Author(s): Louis D’Alecy, 2009

License: Unless otherwise noted, this material is made available under the terms of the Creative Commons Attribution–Non-commercial–Share Alike 3.0 License: http://creativecommons.org/licenses/by-nc-sa/3.0/

We have reviewed this material in accordance with U.S. Copyright Law and have tried to maximize your ability to use, share, and adapt it. The citation key on the following slide provides information about how you may share and adapt this material.

Copyright holders of content included in this material should contact open.michigan@umich.edu with any questions, corrections, or clarification regarding the use of content.

For more information about how to cite these materials visit http://open.umich.edu/education/about/terms-of-use.

Any medical information in this material is intended to inform and educate and is not a tool for self-diagnosis or a replacement for medical evaluation, advice, diagnosis or treatment by a healthcare professional. Please speak to your physician if you have questions about your medical condition.

Viewer discretion is advised: Some medical content is graphic and may not be suitable for all viewers.
Citation Key
for more information see: http://open.umich.edu/wiki/CitationPolicy

Use + Share + Adapt

{ Content the copyright holder, author, or law permits you to use, share and adapt. }

Public Domain – Government: Works that are produced by the U.S. Government. (USC 17 § 105)
Public Domain – Expired: Works that are no longer protected due to an expired copyright term.
Public Domain – Self Dedicated: Works that a copyright holder has dedicated to the public domain.
Creative Commons – Zero Waiver
Creative Commons – Attribution License
Creative Commons – Attribution Share Alike License
Creative Commons – Attribution Noncommercial License
Creative Commons – Attribution Noncommercial Share Alike License
GNU – Free Documentation License

Make Your Own Assessment

{ Content Open.Michigan believes can be used, shared, and adapted because it is ineligible for copyright. }

Public Domain – Ineligible: Works that are ineligible for copyright protection in the U.S. (USC 17 § 102(b)) *laws in your jurisdiction may differ

{ Content Open.Michigan has used under a Fair Use determination. }

Fair Use: Use of works that is determined to be Fair consistent with the U.S. Copyright Act. (USC 17 § 107) *laws in your jurisdiction may differ

Our determination DOES NOT mean that all uses of this 3rd-party content are Fair Uses and we DO NOT guarantee that your use of the content is Fair.
To use this content you should do your own independent analysis to determine whether or not your use will be Fair.
Introduction
Homeostasis/Cardiovascular System
M1 – Cardiovascular/Respiratory Sequence
Louis D’Aleyc, Ph.D.

Fall 2008
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’Aleyecy, Ph.D.

Fall 2008
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

Musculoskeletal

Circulatory
Respiratory

Urinary
Digestive
Endocrine
(Reproductive)

Nervous, Immune, Integumentary
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........
One Organism

15 Cells

EXTERNAL ENVIRONMENT
(outside of organism)

INTERNAL ENVIRONMENT
(extracellular fluid)

This one is in trouble!
Fluid Compartments

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
Circulatory System Interconnects Others

1 thru 4 Interface Int/Ext Environments

1 Respiratory system
2 Digestive System
3 Urinary system
4 Skin

Exchanges of matter

Nutrients salts water
O₂ in CO₂ out

Blood (cells + plasma)

Cell Interstitial fluid

Internal environment

External environment

Unabsorbed matter
Organic waste salts water

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

“We 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)
- error signal
- feedforward

… etc…..
QUANTITATING PHYSIOLOGY

Absolute values:

- body weight = 70 Kg (154 lbs)
- total body water = 42 liters (11 gal)
- cardiac output = 5.5 liters/min
- arterial blood pressure = 120/80 mmHg
- art oxygen pressure (PO₂) = 100 mmHg

Assumes the “70 Kg man” -
avg. adult (male) human body
### 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/m²

\[
\text{cardiac index} = \frac{5.5 \text{ liters/min}}{1.73 \text{ m}^2} = \text{cardiac output} \\
\text{(Assuming 70Kg man has surface area of 1.73 m}^2) \\
\]
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 $T_b$ -- Set point & Error Signal

Changes in internal body temperature

Body temperature

Set point

Error signal

Temperature (°C)

External environmental temperature

Time
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

Integrating Center

Afferent Pathway

| Receptor | nerves & hormones |

Efferent Pathway

| Effector | nerves & hormones |

muscle & glands

STIMULUS

RESPONSE
REGULATION (CONTROL) SYSTEM

Integrating Center

Afferent Pathway

nerves & hormones

Receptor

Efferent Pathway

nerves & hormones

Effector

muscle & glands

STIMULUS

RESPONSE

feedback

D'Alecy
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

Total body water (TBW)

- Volume = 42 L, 60% body weight
- Extracellular fluid (ECF)
  - Volume = 14 L, 1/3 TBW

- Intracellular fluid
  - Volume = 28 L, 2/3 TBW
- Interstitial fluid
  - Volume = 11 L, 80% of ECF
- Plasma
  - Volume = 3 L, 20% of ECF

Bulk flow of blood (plasma)
**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

1. Respiratory system
   - Nutrients
   - Salts
   - Water
   - O₂ in
   - CO₂ out

2. Digestive system
   - Unabsorbed matter

3. Urinary system
   - Organic waste
   - Salts
   - Water

4. Skin

Diffusion = Diff

BF

Diff

Cell

Interstitial fluid

Internal environment

External environment
Total Blood Volume Distribution

Pulmonary Circulation: 12%
Heart: 9%
Arteries: 11%
Arterioles/Capillaries: 7%
Veins/Venules: 61%
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
Physiological Anatomy

Image of Dr. D’Aley and students removed
Lungs

Diffusion

Bulk Flow

Capillaries

Diffusion
Left Atrium
Left Ventricle
Lungs
Capillaries
PUMP
One Way Valves

Blood Flows Only Through Open Valves

Ventricle

Valve open

Valve closed

Contracted

Source Undetermined
Four valves
Four One-way Valves
Venous One-Way Valves
Specific Bulk Flow = Blood Flow

\[
\text{Blood Flow} = \frac{\text{Pressure Difference}}{\text{Resistance}}
\]

**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

Bulk Transport To:
Delivery = Flow \times Concentration

Bulk Transport From:
Removal = Flow \times Concentration

Artery
Capillary
Vein
Consumption
Production
Exchange
Cell

Uptake
Release
D'Alecy
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 × conc.

mg/min = mL/min × mg/mL

DELIVERY = Arterial Blood Flow × Arterial Blood Concentration

REMOVAL = Venous Blood Flow × Venous Blood Concentration

CONSUMPTION = DELIVERY - REMOVAL (page 65 & 95

M&H Fick Principle 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  \times Arterial Blood Concentration

**Example**

\[
\text{Amount / time} = \frac{\text{volume}}{\text{time}} \times \text{concentration}
\]

\[
\text{Amount / time} = \frac{\text{flow}}{\text{time}} \times \text{concentration}
\]

\[
\text{grams/min} = \frac{\text{L}}{\text{min}} \times \text{grams / L}
\]

\[
5\text{g/min} = \frac{5\text{L}}{\text{min}} \times 1\text{g / L}
\]
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’Aleyc
Slide 25: D’Aleyc
Slide 26: McGraw-Hill
Slide 28: Wellcome Library, http://creativecommons.org/licenses/by-nc/2.0/uk/
Slide 36: Source Undetermined
Slide 40: D’Aleyc
Slide 41: D’Aleyc
Slide 48: McGraw-Hill
Slide 50: McGraw-Hill
Fig 1-4, http://wwwmhhe.com/biosci/esp/2001_gbio/folder_structure/an/m7/s3/assets/images/anm7s3_1.jpg
Slide 52: Source Undetermined
Slide 55: D’Aleyc
Slide 56: D’Aleyc
Slide 57: D’Aleyc
Slide 58: Source Undetermined
Slide 60: D’Aleyc
Slide 61: D’Aleyc
Slide 64: D’Aleyc