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Introduction Homeostasis/Cardiovascular System

M1 – Cardiovascular/Respiratory Sequence

Louis D'Alecy, Ph.D.

Fall 2008

University of Michigan
Medical School

Monday 10/27/08, 8:40
Sequence Introduction

(15 slides 20 minutes)

1. Organization
2. Testable Content etc.
3. Quizzes and Final

Primary Sequence Contacts

- Louis G. D'Alecy, Sequence Coordinator
- Professor of Physiology
- Department of Molecular and Integrative Physiology

- Sara J. Weir Staff Support

Cardiovascular Sequence -

-help you gain a basic understanding of the elements of structure and function of the CV-system in humans

-position you for life-long learning of these elements

Sequence “Philosophy”
&
CAUTIONS

- We are here to help you learn.
- We will try to integrate content across “presenters”.
- Medicine is an art as well as a science, thus there are few, if any, absolute truths.
- It is Pass/Fail so try to learn as well as pass the test!!
- Physiology is the scientific foundation of medicine.

I shalt not:

- “swear”
- “curse”
- “be crass”
- “use sailor talk”
- “be unprofessional”

At least I’ll try and when I fail -- and I will -- I am sorry.

SEQUENCE CONTENT??

Why Autonomic Physiology &

Pharmacology in CV-Resp Sequence?

Gross/Histo labs ** do dissections******

Computer Self-Study

Text books? …one each CV & Resp

Handouts? …many, many

"PORTAL"-- "notices" & damage control

Longitudinal case -- separate content

Small group -- only testable content only

TESTABLE CONTENT

(i.e.. “What’s on the test?”

Or ***** What can be on the test?)

Lecture coverage “primes the pump”

- **not inclusive, highlights, problem areas.**

Testable content is defined by :

lectures and specific objectives.

Specific objectives are “contract” with me.

Precious little can actually be tested

with three quizzes and

one comprehensive final!

Test Composition

Principles used in making up quizzes and final:

Lectures and objectives define testable content.

Content will be tested on **both** quiz and final.

Overall target is an approximately uniform number of questions for each regular lecture hour.

Each “lecture/lab combo” will be treated as two hours of lecture.

About 40 to 60 questions/quiz and **approximately** 100 on final.

All questions have equal weight, 75% is passing.

SEQUENCE CONTENT

(i.e.. “What you should learn?”)

Enough to: **“Do no Harm…..”**

and to

Establish a knowledge base for life long learning of the physiological basis of medicine -- the WHY.

Both are your professional responsibilities.

Without understanding WHY medicine becomes a trade not a profession!

Six Optional Reviews

Three reviews Pre - Quiz

10/31, 11/7, 11/14

One review Pre - Final 11/21

&

Post-Small Group

Q&A 11/6 and 11/20

Open, flexible, no video,

± Audience Response

Testing Highlights

Wk 1-Quiz on ~ 12 h Lect + 3 Lab

Wk 2-Quiz on ~ 14 h Lect + 1 Lab

Wk 3-Quiz on ~ 14 h Lect + 3 Lab

Wk 4-Comprehensive Final on~ 14 h Lect

+ all previous Lect + all previous Labs

"Course Pack" Highlights

- Small Group lists
- General info, TEXT *****
- Contacts
- Summary W-Lect
- Physiology overview
- OBJECTIVES/Lecture
- Selected Obj.
    - (Testable) & key words

Questions?

Text? Read them!!

Mohrman & Heller for CV

Levitzky for Respiration!

Homeostasis and Physiology

M1 – Cardiovascular/Respiratory Sequence

Louis D'Alecy, Ph.D.

Fall 2008

University of Michigan
Medical School

Monday 10/27/08, 9:00
Homeostasis & Physiology

(27 slides, 50 minutes)

1. Function & Survival
2. Internal Environment
3. Fluid Compartments
4. Quantitative Physiology
5. Control vs. Regulation
6. Reflex Arc
7. Negative, Positive, and other Feedback

Anatomy -the study of structure of living organisms

Physiology -the study of function in living organisms (Patients !!)

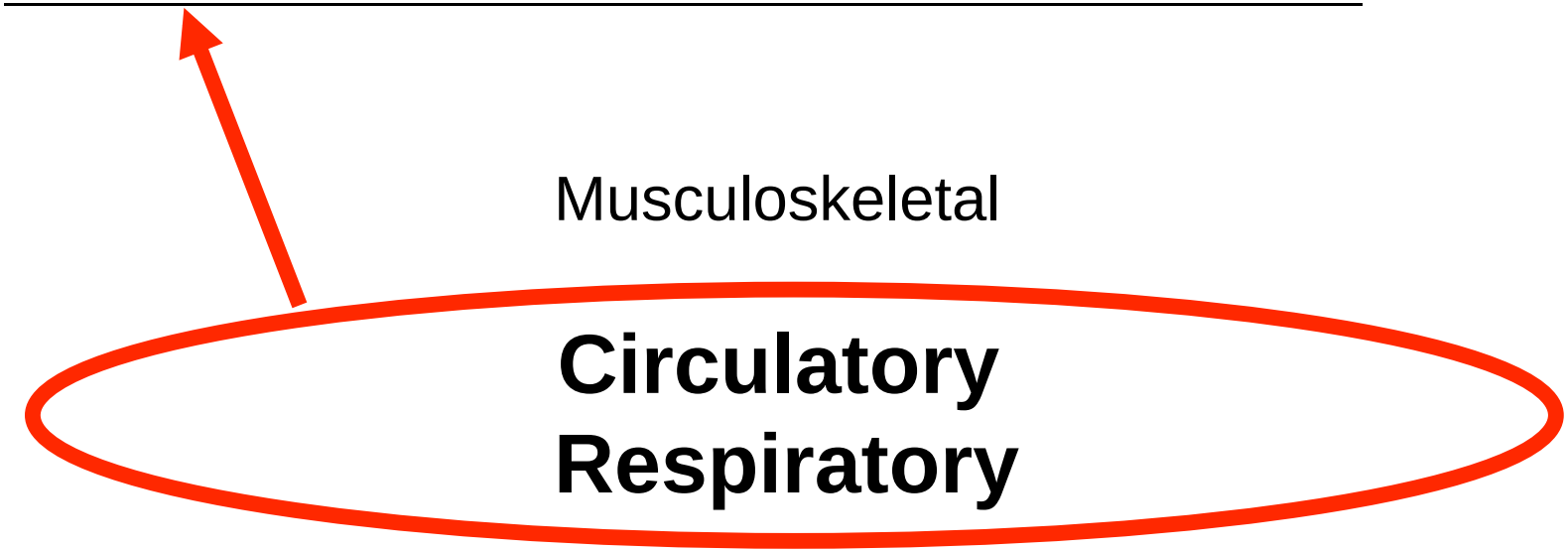
Physiology - the study of function in living organisms

Functions-

- survival of individual

- reproduction-- survival of species

SURVIVAL & INTEGRATED SYSTEMS

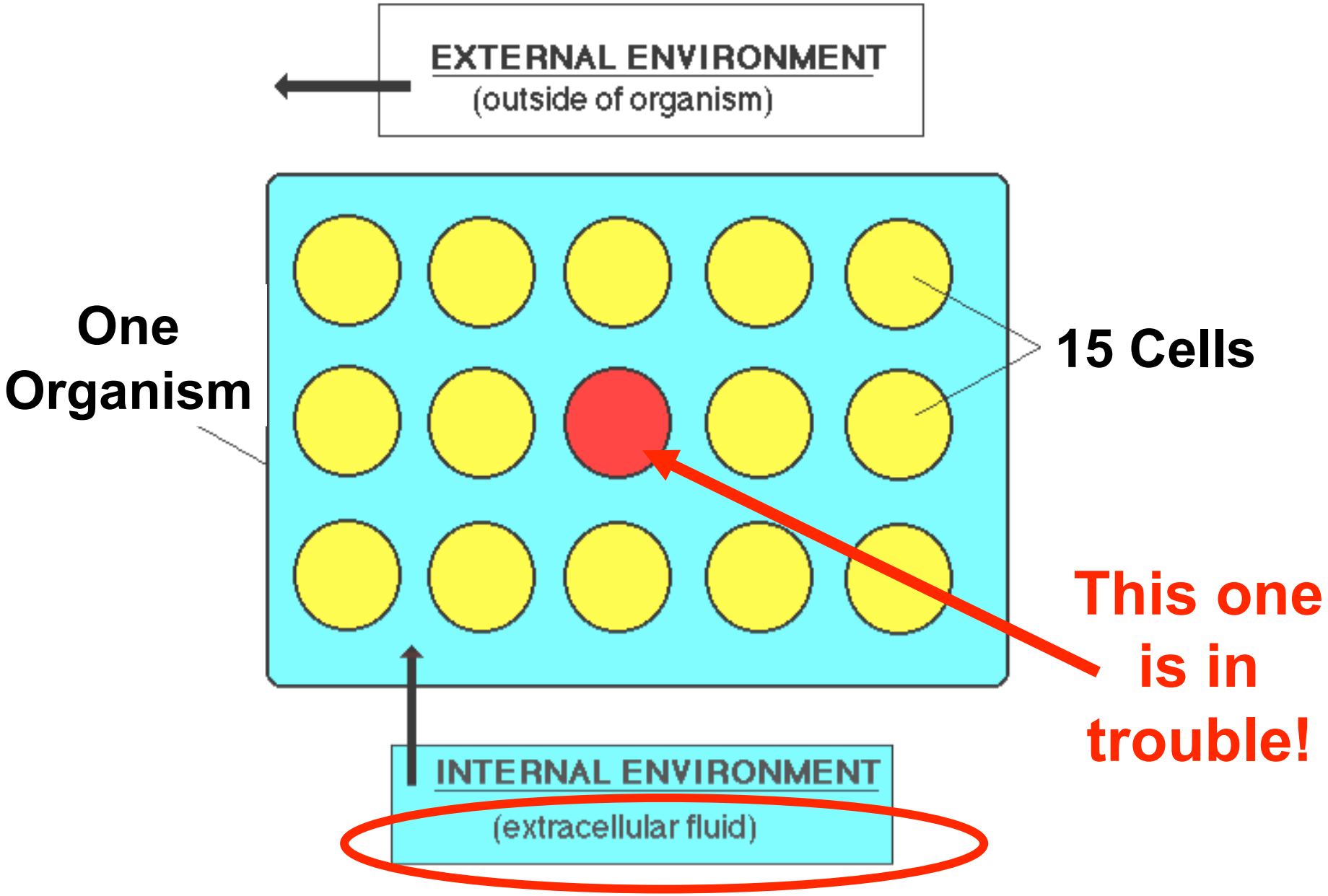


Nervous, Immune, Integumentry
Systems, & Psychosocial Systems

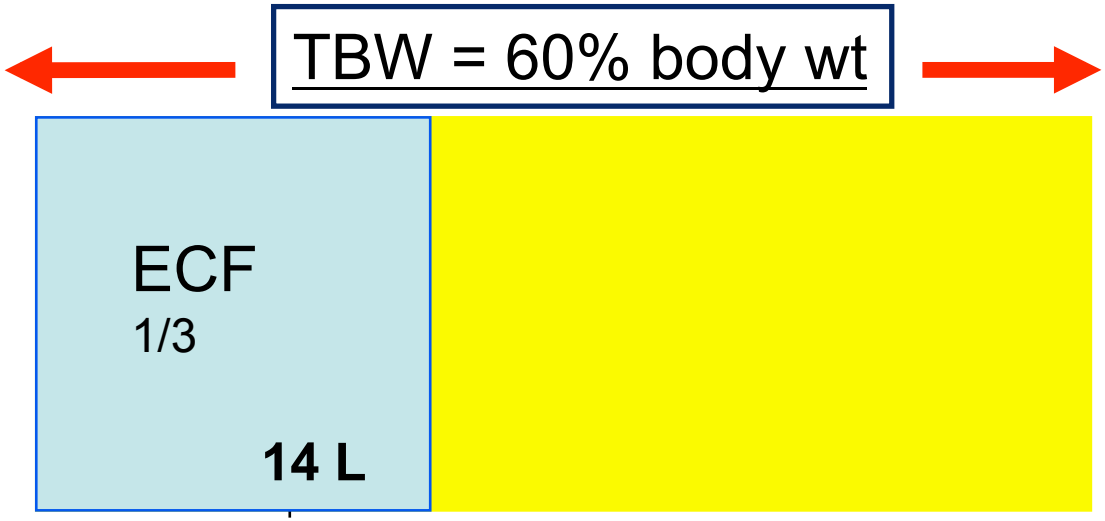
Survival of the individual depends upon the survival of the single cell.

Single cell survival depends on the composition of the environment immediately surrounding the individual cell.

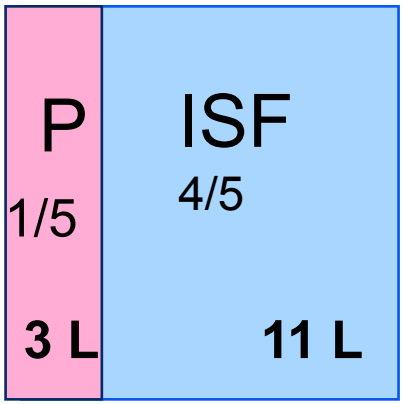
nutrients
oxygen
***** temperature *****
pH
osmolarity
ions - Na, K, Ca, Mg, HCO_3, Cl
toxic compounds
harmful microorganisms
etc., etc……..


EXTERNAL ENVIRONMENT
(outside of organism)
One Organism
15 Cells
This one is in trouble!
INTERNAL ENVIRONMENT
(extracellular fluid)

Fluid Compartments



INTERNAL ENVIRONMENT



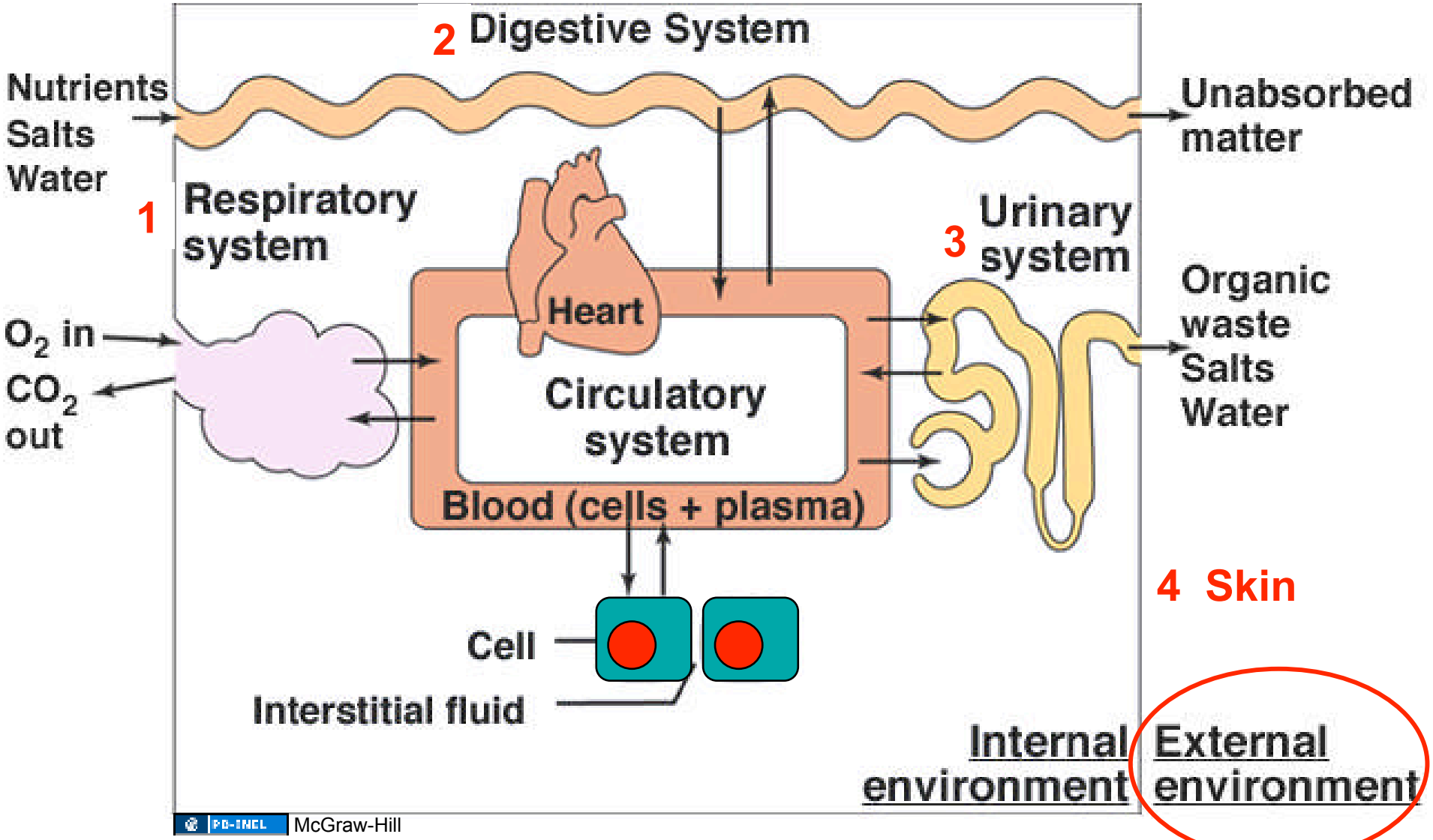
For a 70 Kg person

TBW = total body water = 42 L
ECF = extracellular fluid = 14 L
ICF = intracellular fluid = 28 L
P = plasma = 3 L
ISF = interstitial fluid = 11 L

1 thru 4 Interface Int/Ext Environments

Exchanges of matter

Circulatory System Interconnects Others



Claude Bernard (1813-1878)

130 Years ago

PD-EXP Léon Augustin L'hermitte, The Lesson of Claude Bernard (1813-78) Or, The Session at the Vivisection Laboratory

Relative Stability

of a Multi-cellular organism

"It is the fixity of the internal environment that is the condition of a free and independent life. All the vital mechanisms, however varied they may be, have only one object, that of preserving (constant) the conditions of life in the internal environment" 1878

Internal Environment = Extracellular Fluid

Walter B. Cannon (1871 - 1945)

The nearly constant state of the composition of the internal environment. 1926

HOMEOSTASIS - the relatively stable condition of the extracellular fluid that results from regulatory system actions.

"constancy" of the internal environment

Objectives

Student understands the concepts of the internal environment and homeostatic control systems:

1. States the importance of the internal environment for cell survival.
2. Defines and identifies the location of the internal environment.
3. States the relative magnitudes of the body's fluid compartments.

……etc. ……..

11. Defines the terms -set point and error signal.
12. Defines feedforward regulation.

KEY TERMS

internal environment
extracellular fluid (ECF)
intracellular fluid (ICF) … etc…..
error signal
feedforward

QUANTITATING PHYSIOLOGY

Absolute values:

body weight = 70 Kg (154 lbs)

total body water = 42 liters (11gal)

cardiac output = 5.5 liters/min

arterial blood pressure = 120/80 mmHg

art oxygen pressure(PO_2) = 100 mmHg

Assumes the “70 Kg man” -

avg. adult (male) human body

QUANTITATING PHYSIOLOGY

Absolute values:

total body water = 42 liters

cardiac output = 5.5 liters/min

Assumes the “70 Kg man” - AVG adult (male) human body

(200 lbs. = 90 Kg)

Normalized values:

--vary with body size, surface area, age, gender, etc.

--body surface area is based on height, wt, gender, and age

(70 kg man surface area 1.73 square meters)

Normalized values:

Example #1:

total body water = 0.6 liters/Kg of body weight

total body water = 70Kg X 0.6 liters/Kg = 42 liters

Example #2:

cardiac index = 3.2 L / min/m^2

cardiac index = $\frac{\text{5.5 liters/min}}{\text{1.73 } m^2}$ = $\frac{\text{cardiac output}}{\text{surface area}}$

(Assuming 70Kg man has surface area of 1.73 m^2)

CONDITIONS OF QUANTITATION
often
RESTING - BASAL STATE
BASAL METABOLIC RATE (BMR)

1. Awake - not asleep
2. Relaxed - not exercising
3. Fasting - not digesting a meal
4. At a comfortable environmental temperature
5. Emotionally relaxed - not stressed

- The metabolic energy to maintain BMR is about 75 kcal / hr which is similar to a 75 watt light bulb.
- "Physiological reference" - BMR not seen clinically
- Different parameters have other "conditions"

Homeostatic Control System (Regulation)
****Essential Questions****

1. What variable is “maintained” (regulated)?
2. How (where) is variable sensed?
3. How (where) is information integrated?
4. What effectors are controlled?
5. What is a set point?
6. What is an error signal?

Control vs. Regulate

Dictionary

Control: the power to influence or direct the course of events.

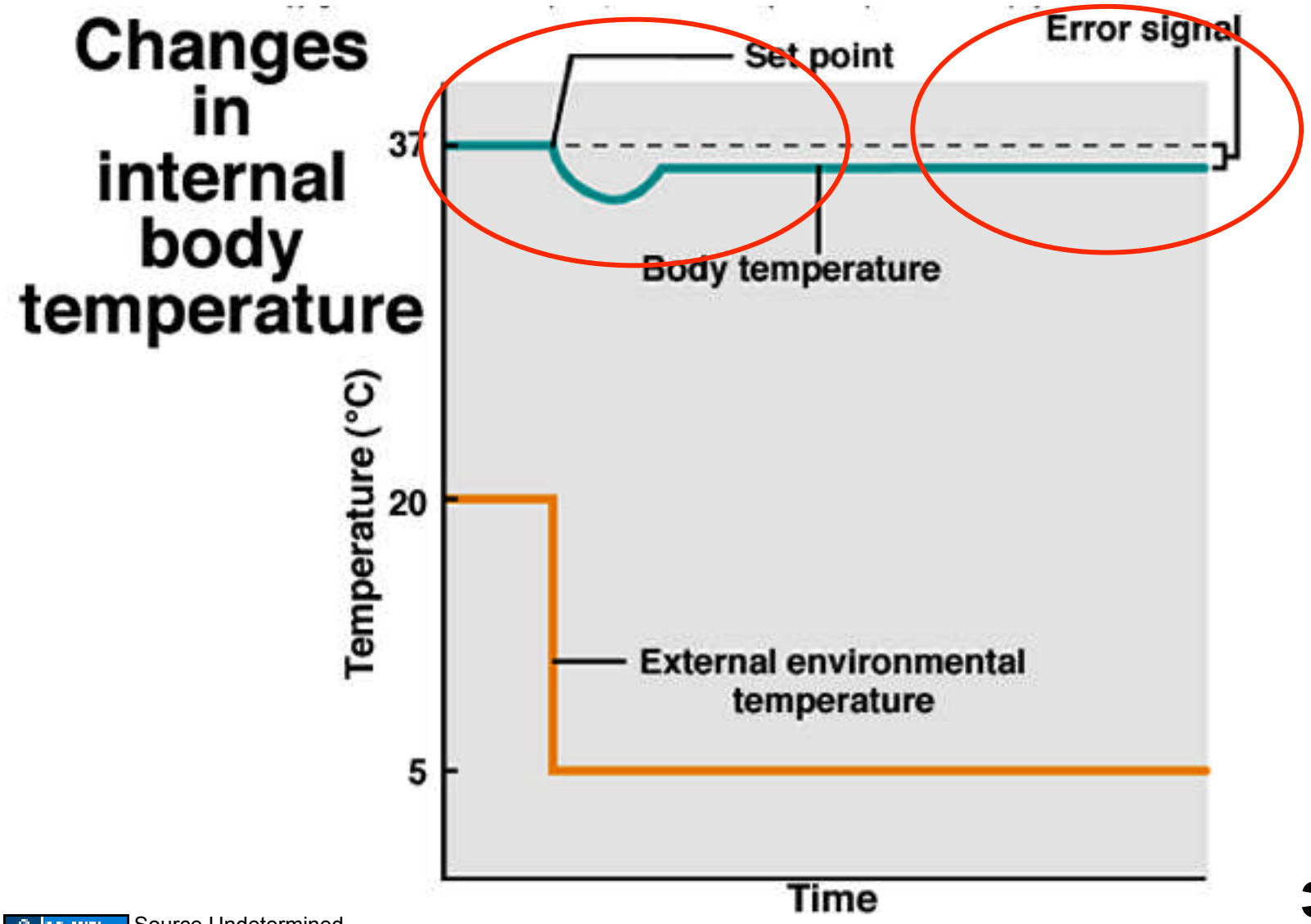
Regulate: to control or maintain a process so it operates properly.

Physiologist

Control: the ability to modify a physiological variable
i.e. ability to increase or decrease heart rate.

Regulate: sensing and maintaining a physiological variable within normal limits i.e. Baroreceptor sensing of arterial blood pressure and its reflex control within normal limits (set point).

Change Tb -- Set point & Error Signal



Definitions: set point & error signal

Set point: the steady state value maintained by homeostatic control systems.

Error signal: the steady state difference between the level of the regulated variable in a control system and the set point for that variable.

CONTROL SYSTEM GENERALIZATIONS

1. **Homeostatic control systems cannot maintain complete constancy of controlled variable. (Error signal ***)**

2. **It is not possible for everything to be maintained relatively constant by homeostatic control systems.**

3. **Stability of a variable is achieved by balancing inputs (+) and outputs (-).**

4. **The set point of a homeostatic control system can be reset - raised or lowered.**

5. **Multiple control systems can operate on the same variable.**

NEGATIVE FEEDBACK:

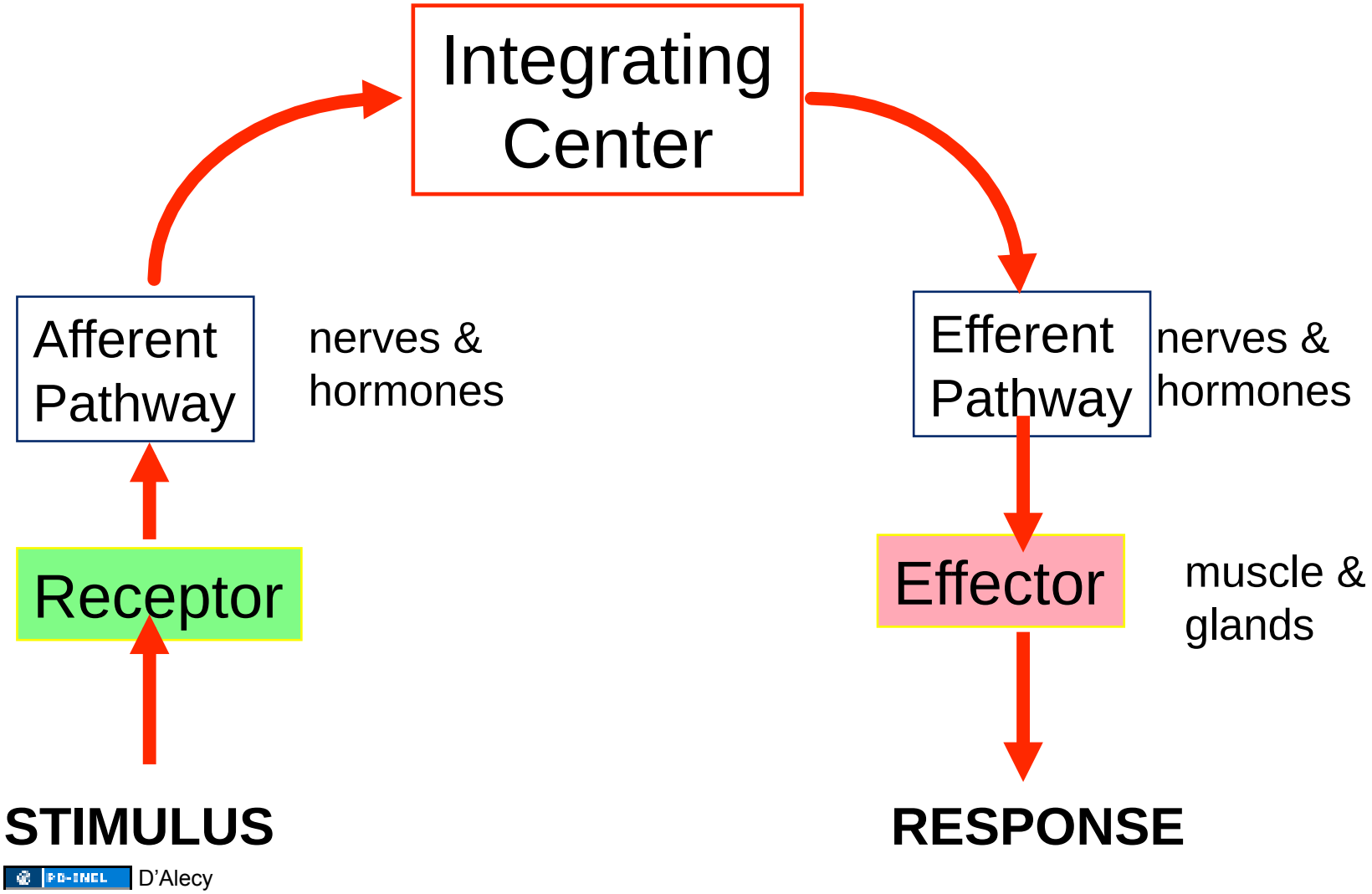
_____

_____**- is the major homeostatic mechanism**

In a negative feedback system the response moves stimulus in a direction opposite to (negative to) the direction of the original stimulus.

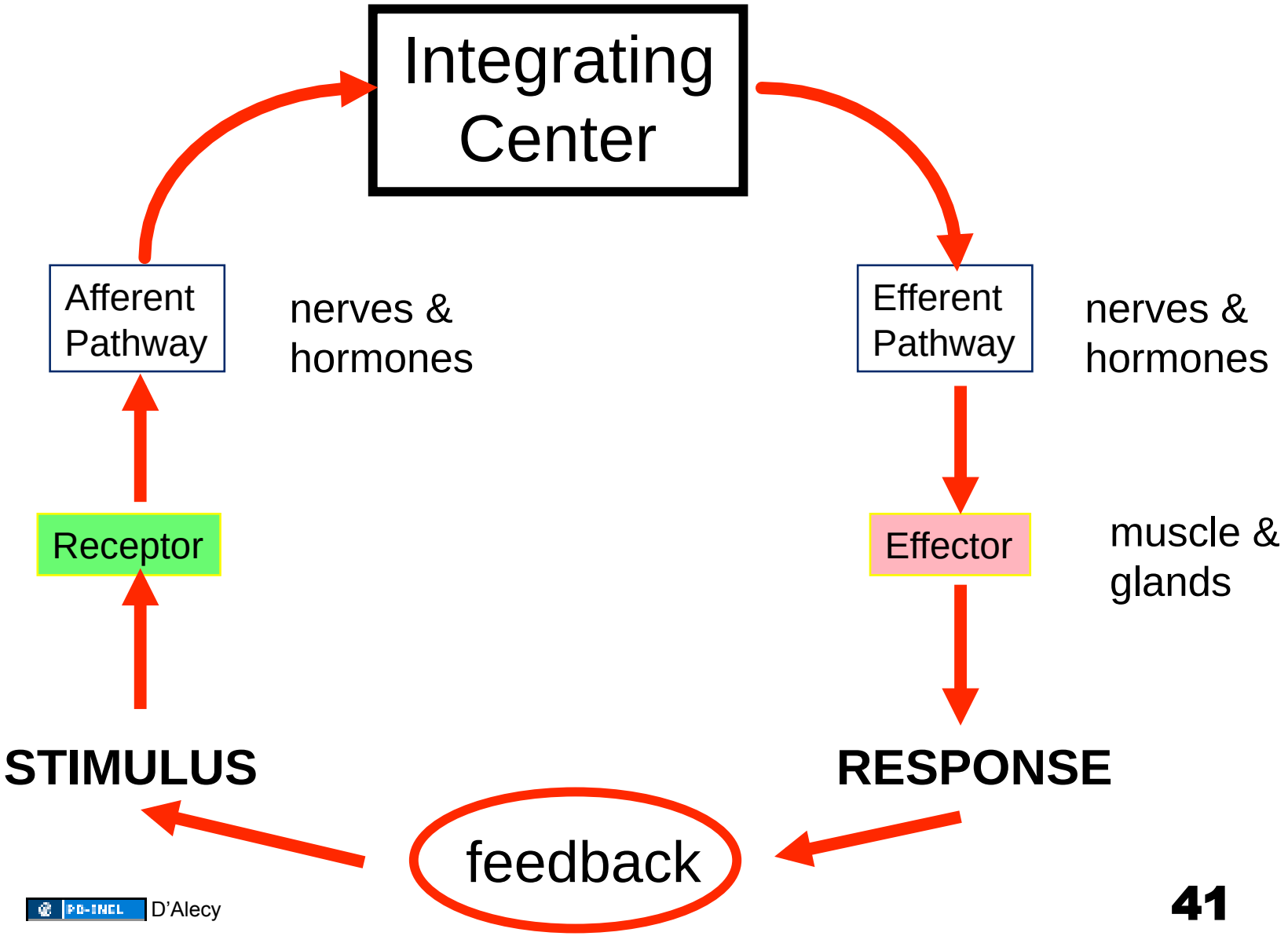
Examples: blood pressure,
body temperature, blood glucose

REFLEX ARC



PG-INCL D'Alecy

REGULATION (CONTROL) SYSTEM



POSITIVE FEEDBACK:

_____ - unstable - explosive - but useful

Response moves stimulus in the same (positive) direction as the original stimulus.

Examples: blood clotting , parturition
LH surge during ovarian cycle,
pepsin activation in stomach,
rising phase of action potential

Feedforward - system **anticipates** change in a controlled (regulated) variable before it occurs by monitoring changes in the external environment.

Examples:

1) Skin temperature receptors alter the body's heat production and heat loss mechanisms before there is a change in core body temperature.

2) Glucose receptors in GI tract increase insulin secretion before glucose absorption has raised blood glucose.

Homeostatic Control System
Essential Question
"Same Question(s)"

What are the cause and effect sequences of physical and chemical events that lead to a particular

increase or decrease

in a function (or variable) in response to a change in the internal environment?

Summary
HOMEOSTATIC CONTROL SYSTEMS

- **REFLEX** Involuntary, built-in response to a stimulus
- **REFLEX ARC** Pathway(s) between stimulus and response in a reflex
- **NEGATIVE FEEDBACK SYSTEM**
- Responses tend to move variable back in the opposite direction.
- **POSITIVE FEEDBACK SYSTEM**

  Response moves the variable further in the same direction.
- **SET POINT** The normal value for the variable to be controlled.

  Set point can be physiologically reset (e.g. fever)
- **ERROR SIGNAL** Difference between set point and actual value of variable.

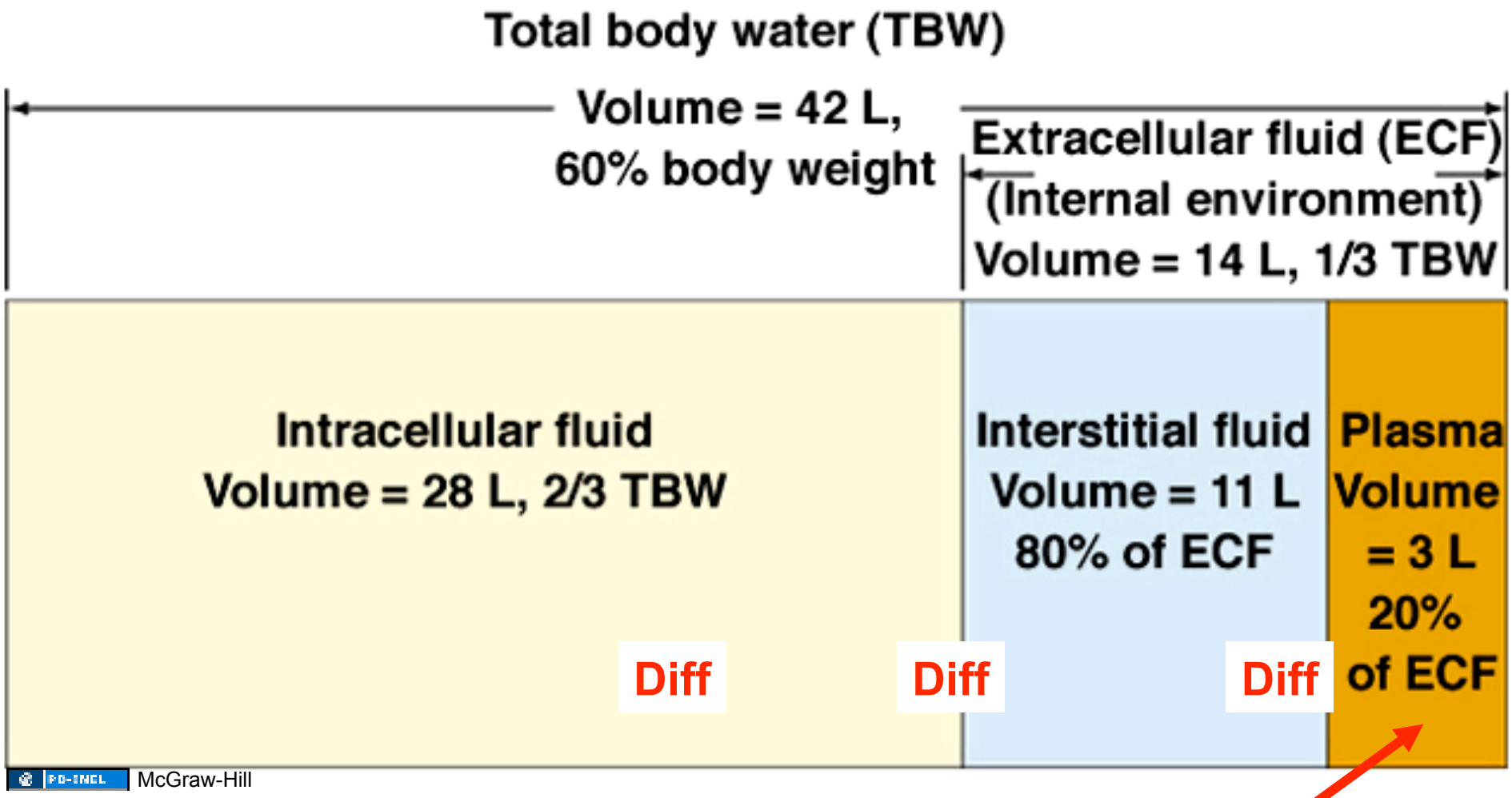
Monday 10/27/08, 10:00 Fundamentals of Cardiovascular System (24 Slides 50 minutes)

- CV Physiology Week #1 Outline
- Bulk flow vs. Diffusion Exchange of matter
- “Physiological structure”
- Circuit
- Valves & Pumps
- Metabolic Exchange

Week #1 Fundamentals of Cardiovascular Physiology

1.- Introduction and Homeostasis	10/27/08
2.- Physiologic Basis Of Cardiovascular System	10/27/08
3- Cardiac Muscle	10/28/08
4- Cardiac Mechanics	10/28/08
5- Cardiac Hydraulics	10/29/08
6- Physiological basis of ECG I	10/31/08
7- Physiological basis of ECG II	10/31/08

Fluid compartments of the body



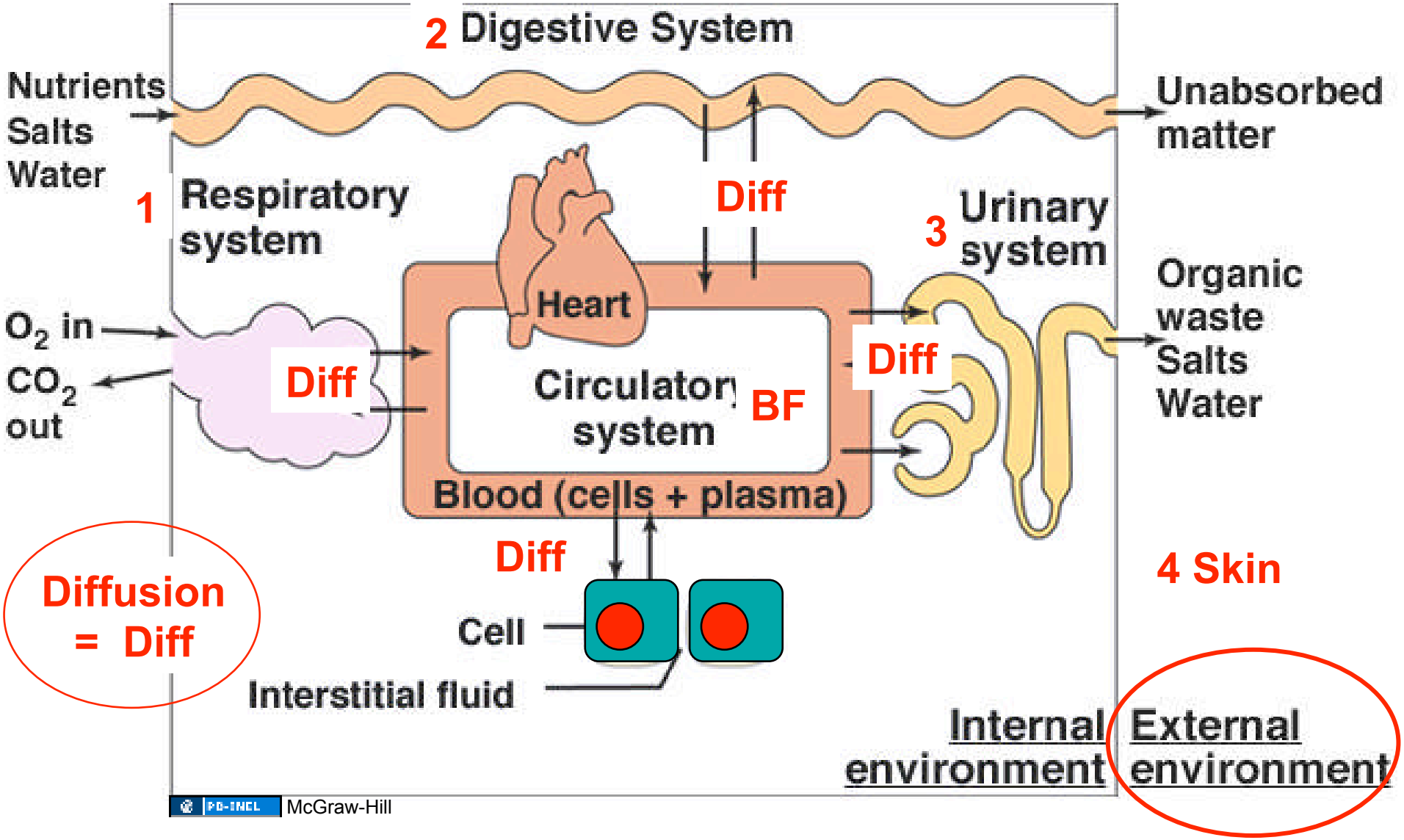
Bulk Flow: the movement of fluids or gases from a region of higher pressure to one of lower pressure.

Diffusion: the movement of molecules from a region of higher concentration to a region of lower concentration.

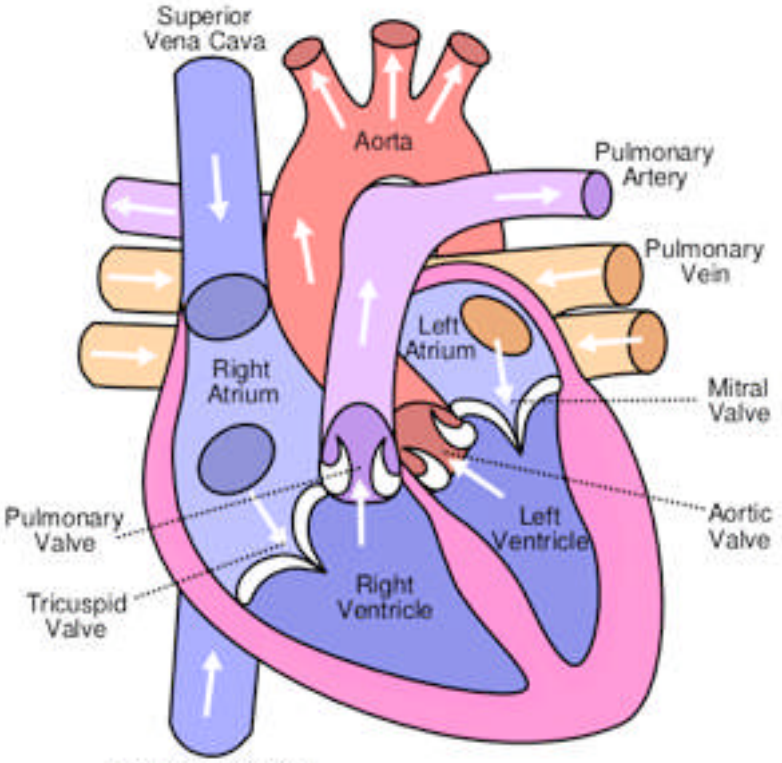
Exchanges of matter

Bulk Flow =BF

Circulatory System Interconnects Others By BF



Diffusion = Diff



GNU-FDL Yaddah (Wikimedia)

Image of systemic and pulmonary circulation removed

Please see: http://www.mhhe.com/biosci/esp/2001_gbio/folder_structure/an/m7/s3/assets/images/anm7s3_1.jpg

Original Image: McGraw-Hill, M&H Fig 1-4

Total Blood Volume Distribution

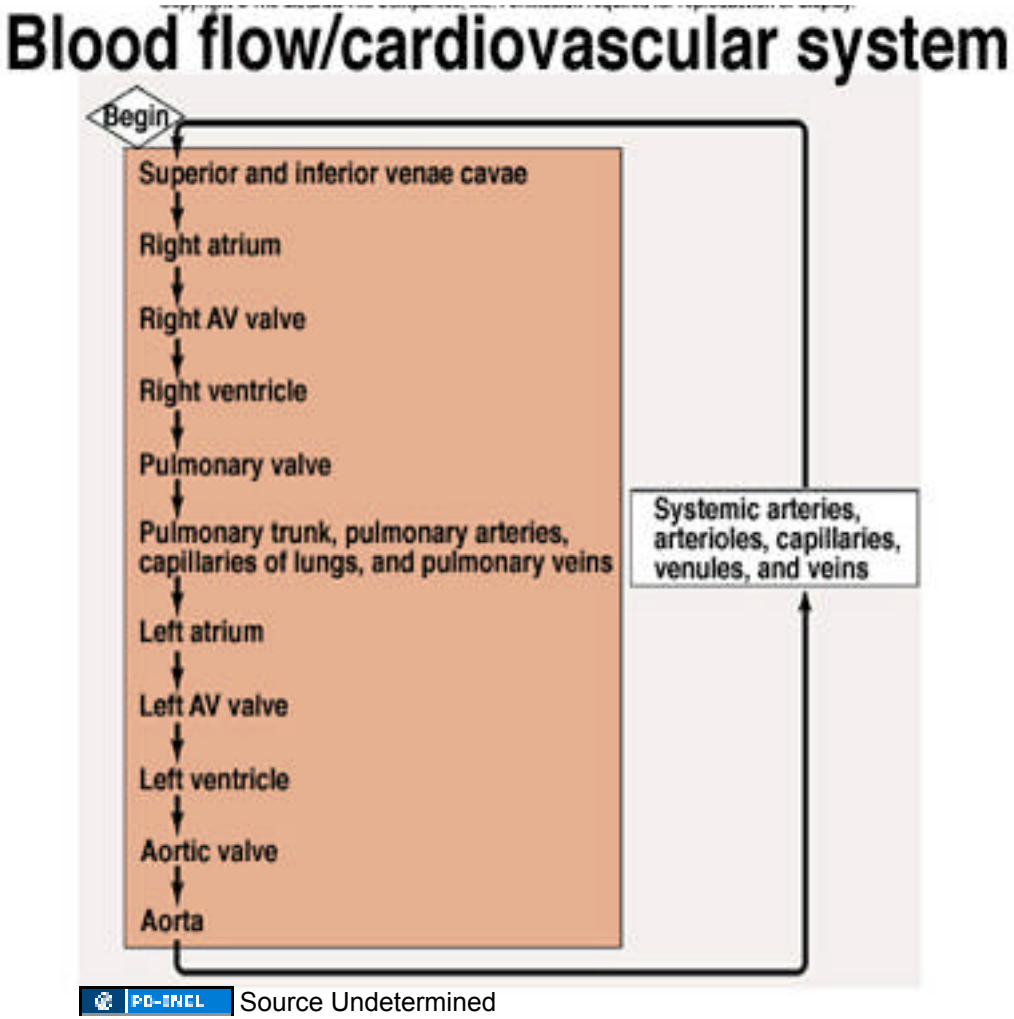
Pulmonary Circulation: 12%

Heart: 9%

Arteries: 11%

Arterioles/Capillaries: 7%

Veins/Venules: 61%



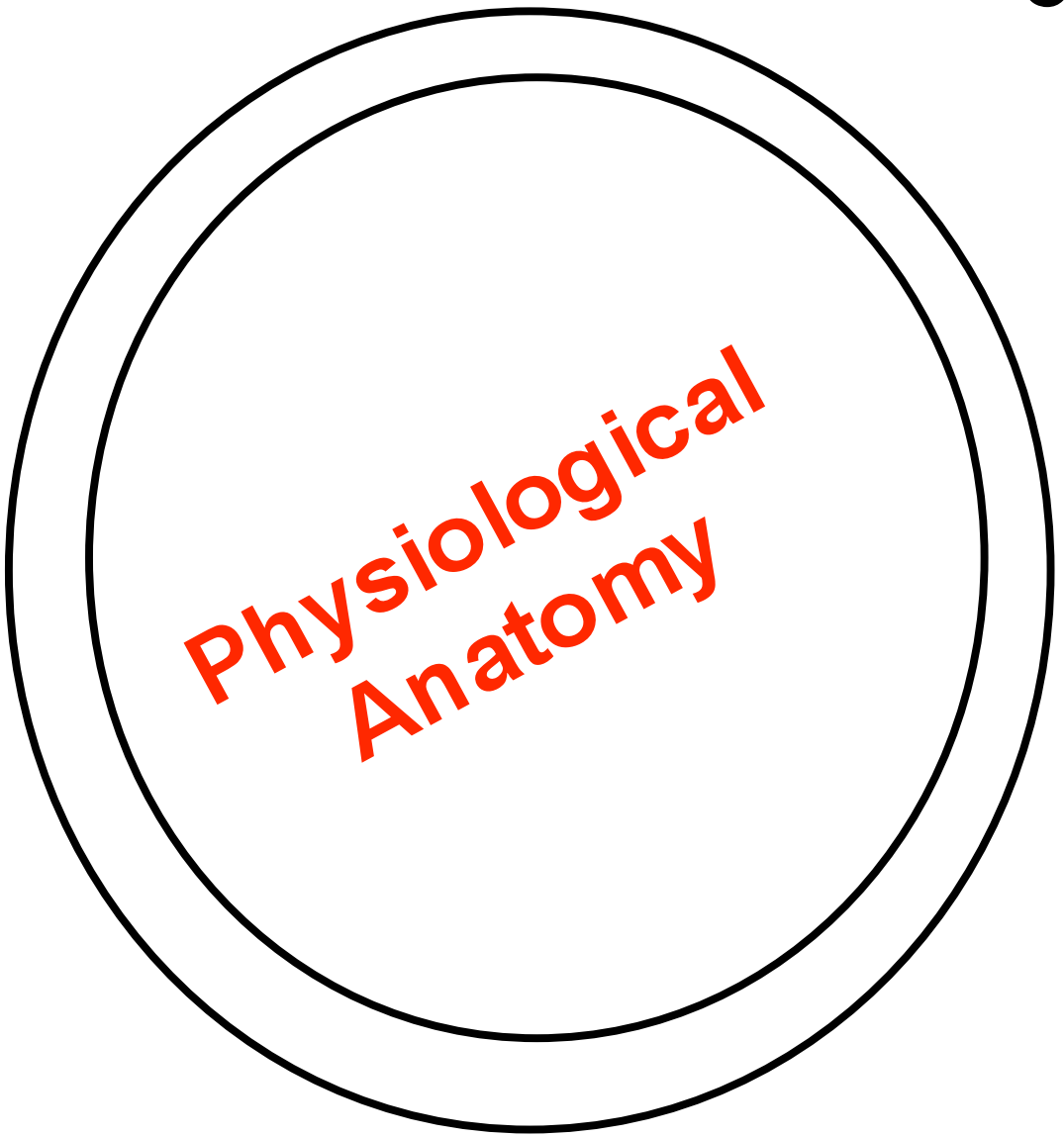
PD-INCL Source Undetermined

Essential Circulatory Role in Homeostasis
~ "constancy" of internal environment

(1) Adequate blood **flow** through capillaries

(2) Adequate blood **composition** for maintaining interstitial fluid composition and thus function.

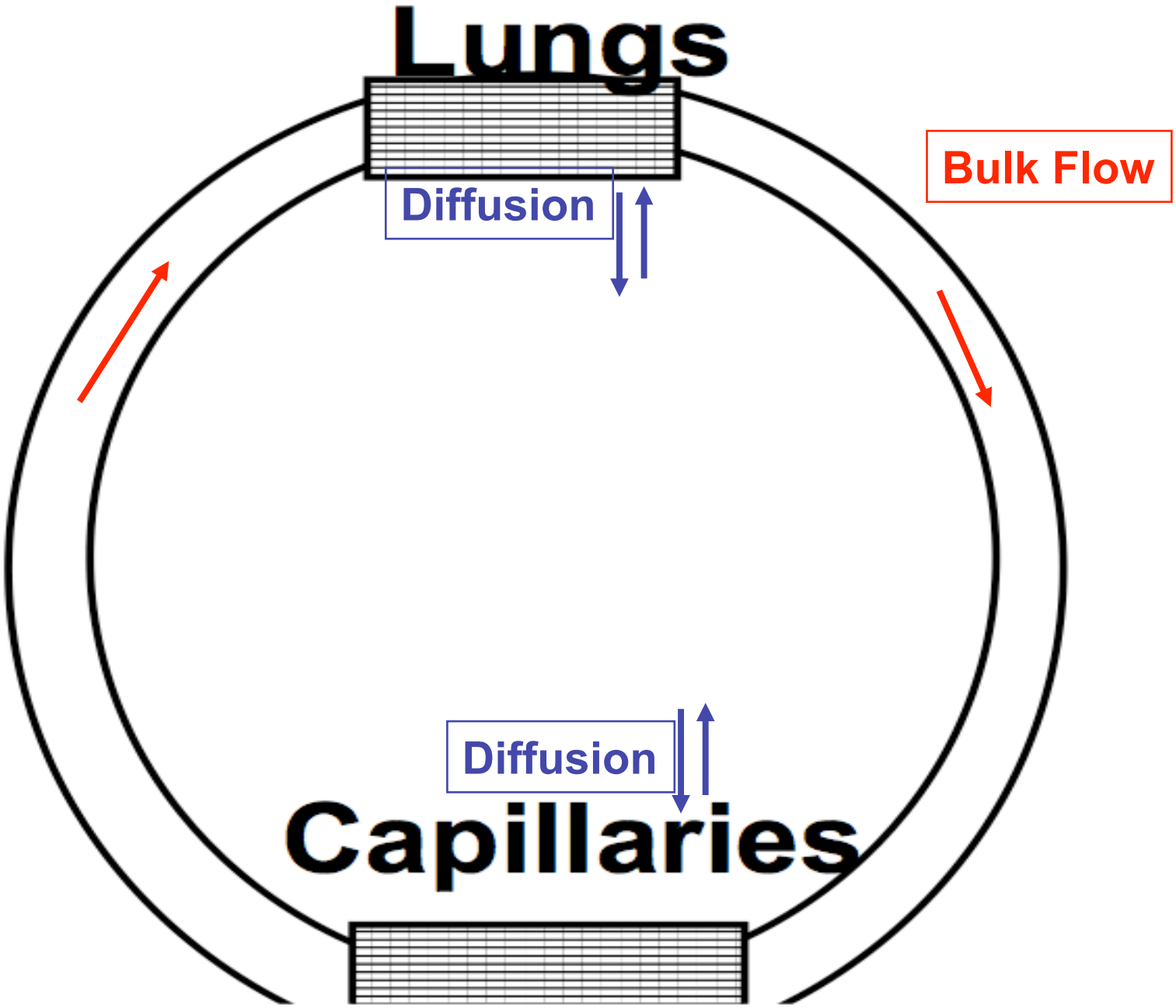
The “Circulation” is a Continuous Tube or Circuit

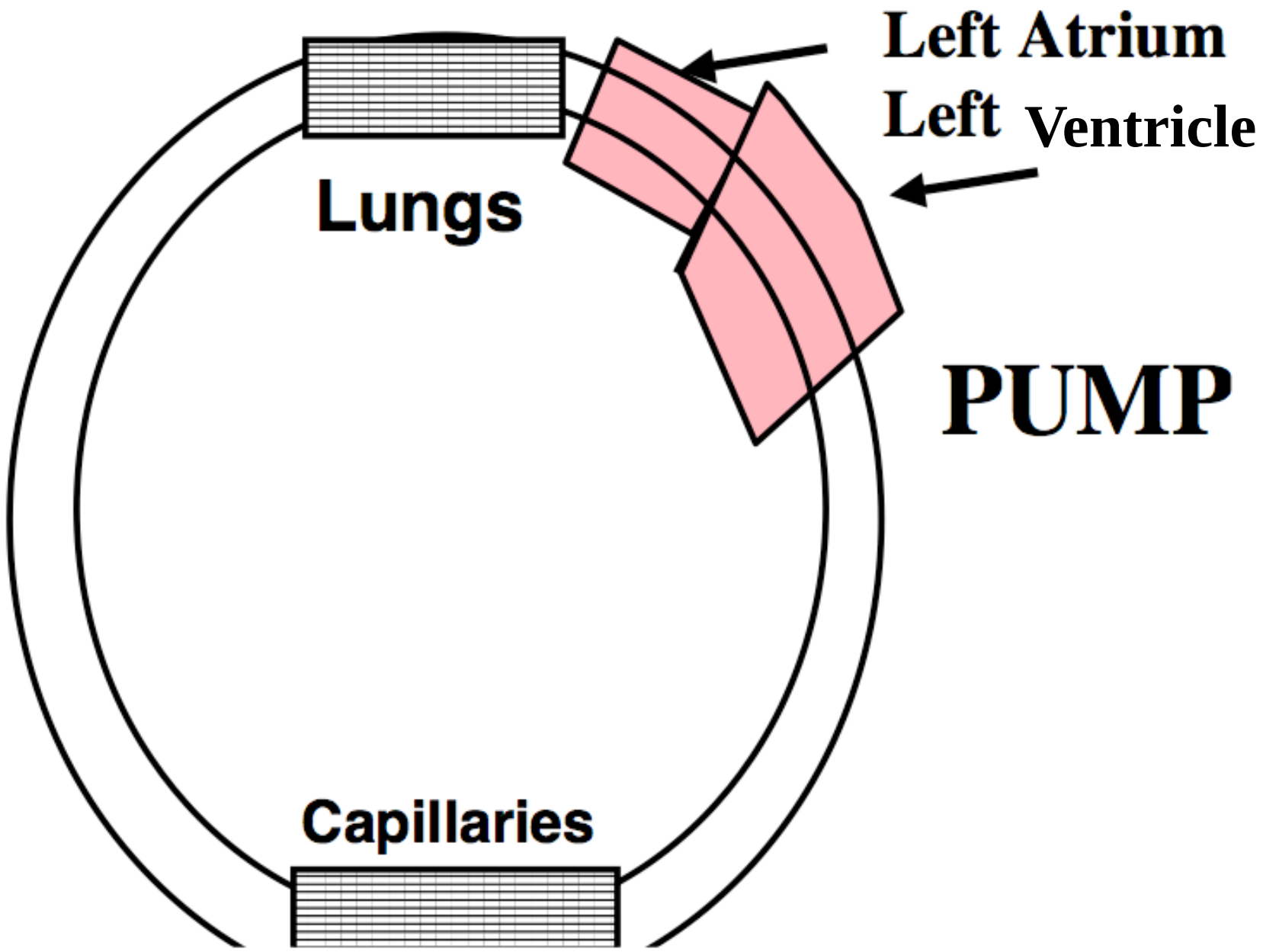


Physiological Anatomy

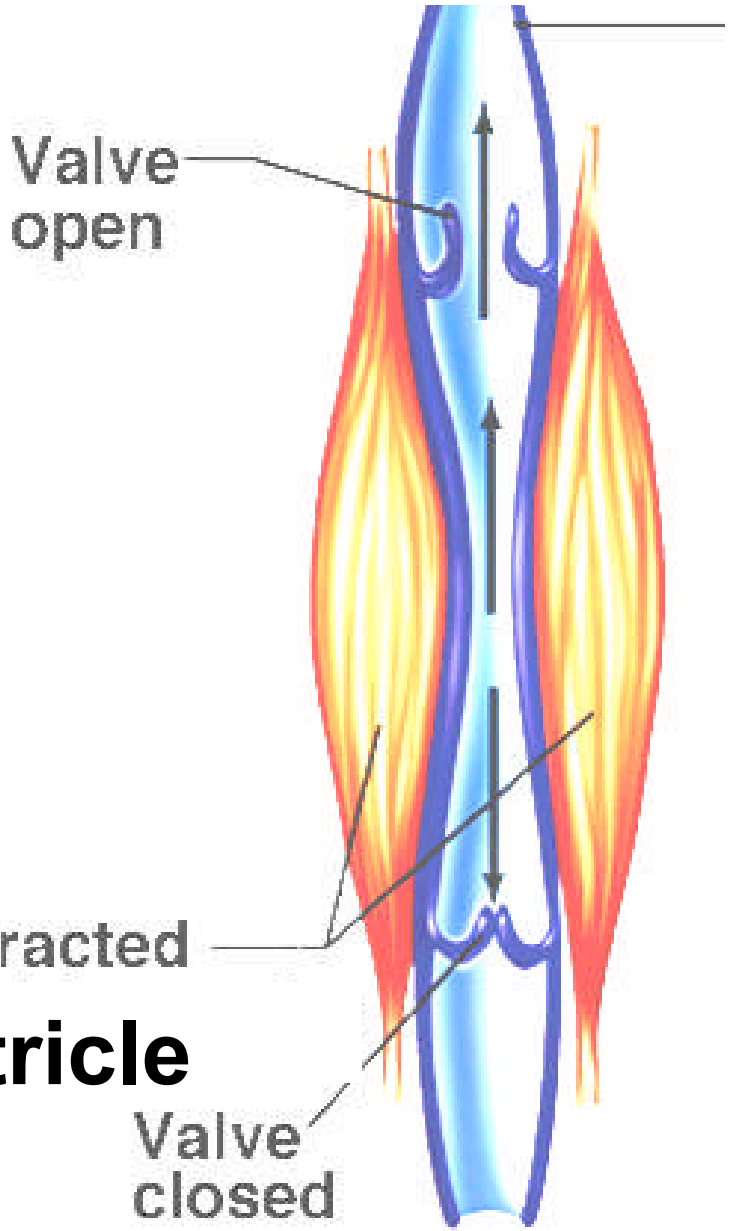
PD-INCL D'Alecy

Image of Dr. D'Alecy and students removed

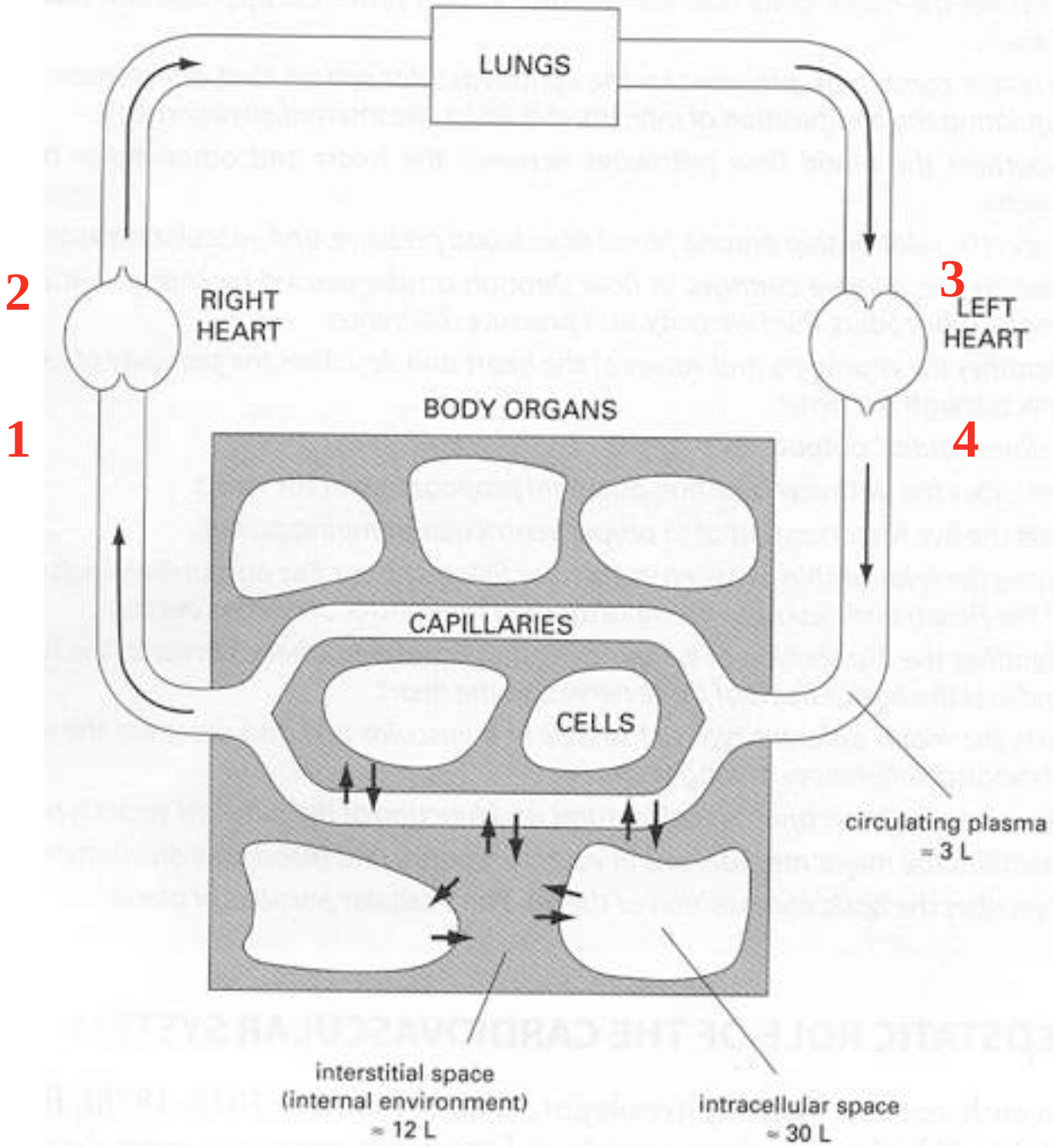

Lungs
Diffusion
Bulk Flow
Diffusion
Capillaries



One Way Valves



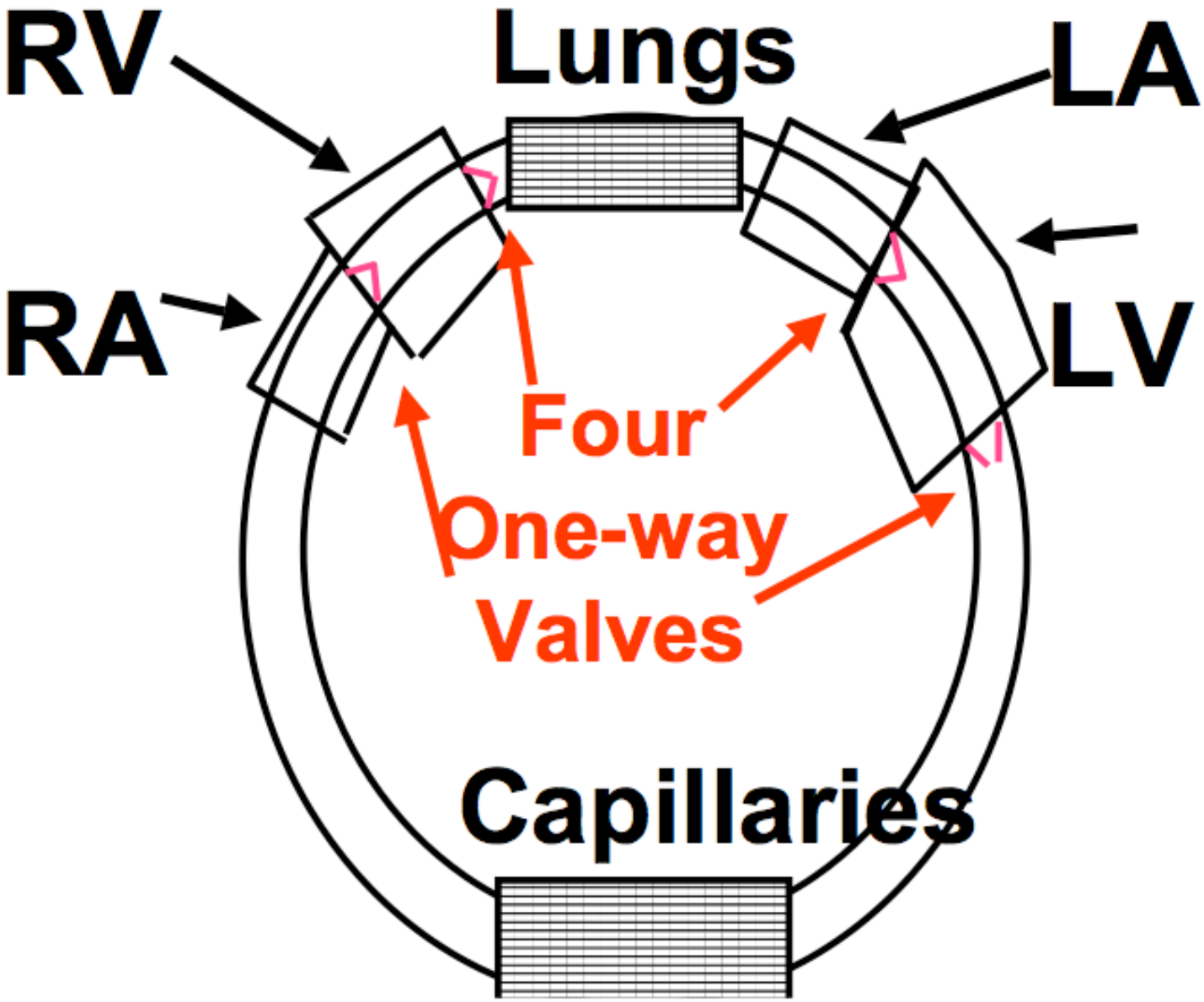
Blood Flows Only Through Open Valves



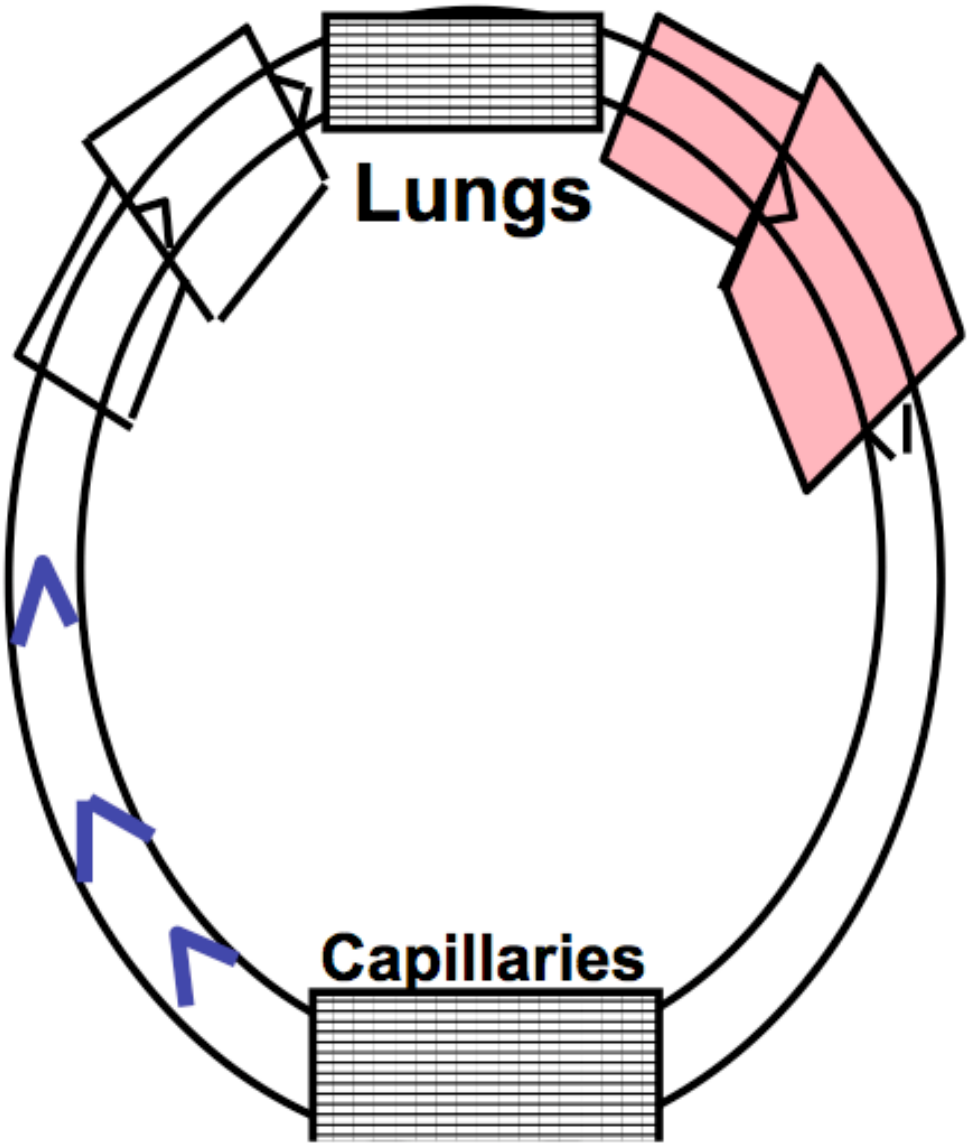
Four valves

MH Fig 1.1

 Mohrman and Heller. Cardiovascular Physiology. McGraw-Hill, 2006. 6th ed.



Venous One-Way Valves



Specific Bulk Flow = Blood Flow

$$\textbf{Blood Flow} = \frac{\textbf{Pressure Difference}}{\textbf{Resistance}}$$

WORD EQUATION: Blood flow is directly proportional to pressure difference and inversely proportional to resistance.

To increase blood flow

increase the pressure difference
or
decrease the resistance to flow.

BLOOD FLOW:

is measured in a volume / time.

e.g. mL / min or L / min

BLOOD COMPOSITION:

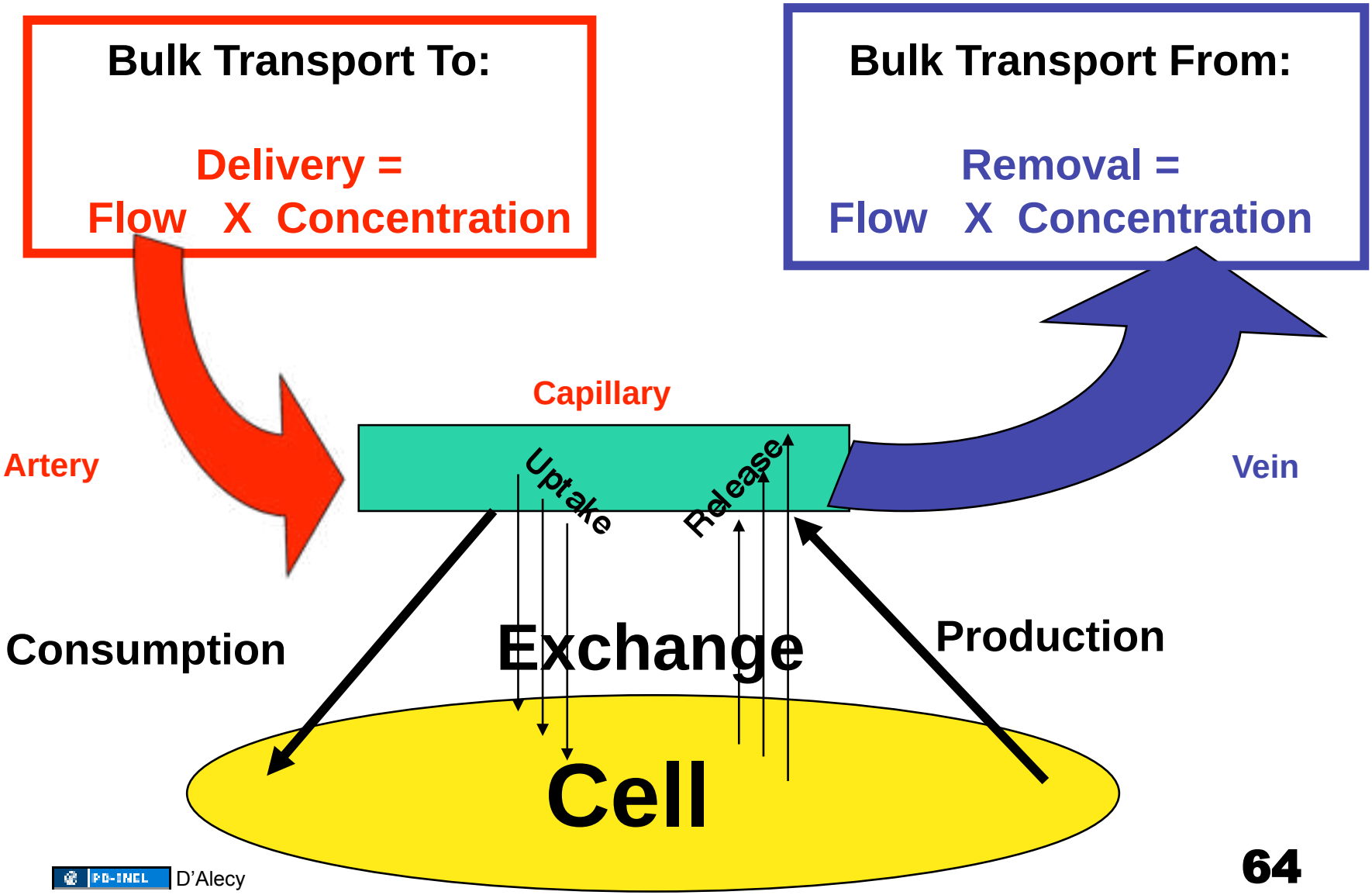
(or concentration)

is measured in (amount) mass / volume.

e.g. mg / mL

Note: Normal blood flow is a special form of bulk flow in blood vessels.

METABOLIC EXCHANGE



So what -- “exchange”?

- Not just abstract concept.
- Integral part of medical practice.
- Essential for patient management in
  - Intensive care unit (ICU)
- Oxygen delivery (DO_2)
  - vs. consumption (VO_2) integrates cardiovascular and respiratory function.
- “This is what we do -- optimize O_2 delivery.”

STANDARD EXCHANGE FORMULAS

Amount / time = volume / time X conc.

mg/min = mL / min X mg / mL

DELIVERY = Arterial Blood Flow X Arterial Blood Concentration

REMOVAL = Venous Blood Flow X Venous Blood Concentration

CONSUMPTION = DELIVERY **-** REMOVAL (page 65 & 95 M&H Fick Prin as utilization)

PRODUCTION = REMOVAL **-** DELIVERY

Amount of glucose **delivered** per unit time is equal to the volume of blood delivered per unit time(flow) multiplied by the concentration of glucose in g/L in that blood.

DELIVERY = Arterial Blood Flow X Arterial Blood Concentration

Example

Amount / time = volume / time X concentration

Amount / time = flow X concentration

grams/min = L / min X grams / L

5g/min = 5L / min X 1g / L

Fick Principle

When:

Arterial Blood Flow = Venous Blood Flow = **FLOW**

CONSUMPTION = FLOW(Art. Conc. **-** Venous Conc.)

PRODUCTION = FLOW (Venous Conc. **-** Art. Conc.)

Varying Role of Cardiovascular System Depending on Routes of Administration

Intravenous
Intra-arterial

Intramuscular
Subcutaneous

Intradermal
Transdermal

Inhalation
Intra-ocular
Nasal
Topical

Additional Source Information

for more information see: http://open.umich.edu/wiki/CitationPolicy

Slide 24: D' Alecy

Slide 25: D' Alecy

Slide 26: McGraw-Hill

Slide 27: Léon Augustin L'hermitte, The Lesson of Claude Bernard (1813-78) Or, The Session at the Vivisection Laboratory in Nature Reviews Molecular Cell Biology 2, 703-708 (September 2001), http://www.nature.com/nrm/journal/v2/n9/images/nrm0901_703a_f1.gif

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