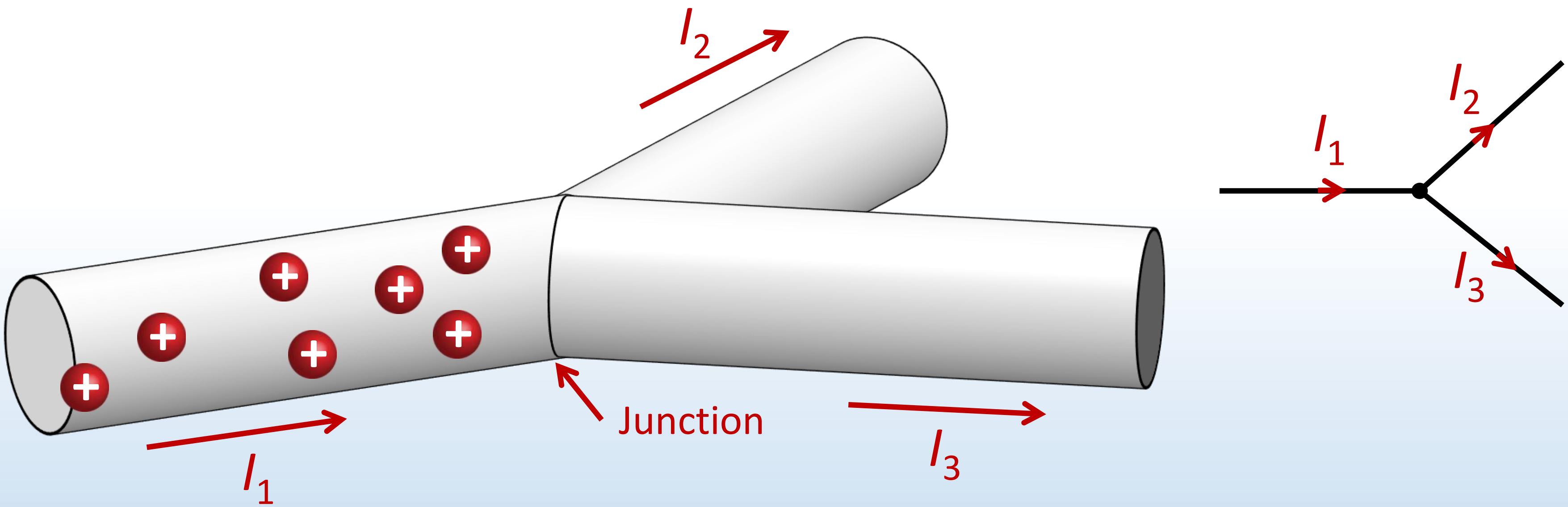
Calculation: vascular resistance

Calculate the current *I* through the vascular circuit and the voltages across the different types of vessels



Kirchhoff junction rule

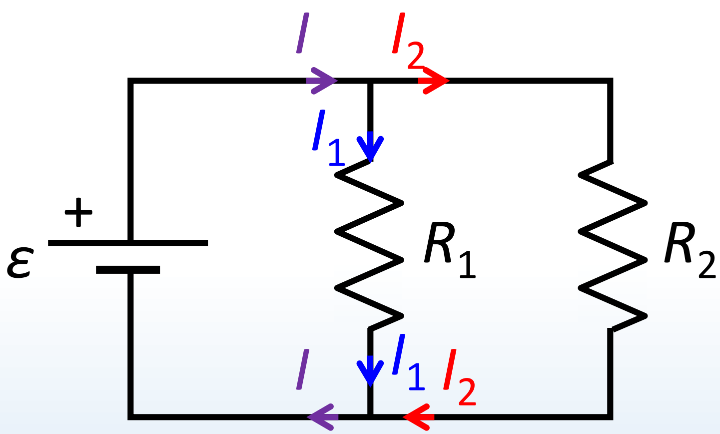
Charges flowing through a junction split. By conservation of charge, the sum of currents into a junction equals the sum of currents out of a junction

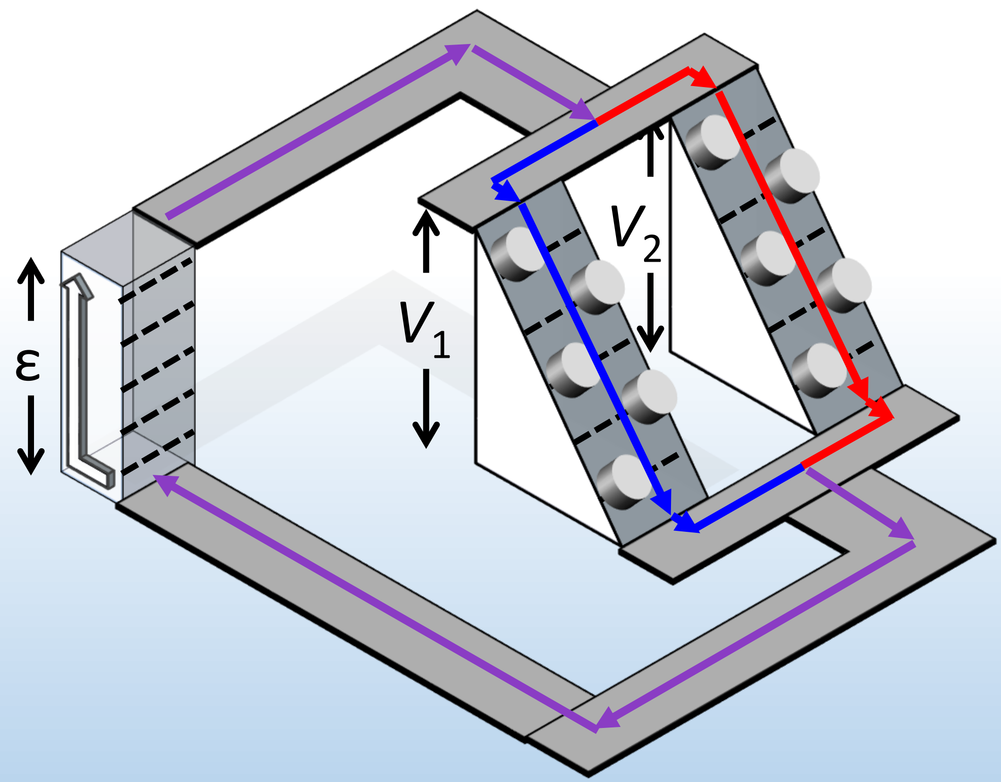


$$\boxed{\sum I_{in} = \sum I_{out}}$$

Parallel components

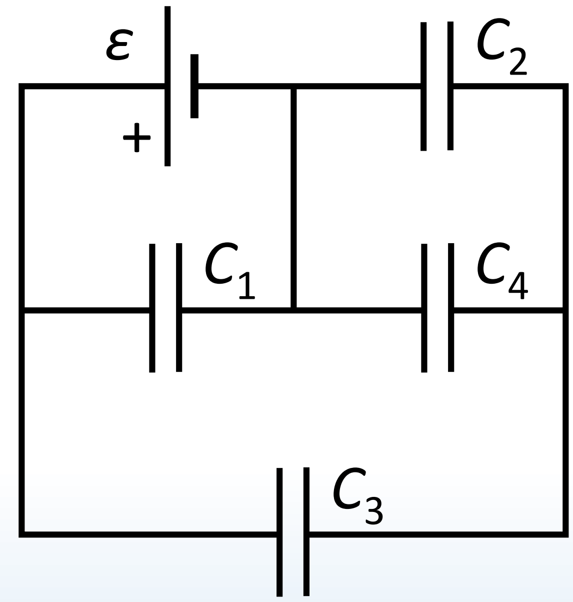
Components are said to be *in parallel* when both ends are connected to each other, forming a loop containing only them





ACT: Parallel or series?

Consider the circuit to the right. Which of the following statements is true?



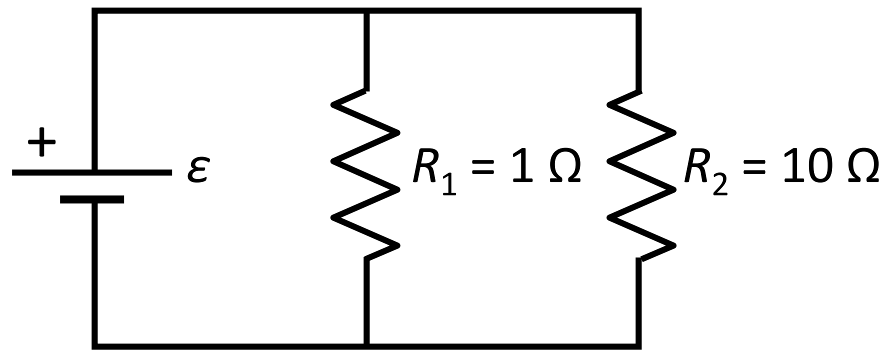
A. C_1 & C_4 are in series

B. C_2 & C_4 are in parallel

C. C_1 & C_3 are in parallel

ACT: Resistors in parallel

Consider a circuit with two resistors R_1 and R_2 in parallel. Compare I_1, the current through R_1, to I_2, the current through R_2:



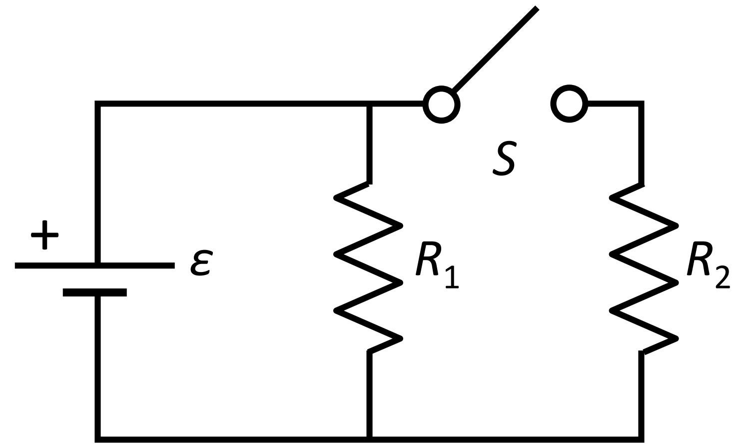
A. $I_1 > I_2$

B. $I_1 = I_2$

C. $I_1 < I_2$

ACT: CheckPoint 2.3

Now we add a switch *S*. What happens to the current out of the ***battery*** when the switch is closed?



A. $I_{battery}$ increases

B. $I_{battery}$ remains the same

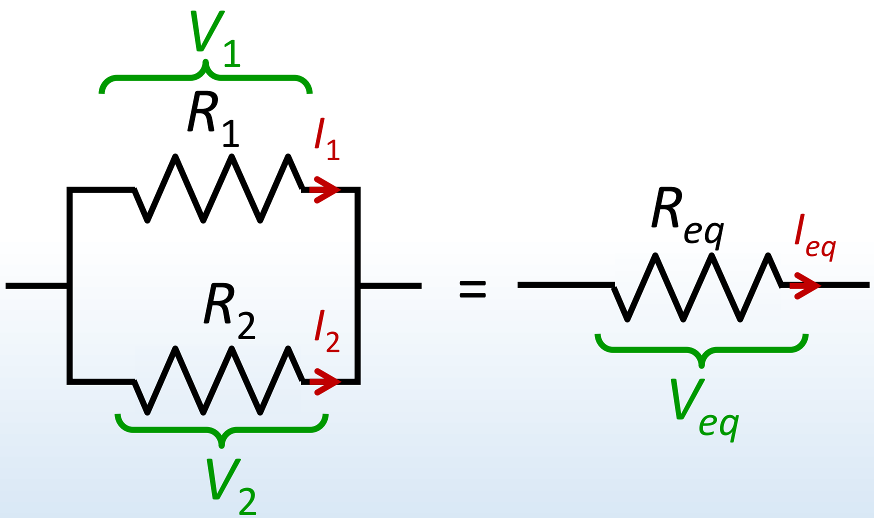
C. $I_{battery}$ decreases

DEMO

Equivalent resistance & capacitance

Circuit behaves the same as if *parallel* components were replaced by a *single, equivalent* component

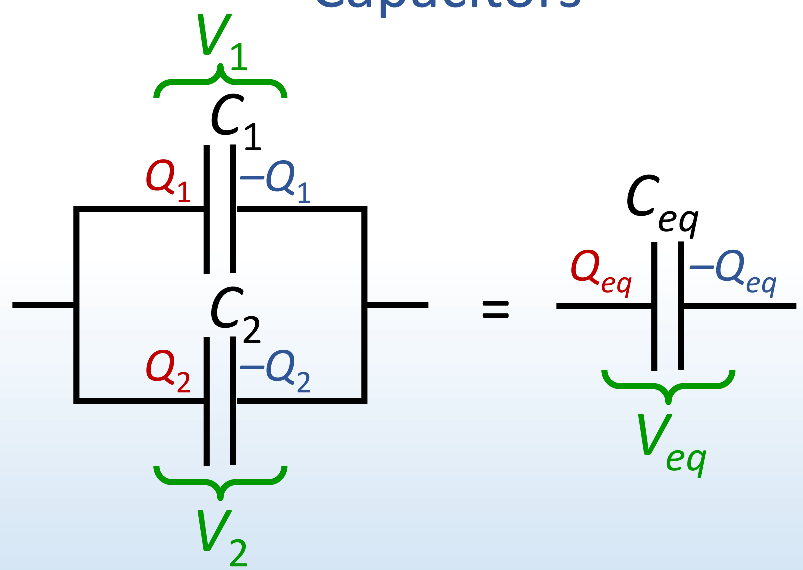
Resistors



$$I_1 + I_2 = I_{eq} \qquad V_1 = V_2 = V_{eq}$$

$$\boxed{\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}}$$

Capacitors

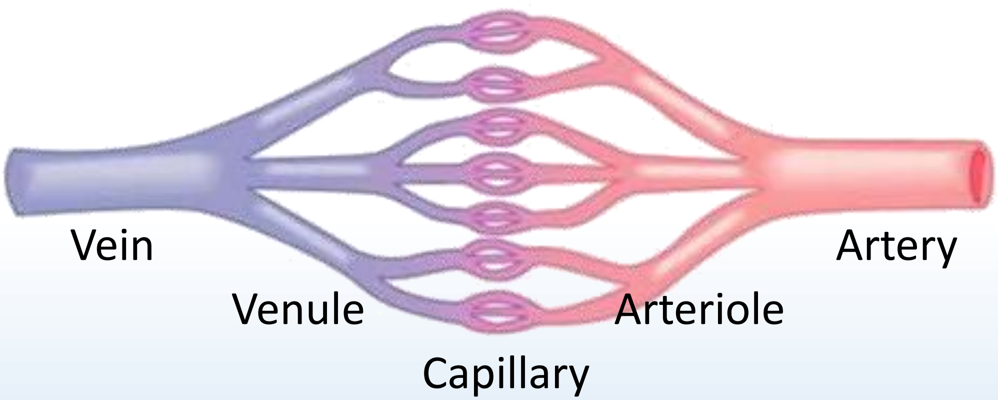


$$Q_1 + Q_2 = Q_{eq} \qquad V_1 = V_2 = V_{eq}$$

$$\boxed{C_{eq} = C_1 + C_2}$$

Calculation: vascular resistance

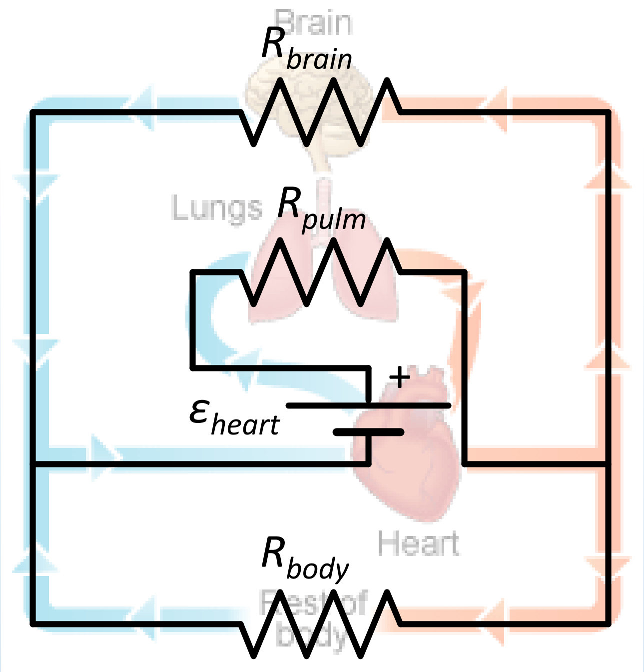
In previous calculation, capillaric resistance accounts for ~20% of total vascular resistance, yet capillaries are the thinnest blood vessels, and should have the *highest* resistance. Why?



Calculation: cardiovascular system

The human cardiovascular system consists of two circuits: *pulmonary* circulation which carries blood though the lungs, and *systemic* circulation which carries blood to the organs

The organs of the body are connected in parallel in the systemic circuit



Simple circuit model*:

R_{pulm} = 12 Ω, R_{brain} = 1 kΩ,
R_{body} = 160 Ω, ε_{heart} = 120 V

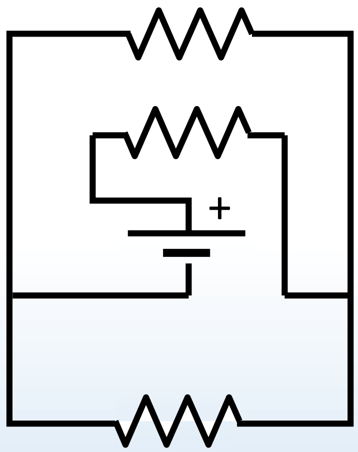
*Numbers represent accurate relative values

Calculate current through each component of circulatory system

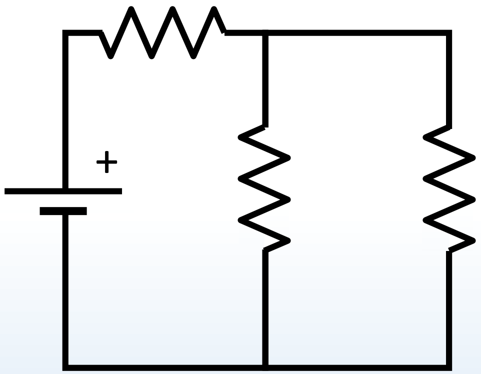
ACT: analyzing circuits

Which of the following circuit is different than the others?

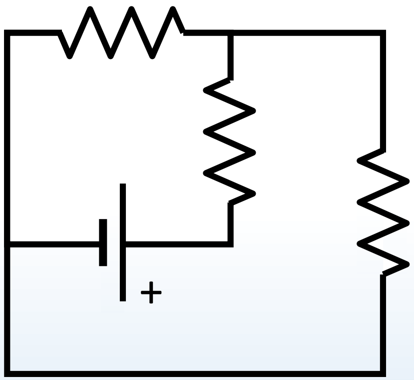
I



II



III

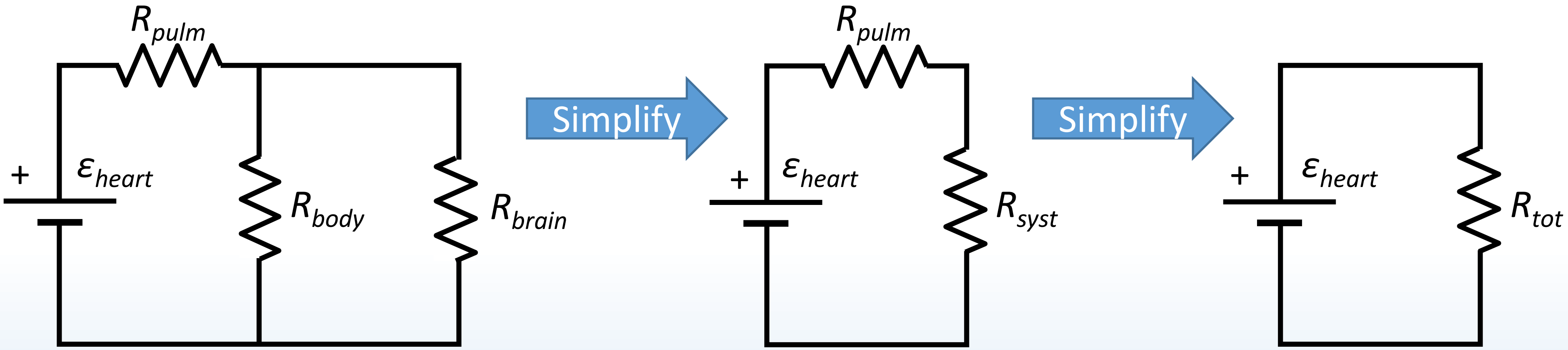


A. Circuit I
B. Circuit II
C. Circuit III
D. All three are equivalent
E. All three are different

Calculation: circulatory system

Calculate current through each component of circulatory system

R_{pulm} = 12 Ω, R_{brain} = 1 kΩ, R_{body} = 160 Ω, ε_{heart} = 120 V



R_{brain} & R_{body} are in parallel

$$\frac{1}{R_{syst}} = \frac{1}{R_{brain}} + \frac{1}{R_{body}}$$

$$V_{syst} = V_{brain} = V_{body}$$

$$I_{syst} = I_{brain} + I_{body}$$

R_{pulm} & R_{syst} are in series

$$R_{tot} = R_{pulm} + R_{syst}$$

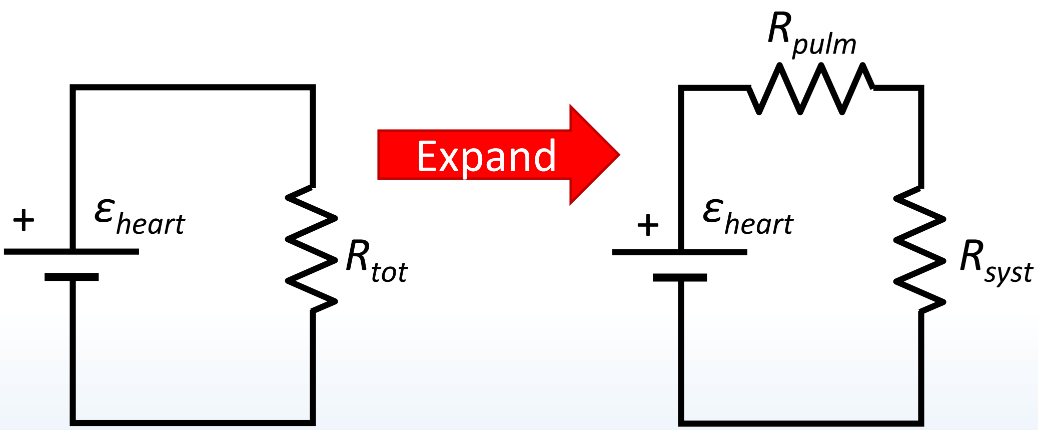
$$V_{tot} = V_{pulm} + V_{syst} = \varepsilon_{heart}$$

$$I_{heart} = I_{pulm} = I_{syst}$$

Calculation: circulatory system

Calculate current through each component of circulatory system

R_{pulm} = 12 Ω, R_{brain} = 1 kΩ, R_{body} = 160 Ω, ε_{heart} = 120 V



R_{pulm} & R_{syst} are in series

$$R_{tot} = R_{pulm} + R_{syst}$$

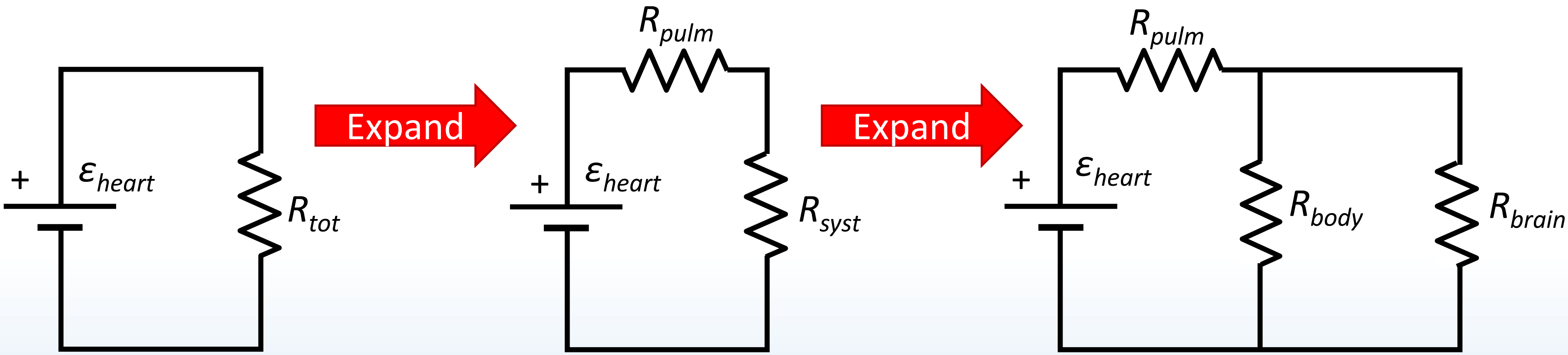
$$V_{tot} = V_{pulm} + V_{syst} = \varepsilon_{heart}$$

$$I_{pulm} = I_{syst} = I_{heart}$$

Calculation: circulatory system

Calculate current through each component of circulatory system

R_{pulm} = 12 Ω, R_{brain} = 1 kΩ, R_{body} = 160 Ω, ε_{heart} = 120 V



R_{brain} & R_{body} are in parallel

$$\frac{1}{R_{syst}} = \frac{1}{R_{brain}} + \frac{1}{R_{body}}$$

$$V_{syst} = V_{brain} = V_{body}$$

$$I_{syst} = I_{brain} + I_{body}$$

Summary of today's lecture

- Two basic principles:
- <u>Kirchhoff loop rule</u>

  Voltages around circuit loop sum to zero (based on conservation of energy)

$$\sum \Delta V = 0$$

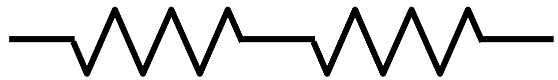
- <u>Kirchhoff junction rule</u>

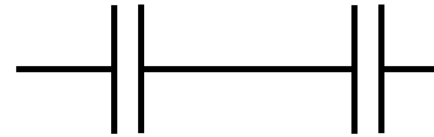
  Currents into a circuit branch equal currents out (based on conservation of charge)

$$\sum I_{in} = \sum I_{out}$$

Summary of today's lecture

- Series components





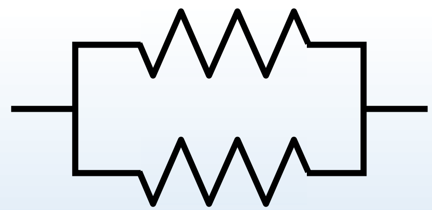
  Currents are the same $I_{eq} = I_1 = I_2$

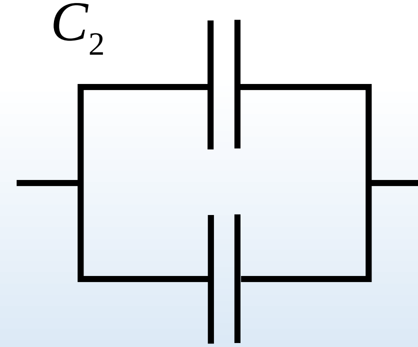
  Voltages add $V_{eq} = V_1 + V_2$

  Resistors $R_{eq} = R_1 + R_2$

  Capacitors $\dfrac{1}{C_{eq}} = \dfrac{1}{C_1} + \dfrac{1}{C_2}$

- Parallel components





  Voltages are the same $V_{eq} = V_1 = V_2$

  Currents add $I_{eq} = I_1 + I_2$

  Resistors $\dfrac{1}{R_{eq}} = \dfrac{1}{R_1} + \dfrac{1}{R_2}$

  Capacitors $C_{eq} = C_1 + C_2$

- Don't mix equations!