ADVANCED ASSESSMENT
Fluids & Electrolytes

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References – Emergency Medicine

Body Is Made Up Of

- Fluid
- Salts
- Solids (organs and tissues)
- Fat (carbon and hydrogen = minimal water)

Fluids and Electrolytes

- Body Fluids
  - Mainly water
  - Found in all body compartments
    - Electrolytes
      - Acids, Bases and Salts
      - Substances that dissolve in water, conduct electricity and dissociate into ions

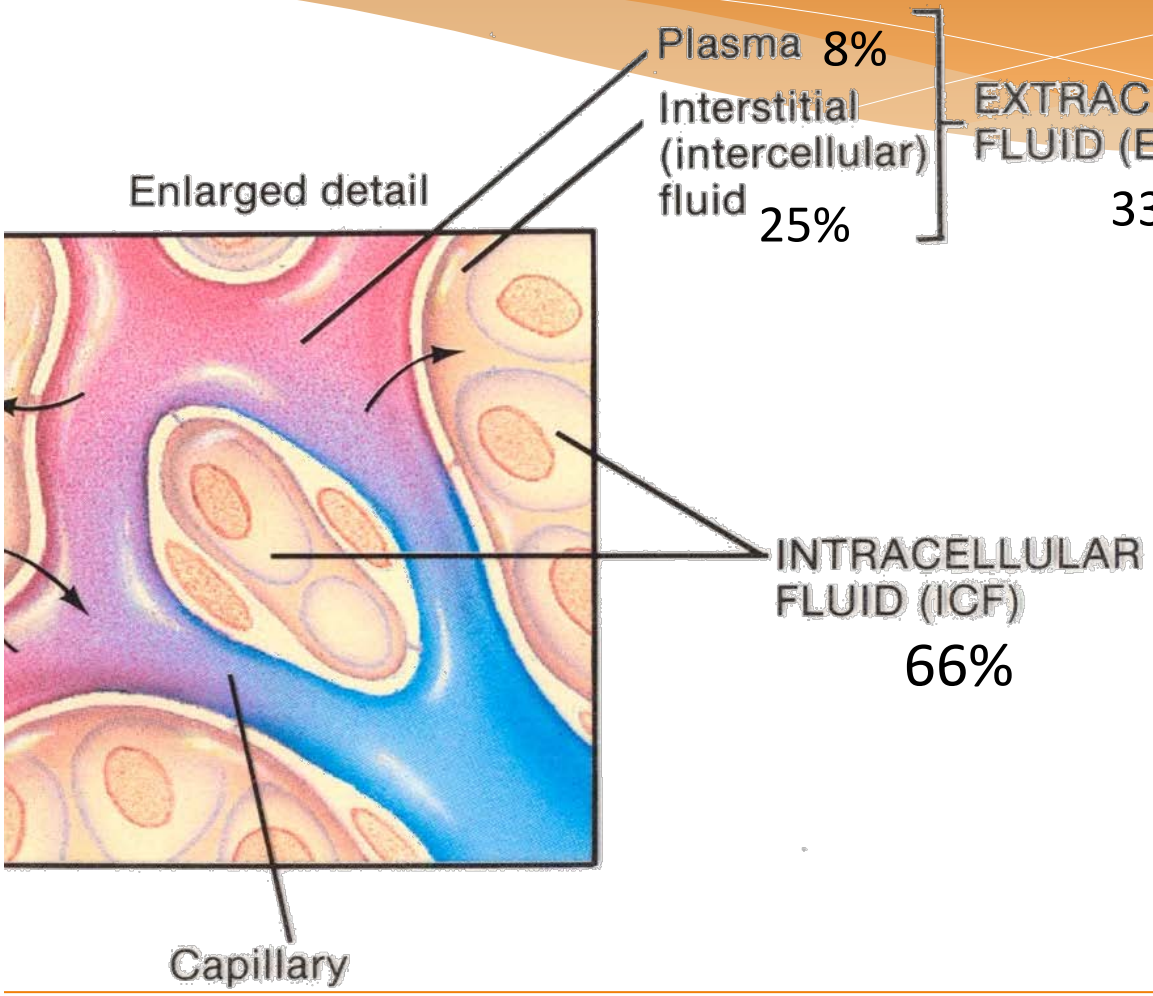
Body Water Volume

- Approx. 42 litres
  - 28 intracellular
  - 10.5 interstitial
  - 3.5 intravascular

Water Distribution

- 60% of normal adult male
- 57 % adult female
- 70 % 1 year old
- 80 % newborn (greater volume extracellular)

Distribution



Functions - Water

- Building of cell protoplasm
- protects body tissues such as spinal cord and brain
- maintain normal osmotic pressure in the body
- major constituent of blood
- regulation of body temperature

Blood

- Made up of Liquid and Formed Elements

Liquid (Plasma 55%)

- 92 % Water
- 8 % Proteins
- Albumin (main plasma colloid)
- Fibrinogen (clotting)
- Globulin (alpha, beta, gamma)
- Play a role in immunity

FORMED ELEMENTS 45%

Red Blood Cells

- 5.2 -> 5.4 million/ml (male)
- 4.5 million/ml (female)
- Most abundant (95% of formed elements)
- Body makes 2.5 million per second, each last approximately one hundred and twenty days
- Primarily responsible for tissue oxygenation
- Waste cells broken down by spleen

Body Is Made Up Of

- Fluid
- Salts-dissolve in water to form electrolyte solutions
- Solids (organs and tissues)
- Fat (carbon and hydrogen = minimal water)

Electrolytes

- A solution that contains ions and is capable of conducting an electrical charge
- Commonly these solutions are made up of cations and anions.

Cation - an ion with a positive charge

Anion – an ion with a negative charge

Extracellular Cations and Anions

- Cation
  - **Sodium Na+**
  - Calcium Ca++
- Anions
  - Chloride Cl-
  - Bicarbonate HCO3-
  - Biphosphate 2PO4-
  - Sulfate SO4-

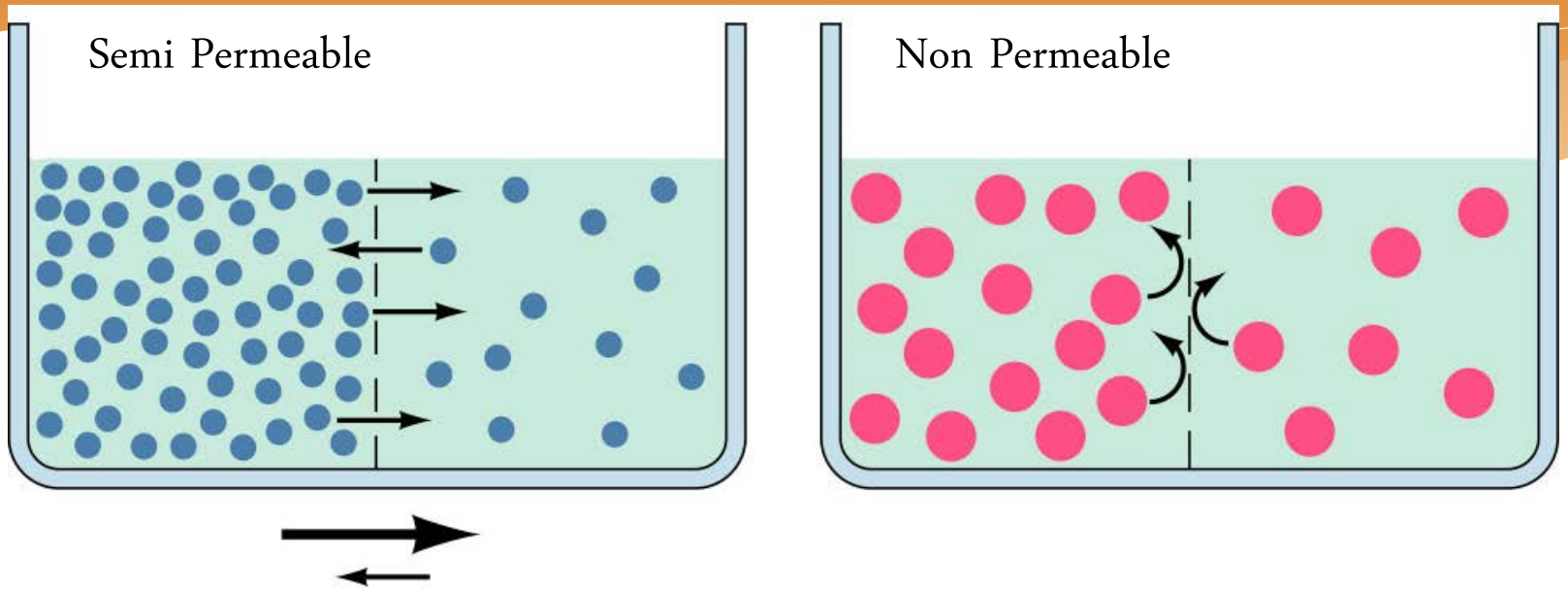
Intracellular Cations and Anions

- Cations
  - **Potassium K+**
  - Calcium Ca++
  - Magnesium Mg+
- Anions
  - Biphosphate 2PO4-
  - Protein

Cell Membranes

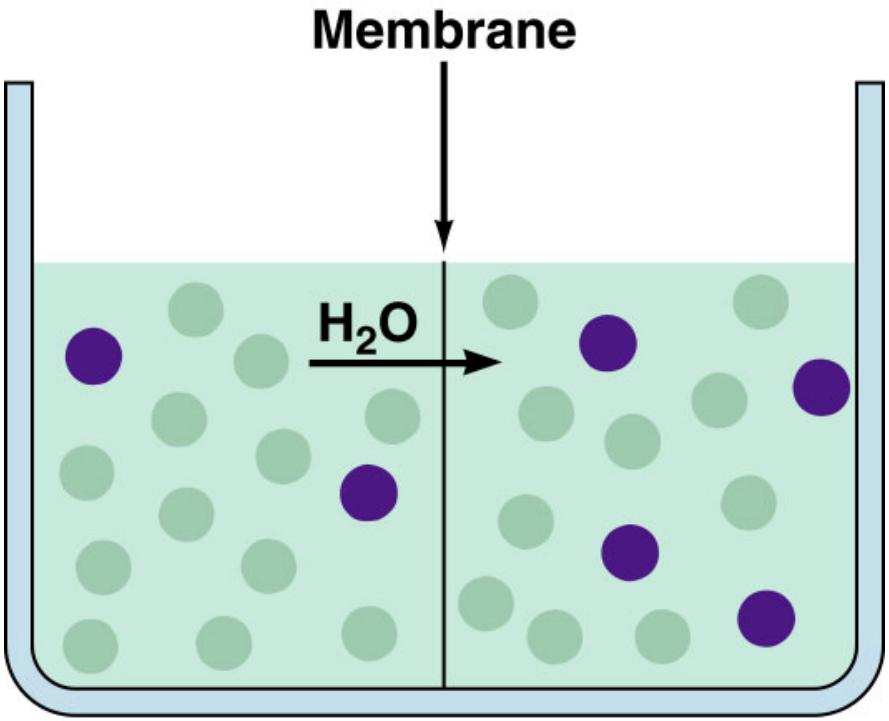
* Cell membranes are made up of lipid bilayers, they are not normally permeable to ions.
* Ions must get into the cell through ion channels
* Normally they will do so through a process known as diffusion

Diffusion



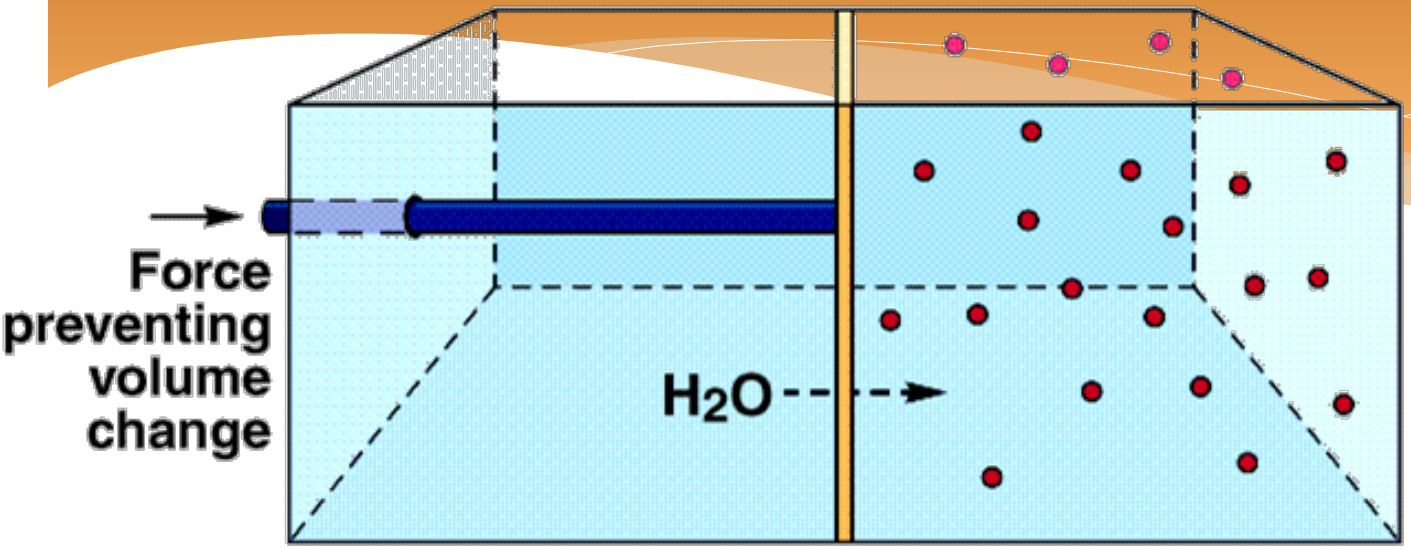
Diffusion : is a net transport of atoms or molecules caused by their random thermal motion in an attempt to equalize concentration differences (DC).

Osmosis



- Diffusion of water through a semi permeable membrane
- from a higher water concentration to a lower water concentration
- From lower solute concentration to a higher solute concentration

Osmotic Pressure

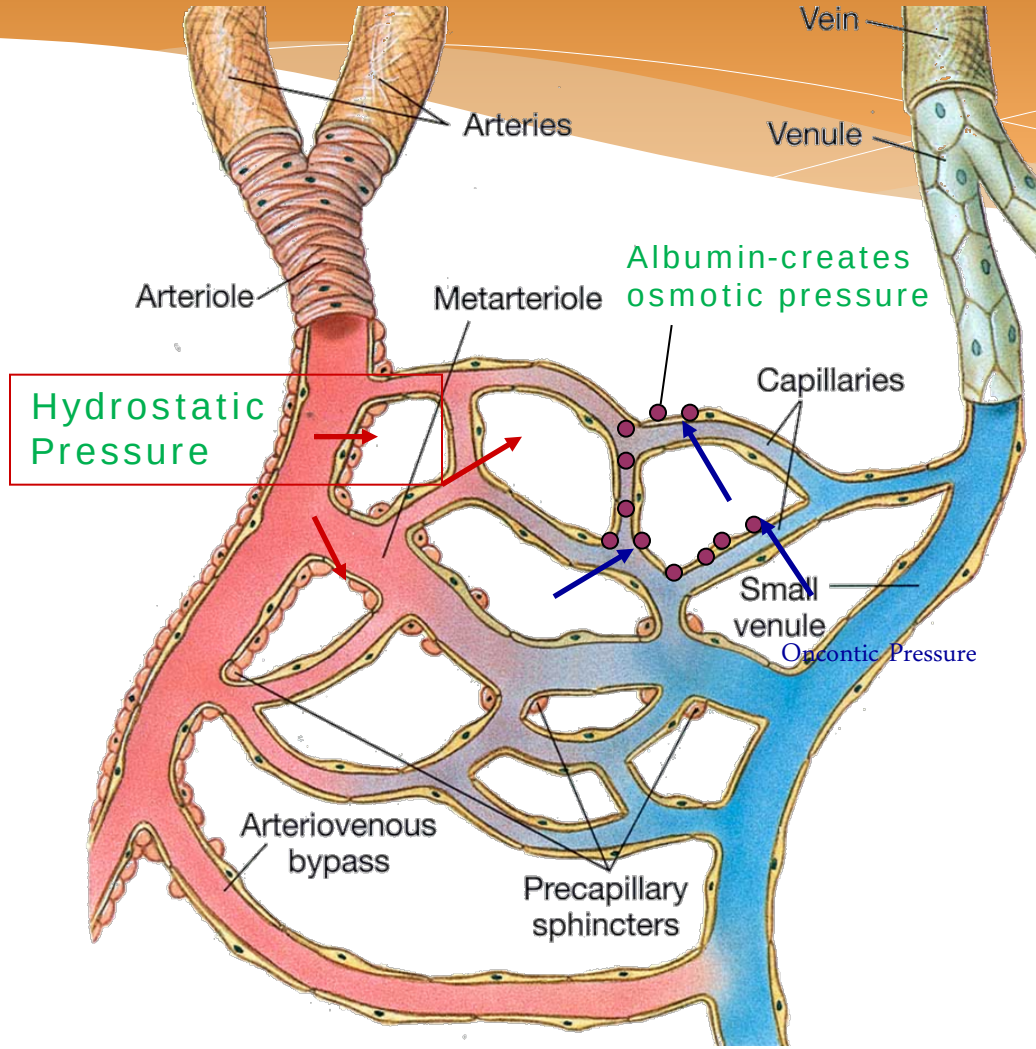


- Osmotic Pressure (p) is the hydrostatic pressure, that must be applied to the side of a semi permeable membrane with higher solute concentration in order to stop the water flux, so that the net water flux is zero

Oncotic Pressure

- The Osmotic Pressure exerted in the vascular compartment due to the presence of plasma proteins
  - Albumin
  - Blood constituents

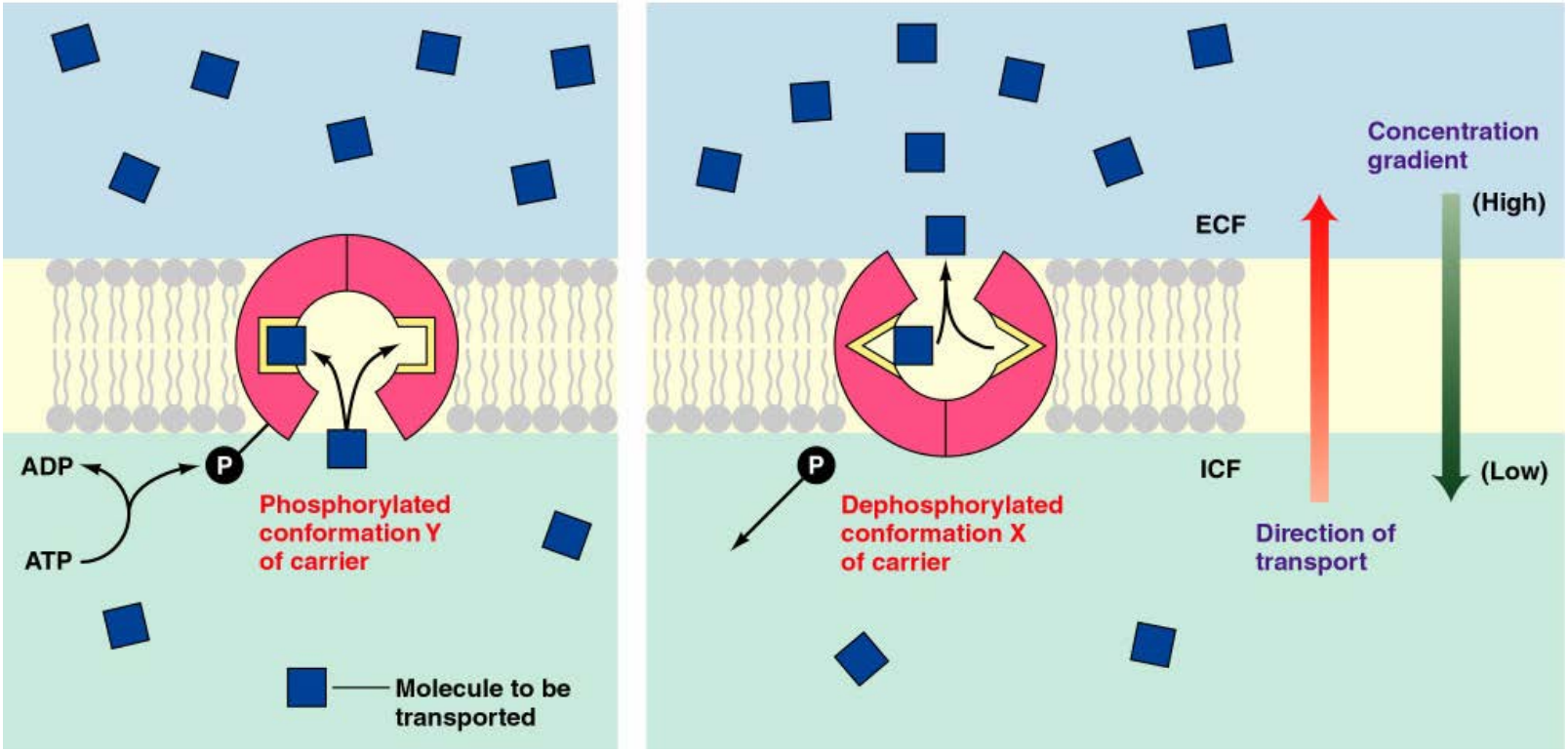
Oncotic Pressure



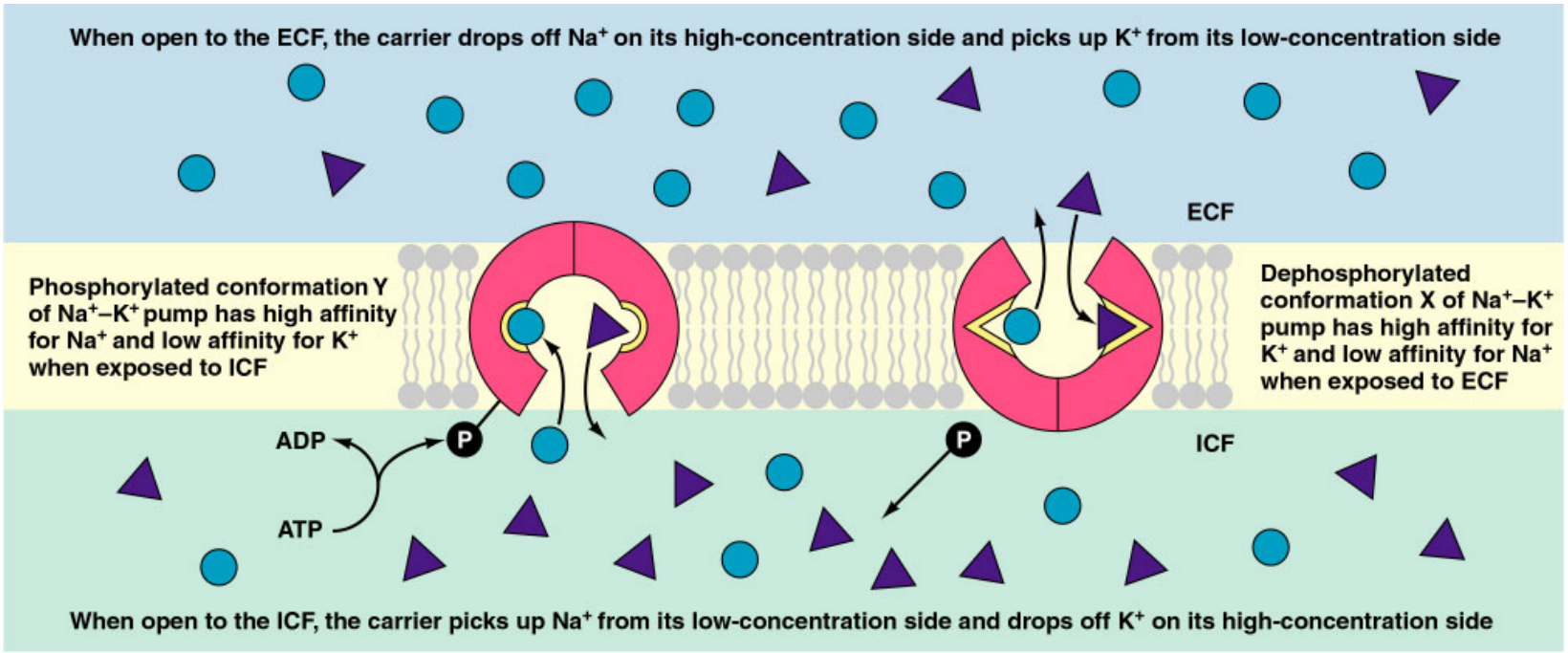
Active Transport

- Movement of molecules and ions against their concentration gradients
  - From lower to higher concentrations
- Requires ATP
- 2 Types of Active Transport:
  - Primary (uses ATP)
  - Secondary (uses electrochemical gradient)

Active Transport



Na^+ / K^+ Pump


When open to the ECF, the carrier drops off Na+ on its high-concentration side and picks up K+ from its low-concentration side
ECF
Phosphorylated conformation Y of Na+–K+ pump has high affinity for Na+ and low affinity for K+ when exposed to ICF
Dephosphorylated conformation X of Na+–K+ pump has high affinity for K+ and low affinity for Na+ when exposed to ECF
ADP
ATP
P
P
ICF
When open to the ICF, the carrier picks up Na+ from its low-concentration side and drops off K+ on its high-concentration side
= Sodium (Na+)
= Potassium (K+)
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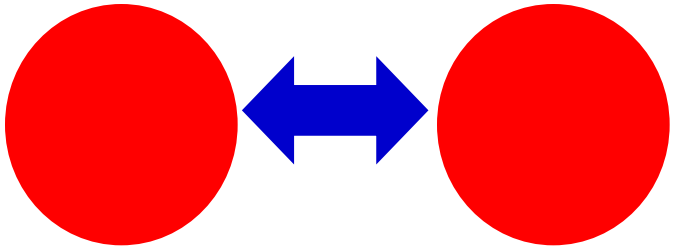
Tonicity

- The effect of a solution on the osmotic movement of H20
  - Isotonic
  - Hypotonic
  - Hypertonic

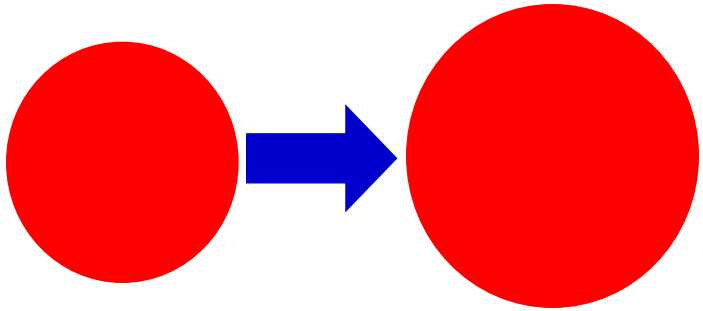
Tonicity

- **Isotonic:**
  - Equal tension to plasma
  - RBCs will not gain or lose H20
    - Normal Saline or Physiological Saline
      - 0.9% NaCl
    - D5W (Dextrose 5% in Water)
      - 5% Glucose
    - Lactated Ringers
      - Glucose, lactic acid, salt



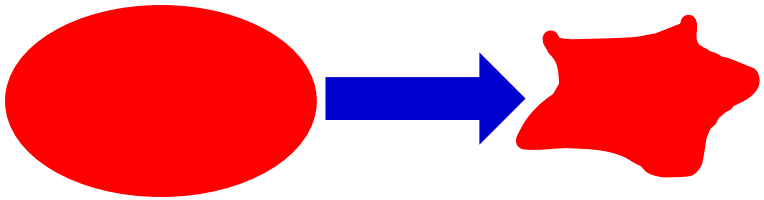
Tonicity

- **Hypotonic:**
  - Osmotically active solutes in a lower osmolality and osmotic pressure than plasma
  - RBC will gain water
    - Water
    - 0.5% saline



Tonicity

- **Hypertonic:**
  - Osmotically active solutes in a higher osmolality and osmotic pressure than plasma
  - RBC will lose water
    - D50
    - Sea Water
    - Dextran



ANATOMY AND PHYSIOLOGY

Veins vs. Arteries

- Low pressure
- Thinner than arteries
- Capacitance system (70% blood volume)
- Valves (legs have large amount of valves)
- No elasticity
- Near Surface
- Dark red blood

- High pressure
- Thick
- Internal and external elastic membrane has property of recoil which propels blood along vessel
- Resistance to flow relative to lumen size
- Deep
- Bright red blood

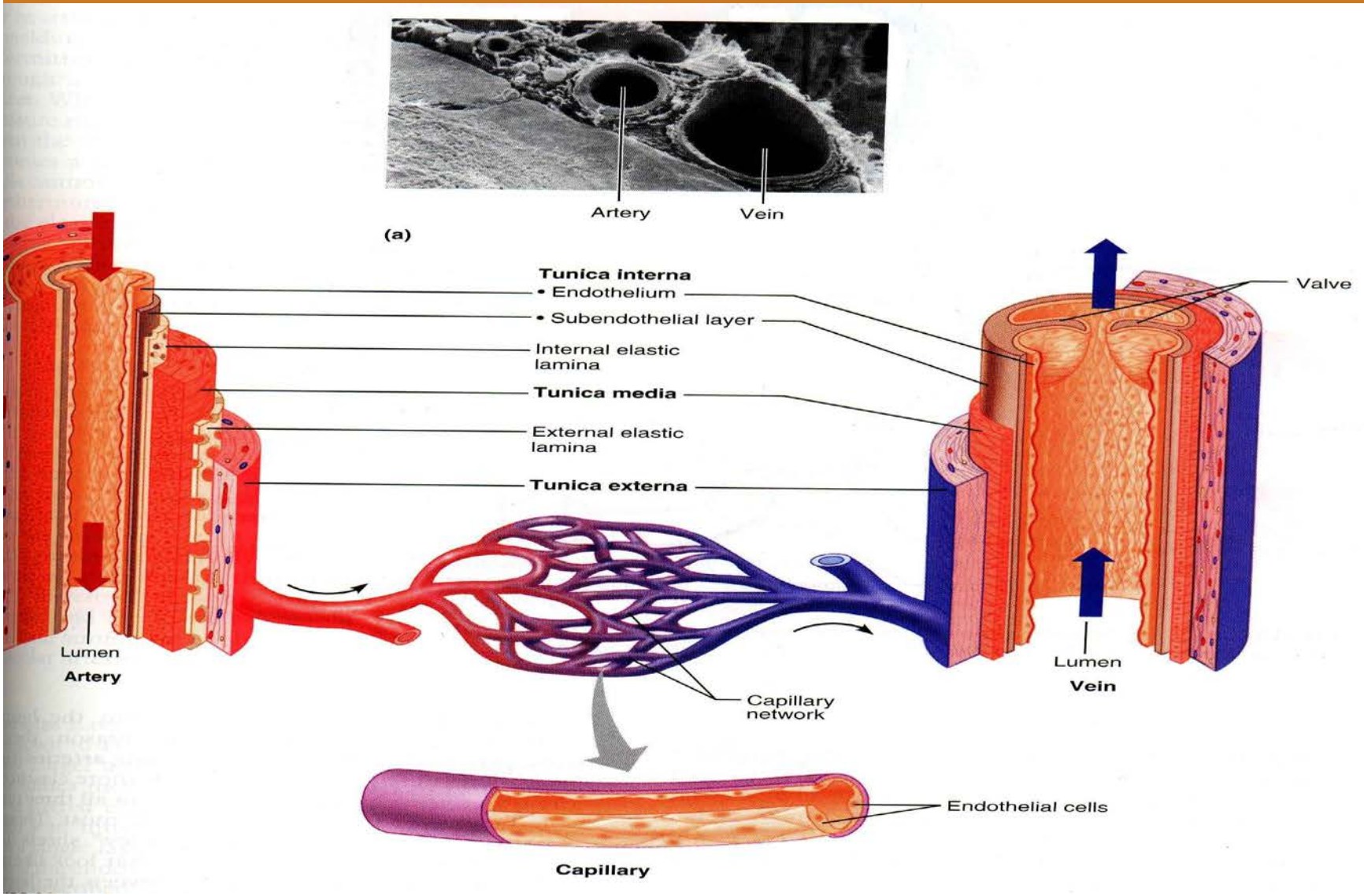
Blood Flow Through the Body

1)Arteries ---> 2)Arterioles --->

3)Pre Capillary Sphincters ---> 4)Capillaries --->

5) Post Capillary Sphincters ---> 6)Venules --->

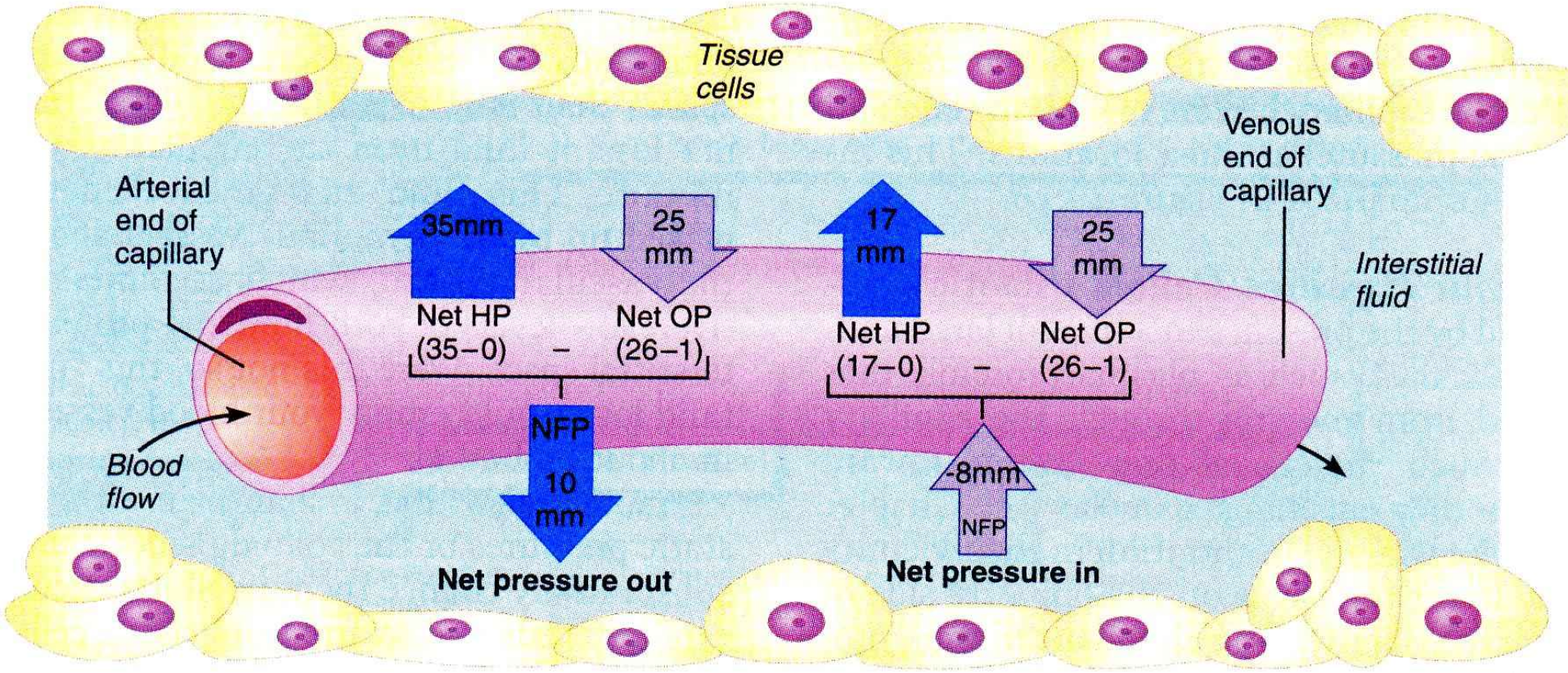
7) Veins


Artery
Vein
(a)
Tunica interna
• Endothelium
• Subendothelial layer
Internal elastic lamina
Tunica media
External elastic lamina
Tunica externa
Valve
Lumen
Artery
Lumen
Vein
Capillary network
Endothelial cells
Capillary

Nutrient Exchange in the Capillary

Hydrostatic Pressure= Force water exerts on vasculature

Colloidal Osmotic Pressure= Drawing or pull of water due to colloids in solution (protein, albumin, glucose)

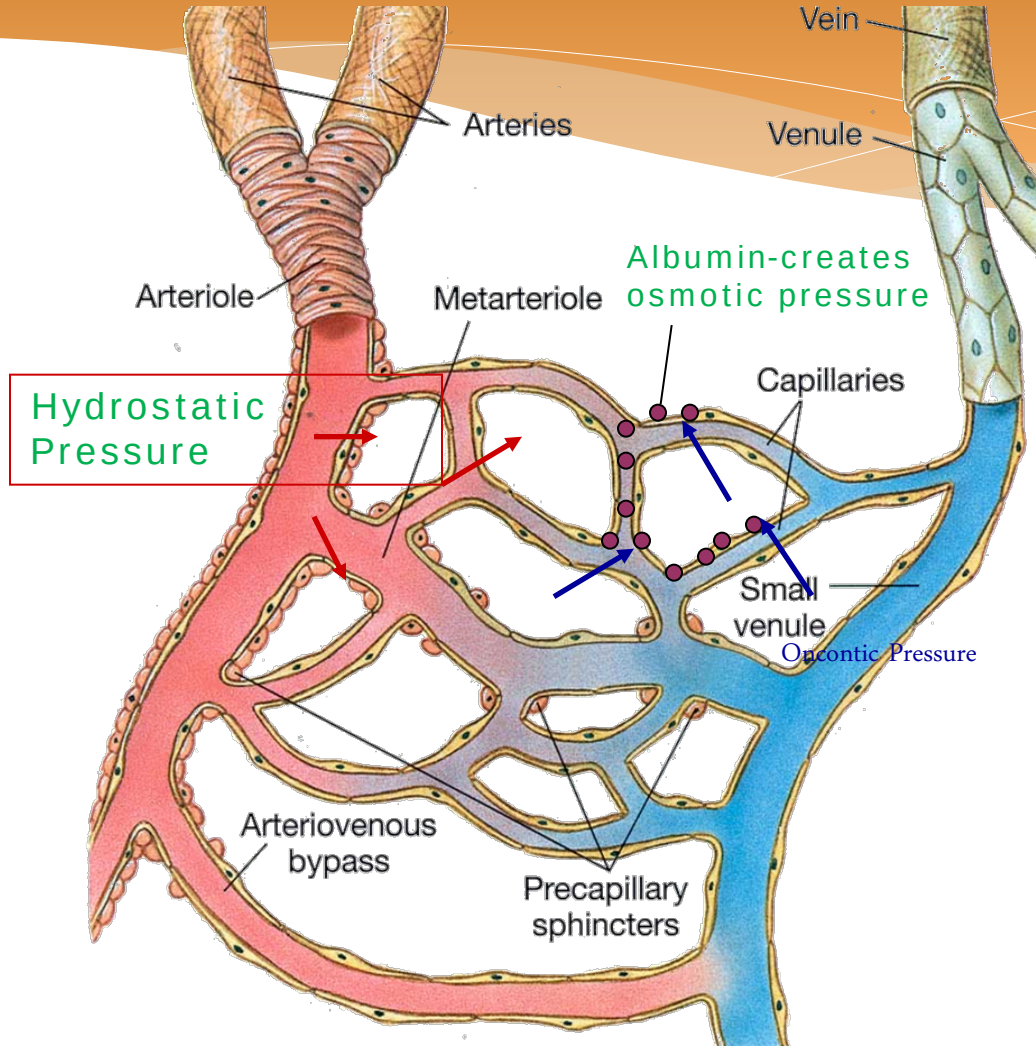


Key to pressure values:

HP_c at arterial end = 35 mm Hg HP_{if} = 0 mm Hg OP_{if} = 1 mm Hg

HP_c at venous end = 17 mm Hg OP_c = 26 mm Hg

Oncotic Pressure



KIDNEY & URINE PRODUCTION

Fluid Balance

- Daily Intake = Daily Loss
- Intake
  - Drinking and eating
- Loss
  - **Urine**
  - Skin
  - Lungs
  - GI Track

Fluid Balance

2500 ml/day = in

2500 ml/day = out

- Insensible losses (water loss you are unaware of)
  - Sweat
  - Respirations

Abnormal Fluid Loss Can Result From

- Disorders that affect the kidneys: ex diabetes mellitus, decrease in anti diuretic hormone(ADHD)
- Water loss from lungs and skin in conditions such as fever and increased respiratory rate
- Skin injuries (burns) third space shift
- G.I Tract (vomiting and diarrhea)

Kidney

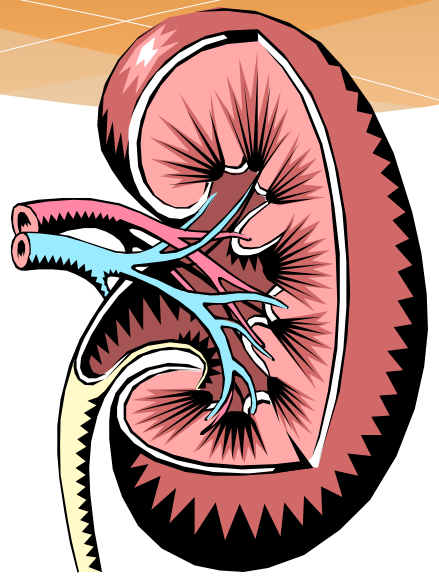
- Removes waste products from blood
- Maintains constant fluid volume and composition
- 2 Kidneys shaped like a kidney bean
- Either side of the vertebral column (superior portion protected by rib cage)
- Protected by fibrous renal capsule (thick adipose tissue)
- Only place in body where blood is filled and drained by an arteriole

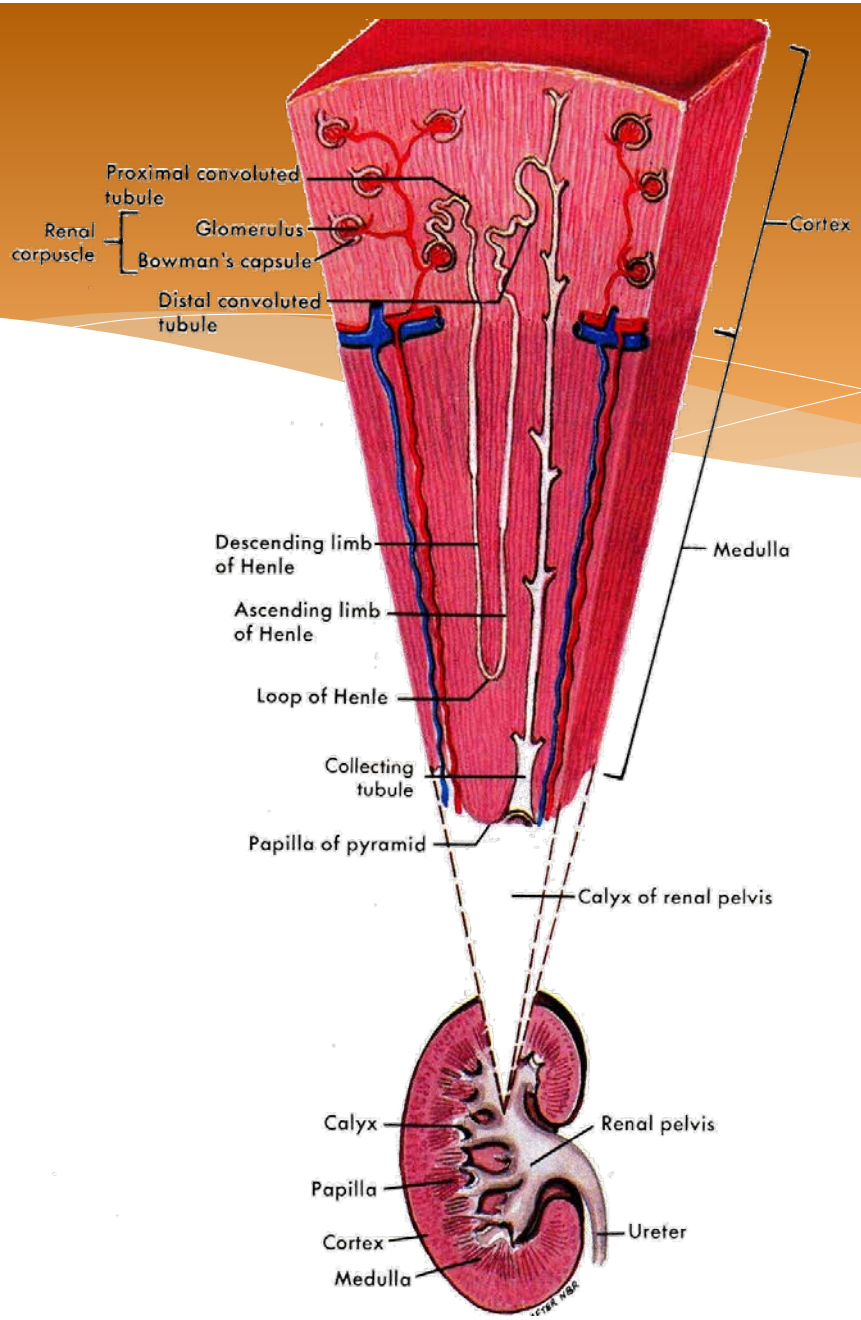
Outer layer of Kidney

>Cortex

Inner layer

>Medulla



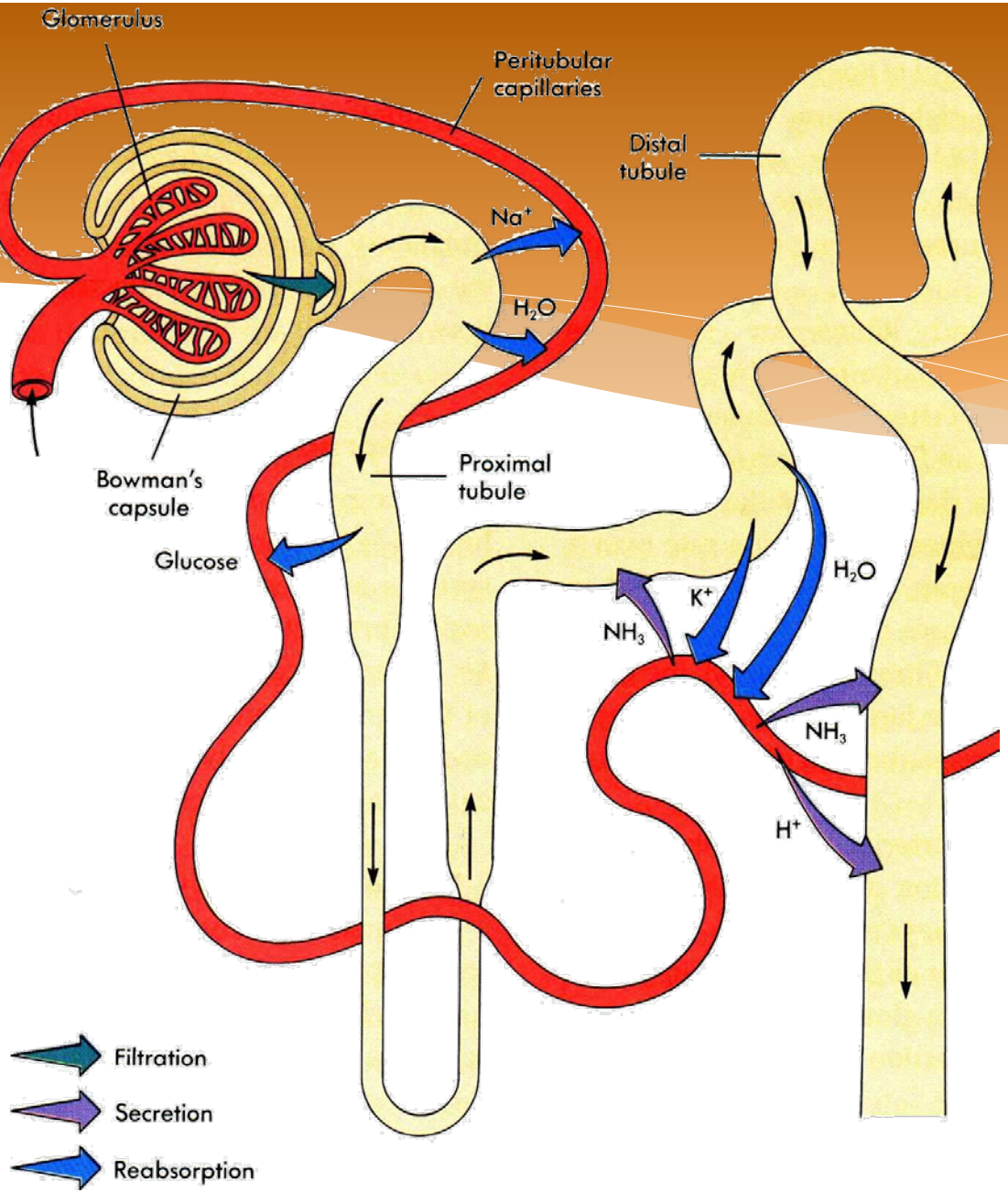

Proximal convoluted tubule
Renal corpuscle
Glomerulus
Bowman's capsule
Distal convoluted tubule
Cortex
Medulla
Descending limb of Henle
Ascending limb of Henle
Loop of Henle
Collecting tubule
Papilla of pyramid
Calyx of renal pelvis
Calyx
Renal pelvis
Papilla
Ureter
Cortex
Medulla

Basic Functional Unit of the Kidney

NEPHRON

More Than 2 Million Per Kidney

Forms Urine


Glomerulus
Peritubular capillaries
Distal tubule
Na^+
H_2O
Bowman's capsule
Proximal tubule
Glucose
H_2O
K^+
NH_3
NH_3
H^+
Filtration
Secretion
Reabsorption

Urine Production

- Blood from Glomerulus passes into Bowman's capsule (**GFR= 180 l per day**, 125ml per minute) producing 1-2 liters of urine/day
- Proximal Convoluted Tubule
- Loop of Henle
- Distal Convoluted Tubule
- Collecting Tubule
- During this process many substances in the filtrate are reabsorbed by the blood capillaries around the tubules (water, glucose, nutrients, sodium, other ions)
- Waste secreted as urine (contains hydrogen, potassium, ammonia)

Why is Holding onto Sodium so Important?

Sodium - Na +

- Major extracellular cation
- Maintains extracellular fluid volume and osmotic pressure
- Ph regulator
- Transmission of nerve and muscle impulses
- Regulates cell membrane permeability

Hyponatremia

- Cause:
  - Volume depletion
  - Hyperglycemia
  - Over secretion of ADH
  - Kidney disease/failure
  - Edema
- Signs and Symptoms
  - Parallel with S&S of fluid volume defecit
  - Loss of skin turgor
  - Tachycardia/ hypotension
  - Lethargy/Muscle weakness
  - Muscle cramps
  - Confusion

Hypernatremia

- Cause:
  - Lack of water
  - Fluid loss exceeds Na+ loss
  - Salt poisoning
- Signs and Symptoms
  - Extreme muscle irritability
  - Dry mucous membranes
  - Flushed skin
  - Thirst
  - Increased Temperature
  - Decreased urine output

Potassium – K+

- Major intracellular cation
- Regulates neuromuscular irritability (especially cardiac)
- Necessary for transmission of electrochemical impulses along nerves and within muscle cells
- Maintains fluid volume within the cell
- Controls hydrogen ion concentration (regulates Ph)

Hypokalemia

- Cause:
  - Decreased K+ intake (not eating, lots of I.V fluid without K+)
  - Excess vomiting, gastric suction, diarrhea
  - Diuretic treatment (thiazides, Lasix)
  - Kidney Disease (unable to reabsorb K+)
- Signs and Symptoms:
  - Muscle weakness, cramps, flaccid paralysis
  - Fatigue, confusion
  - Dysrhythmias, heart block, flat T wave, prolonged Q-T interval
  - Respiratory/Cardiac arrest

Hyperkalemia

- Cause:
  - Respiratory or Metabolic Acidosis
  - Renal failure
  - Crush injuries
  - Excess to rapid K+ administration
- Signs and Symptoms:
  - Weakness to flaccid paralysis
  - Numbness, tingling in face, tongue, hands, feet
  - Increased G.I tone (diarrhea)
  - Heart Arrhythmias
  - Tall peaked T waves
  - Widened QRS

Magnesium Mg+

- Mostly Intracellular
- Plays role in neuromuscular function (excess Mg+ sedates muscles, used as an anti seizure medication for eclampsia)
- Provides energy for Na+/K+ pump
- **Hypomagnesemia: often caused by poor food intake, alcoholics**
- **Causes**
  - **Polymorphic Ventricular Tachycardia**
- Tx
  - Magnesium Sulphate

Calcium Ca+

- Most abundant cation in the body: 99% found in bones and teeth, 1% in plasma
- Muscle contraction
- Formation of bones and teeth
- Blood coagulation
- Control of neuromuscular activity

Bicarbonate HCO3-

- Major part of blood buffer system
- Regulates Ph

PH REGULATION

PH Regulation

PH: NEGATIVE LOG OF HYDROGEN ION

CONCENTRATION –log[H+]

Free hydrogen ion concentration in the body is low, roughly .0000001 mol/l (expressed mathematically 10^{-7})

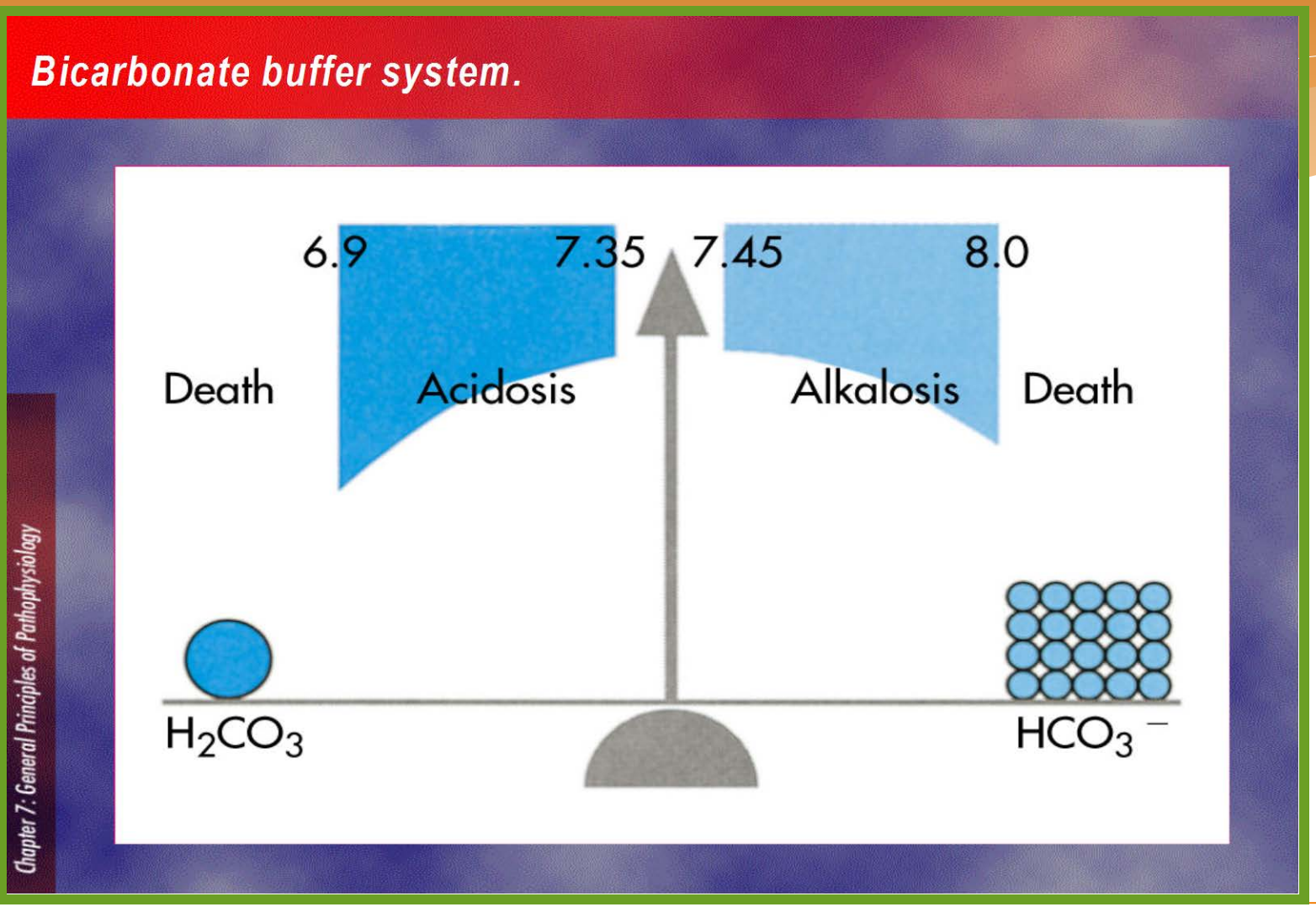
Because numbers are so cumbersome the 10 was dropped and Ph is expressed from range of 1 to 14 with 7 being neutral **(LESS THAN 7 CONSIDERED ACIDIC AND GREATER THAN 7 BEING BASIC)**

PH Regulation

An increase in hydrogen ion concentration makes the solution more acidic **(Ph less than 7)**

- AA decrease in the amount of hydrogen ion concentration makes the solution more alkaline **(Ph greater than 7)**
- **NORMAL Ph IS BETWEEN 7.35 AND 7.45 SO ANYTHING LESS THAN 7.35 IS CONSIDERED TO BE ACIDIC**

PH


Bicarbonate buffer system.
6.9
7.35
7.45
8.0
Death
Acidosis
Alkalosis
Death
H_2CO_3
HCO_3^-
Chapter 7: General Principles of Pathophysiology

Importance of Acid Base Balance

- Normal body function can only occur if the composition of body cells and their surrounding environment are kept relatively constant
- The body must maintain a constant regulation of fluid and electrolytes and acid base balance
- Disturbances of acid base balance lead to cellular dysfunction and death
- **Ph less than 6.8 and greater than 7.9 = DEATH**

- Acid Base Balance refers to the balance of the hydrogen ion concentration in the body fluids
- The body produces large amounts of acids which are bi-products of cellular metabolism
- If acids were allowed to accumulate death would occur
- The body must have mechanisms that can minimize changes in pH

Body Has Two Distinct Tasks

- Prevention of Ph changes in the blood while transporting these hydrogen ions to the organs where they will be excreted
- Elimination of excess hydrogen ions from the body

MECHANISMS OF PH REGULATION AND H+ ION EXCRETION

pH Regulators

- Physiological
- Respiratory
- Renal

Physiological

Acid base buffer is a chemical solution which prevents an excessive change in pH (H+ ion concentration)

- Buffers in the body are either a base or an acid
- If excess base is added to the solution the weak acid portion of a buffer reacts with it to neutralize it
- If excess acid is added to the solution the alkali salt (base) reacts to neutralize it

Physiological

- Keep blood pH changes to a minimum (between 7.35 and 7.45) while transporting hydrogen ions to where they will be excreted
- Act immediately in response to an upset in the balance of hydrogen ions in the body fluids

1. Bicarbonate/Carbonic Acid Buffer System (Major buffer system)
2. Phosphate buffer system
3. Protein buffer system
4. Hemoglobin buffer system

Bicarbonate/Carbonic Acid Buffer System

Glucose + Oxygen = 38 ATP + 6 CO_2 + 6 H_2O

As seen above in Krebs Cycle. CO_2 and Water is the major bi- product of cell metabolism

In the blood stream Carbon Dioxide and Water form Carbonic Acid (inside red blood cell with help from carbonic anhydrase)

$$CO_2 + H_2O \leftrightarrows H_2CO_3 \leftrightarrows H^+ \text{ --- } HCO_3$$

Carbonic Acid Dissociates into Hydrogen (buffered by chemical buffers) and bicarbonate (while being transported to the lungs)

At the Lungs reaction switches to the Left, CO_2 is reformed and blown off. Water dissipates into general water pool.

Respiratory System

- The Lungs are responsible for the regulation of the levels of **VOLATILE ACIDS** (ones that can be blown off at the lungs CO2)

- **AS CO2 LEVELS INCREASE SO DO HYDROGEN LEVELS LIKEWISE IF CO2 LEVELS DECREASE SO DO HYDROGENS LEVELS**

Respiratory System

- With **HYPERVENTILATION CO2** is blown off which ultimately decreases hydrogen Ion concentration (increase pH)
- With **HYPOVENTILATION CO2** is retained which increases hydrogen ion concentration (decrease in pH)
- **LUNGS WORKING ALONE CAN ADJUST HYDROGEN LEVELS WITHIN SECONDS (RAPID)**
- **GETS PH WITHIN NORMAL RANGE BUT CANNOT FINE TUNE IT (AROUND 7.2 TO 7.3)**

Renal System (Kidneys)

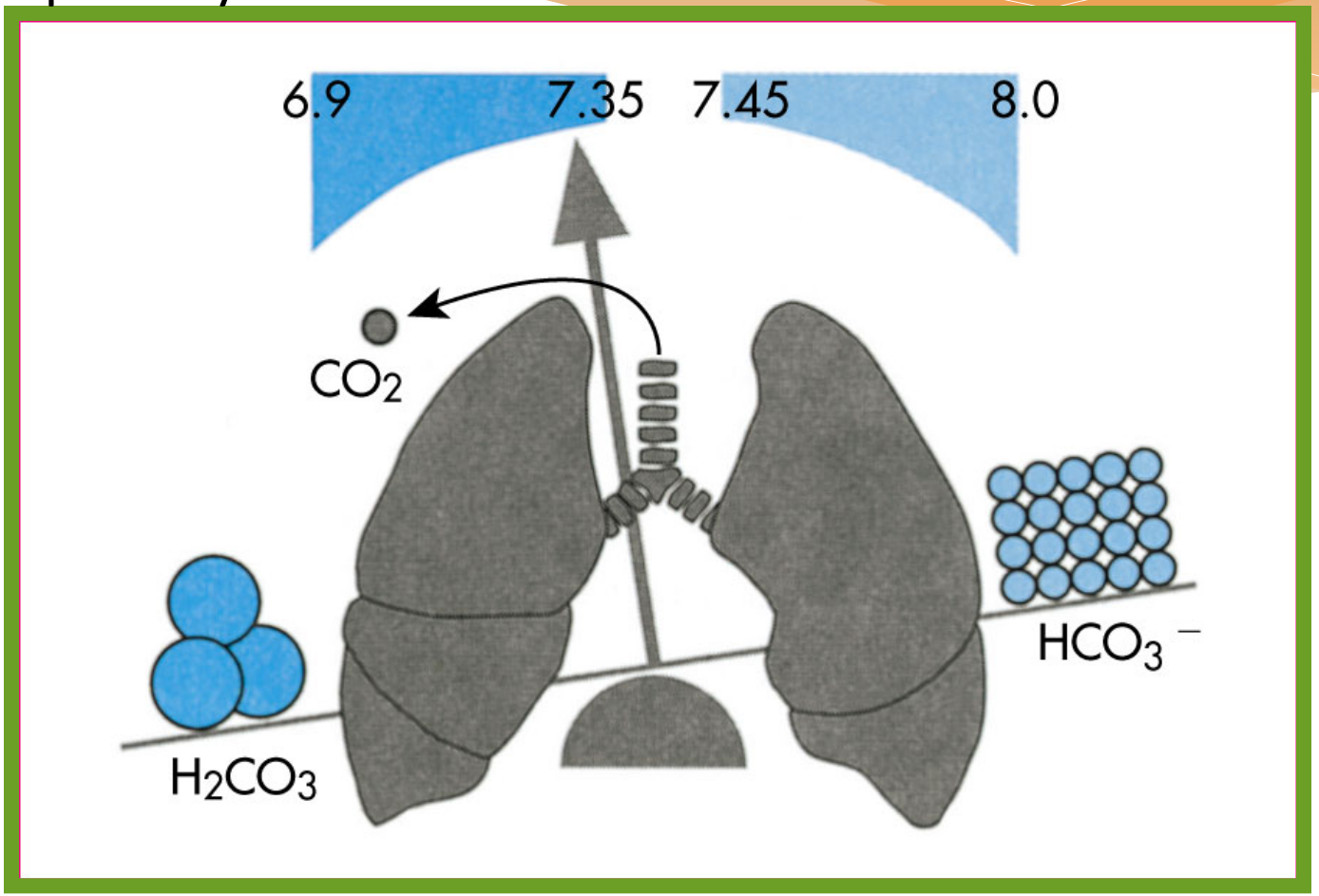
- Responsible for regulation of non volatile or fixed acids (ones that can't be breathed off) **lactic acid, ketone bodies, phosphoric acid and sulfuric acid breakdown into H+ which must be excreted by the kidneys**
- Whenever an imbalance of hydrogen occurs the kidney will adjust the secretion or absorption of acid (H+) or base (HCO_3)

Renal System

- If the body becomes too acidic the kidney retains HCO_3 and excretes H^+
- If the body becomes too alkaline the kidney excretes HCO_3 and retains H^+ ions
- Slow system but fine tunes pH between 7.35 and 7.45

Acid Base Disturbances

- Respiratory Acidosis

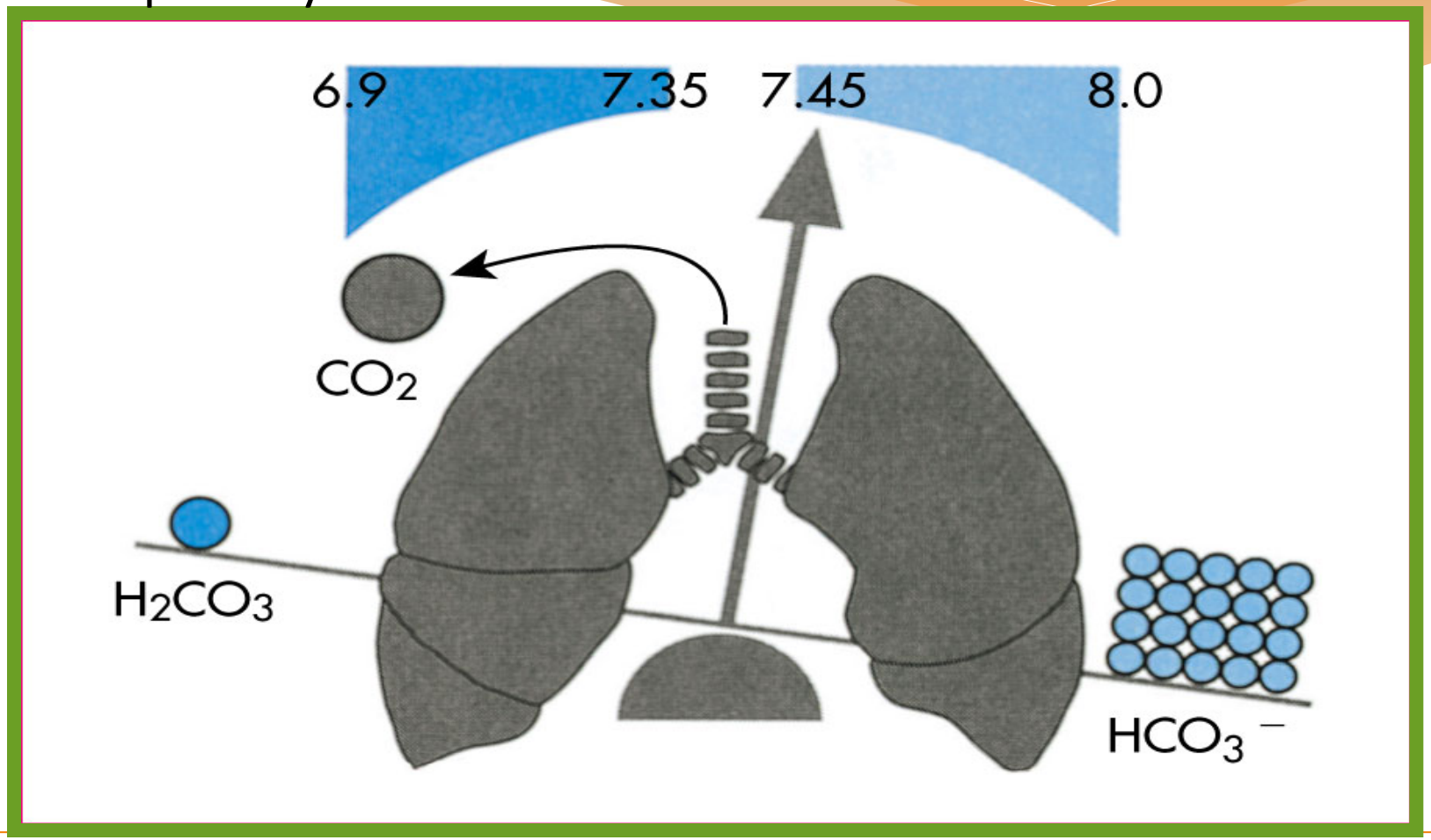


Respiratory Acidosis (Retention of CO_2)

- pH less than 7.35
- Failure of lungs to blow off CO2 which ultimately increases hydrogen ion concentration
- Caused by any pathology that decreases ventilation (lung diseases, drugs that decrease respiratory drive (narcotics, benzodiazepines)
- Kidneys will try to compensate by retaining HCO3 and excreting H+

Acid Base Disturbances

- Respiratory Alkalosis

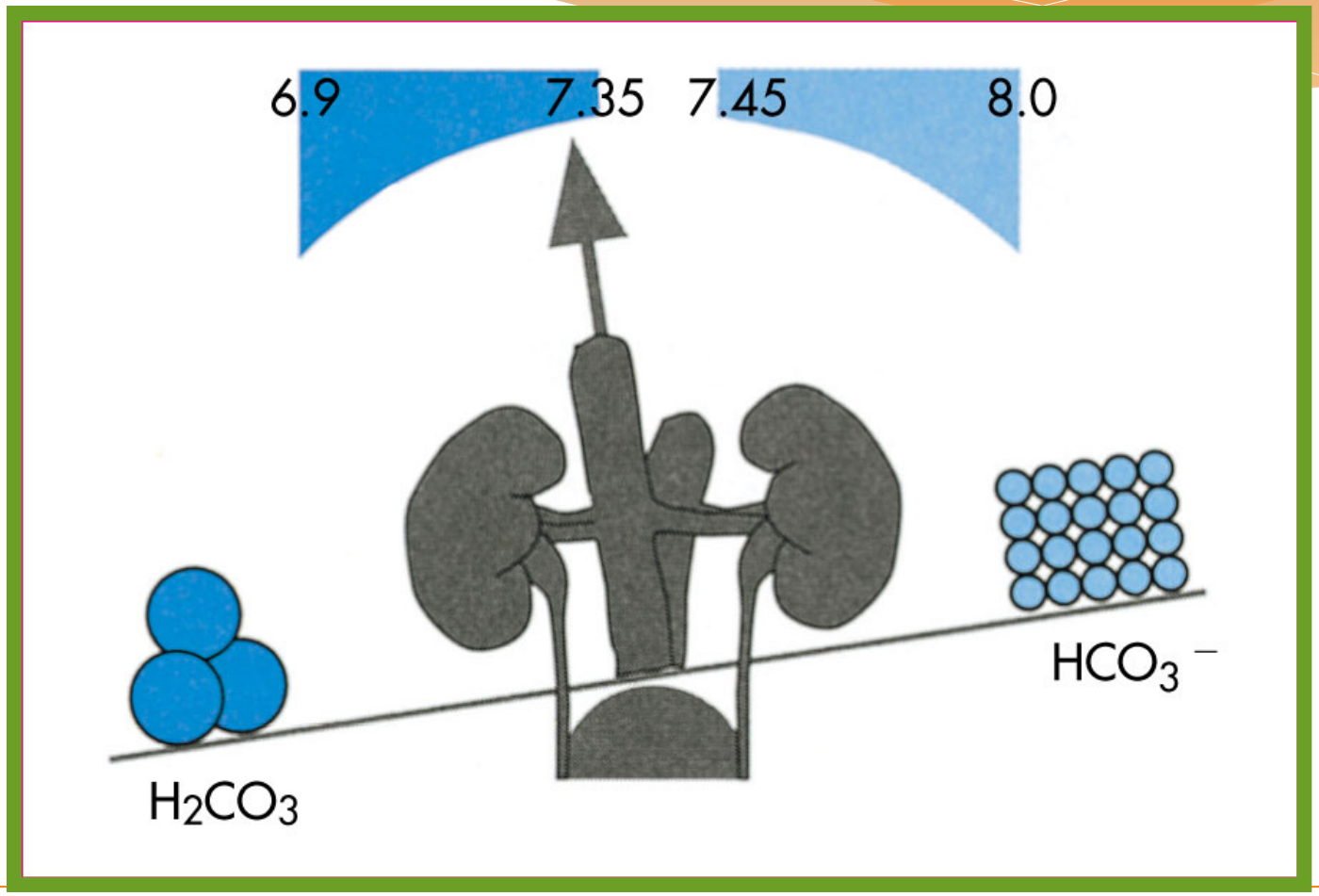


Respiratory Alkalosis

- pH greater than 7.45
- Lungs are blowing off excess CO_2 ultimately decreasing hydrogen ion concentration
- Pathologies that increase ventilation (fever, voluntary hyperventilation)
- Kidney will try to compensate by excreting HCO_3 and retaining H^+

Acid Base Disturbances

- Metabolic Acidosis

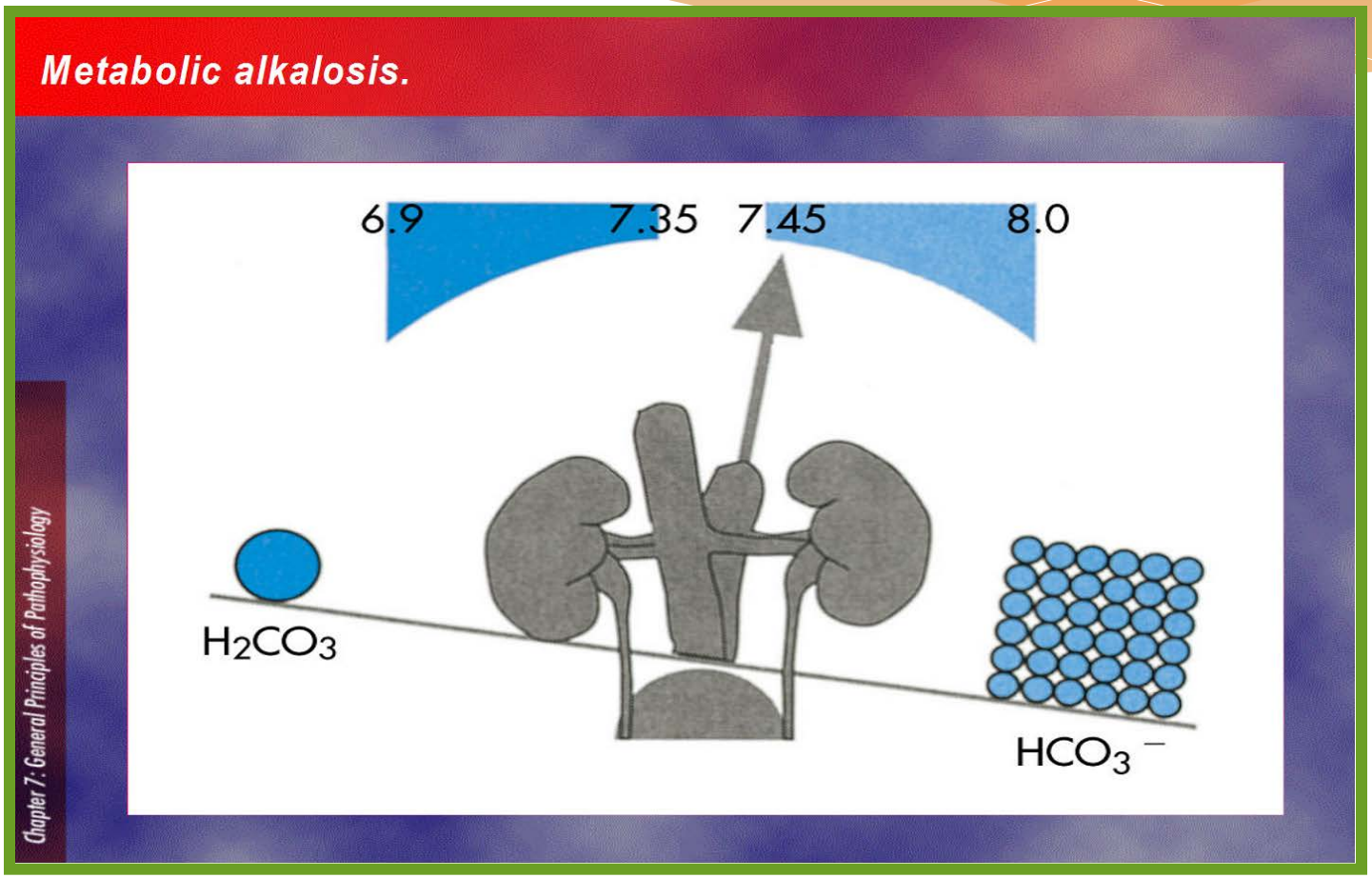


Metabolic Acidosis

- pH less than 7.35
- Caused by an excess of non volatile acids in blood or a loss of HCO_3 in the blood
- Causes: ketone production in uncontrolled diabetics,
  renal failure, severe diarrhea (G.I. loss of bicarbonate)
  aspirin overdose (late)
- Lungs compensate by hyperventilation (blowing off CO_2)

Acid Base Disturbances

- Metabolic Alkalosis



Metabolic Alkalosis

- pH greater than 7.45
- Caused by a decrease in non volatile acids or an increase in HCO_3 in the blood
- Excess HCO_3 administration (cardiac arrest), prolonged vomiting (loss of acid)

Well Done!

Ontario Base Hospital Group

Self-directed Education Program