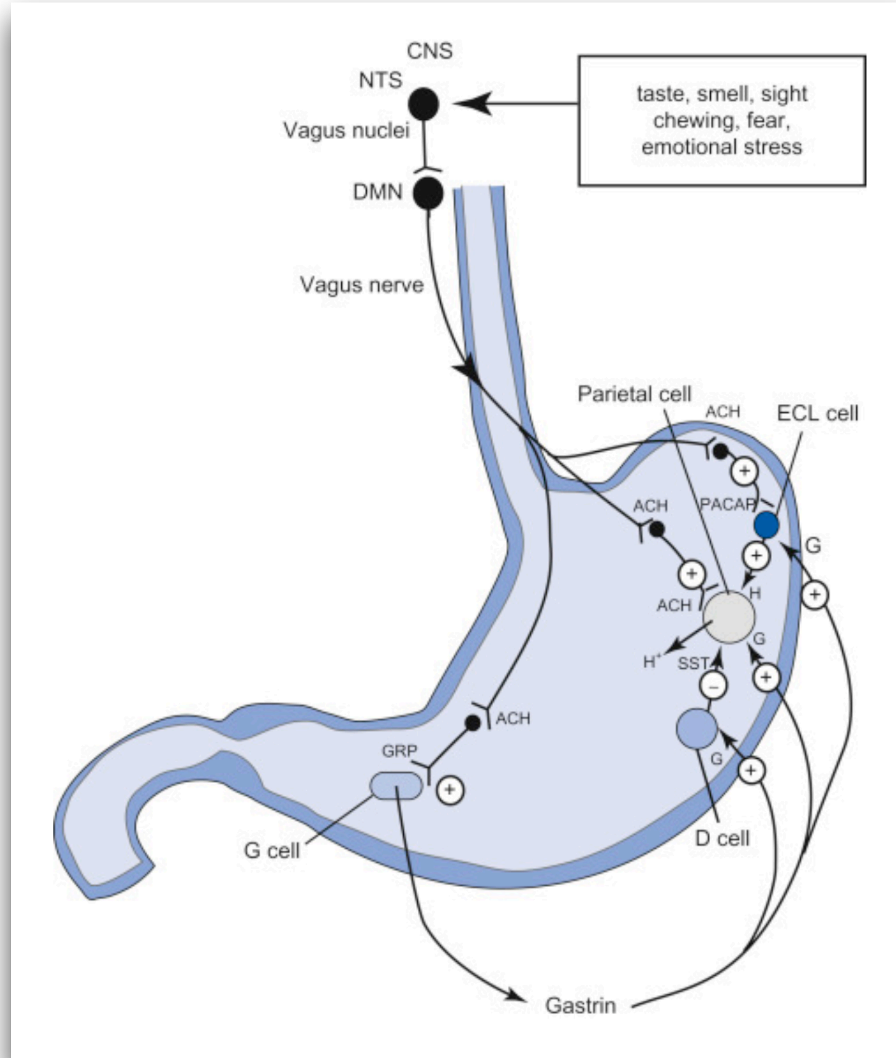
American Physiological Society

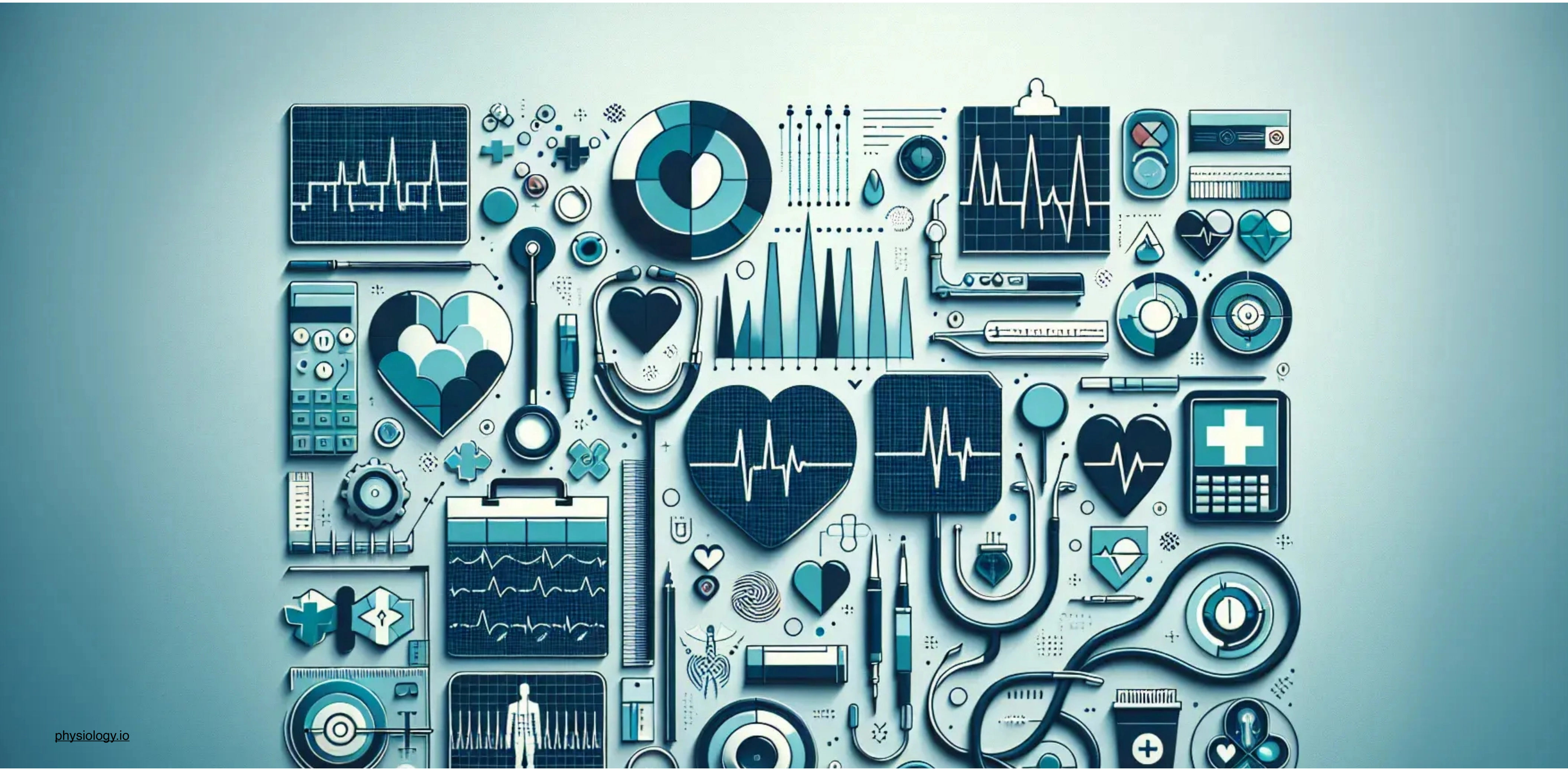
- **Physiology** is the study of the function of the human body.
- We will go over most of the major organs and processes of the human body: the brain and nervous system, heart and lungs, hormones, and digestion.

- A key skill you will learn is how to analyze a pathway, from biological causes to bodily symptoms.

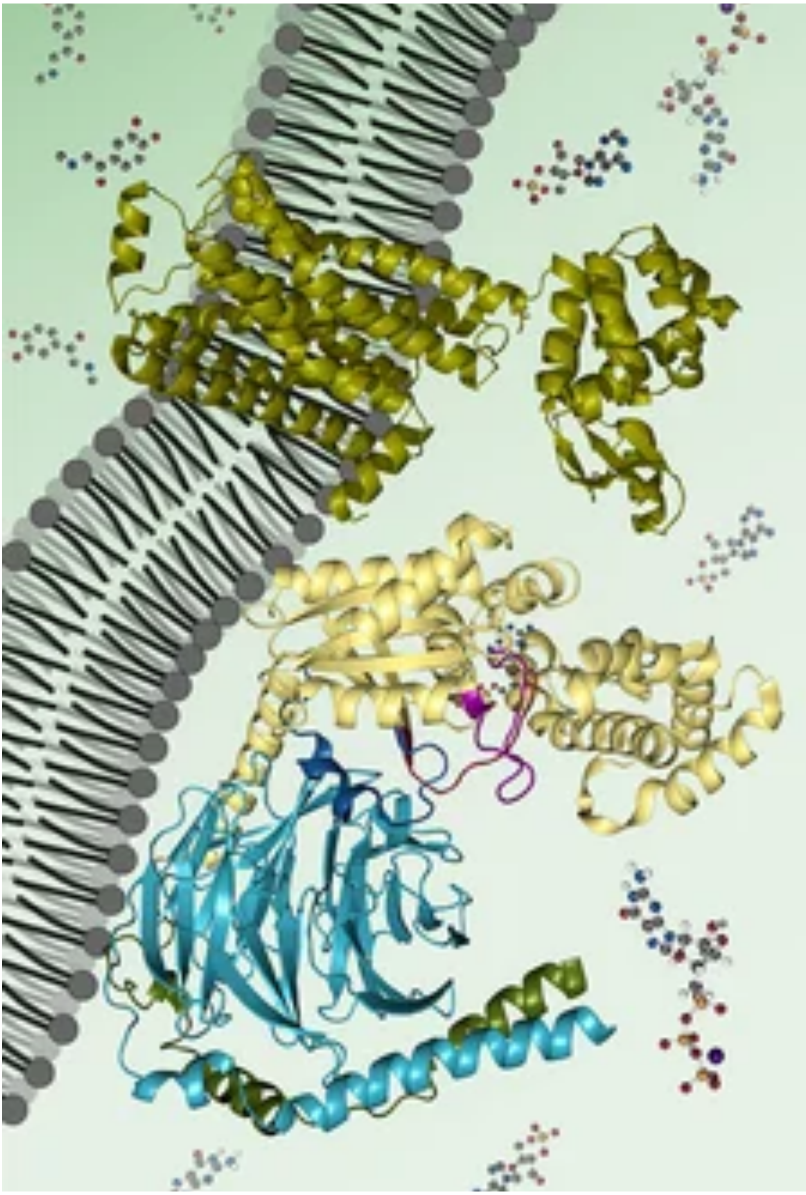


S. Sobrino-Cossío et al in Revista de Gastroenterología de México (English Edition), 2019

- Identifying cause and effect in the body is critical to diagnosing patient's diseases.



physiology.io



- This is NOT a biochemistry course, although we'll draw on what you've learned in your earlier chemistry courses about concentrations, pH, and some basic chemicals.

- This is NOT an anatomy course, but there will be some body parts and tissues that we have to know to understand how organs function. I will provide very explicit guides

Human Physiology PCB 4701

Course credit: 3 hours
Lecture: MW 3:05pm to 4:20 pm
Meeting place: HCB 0102

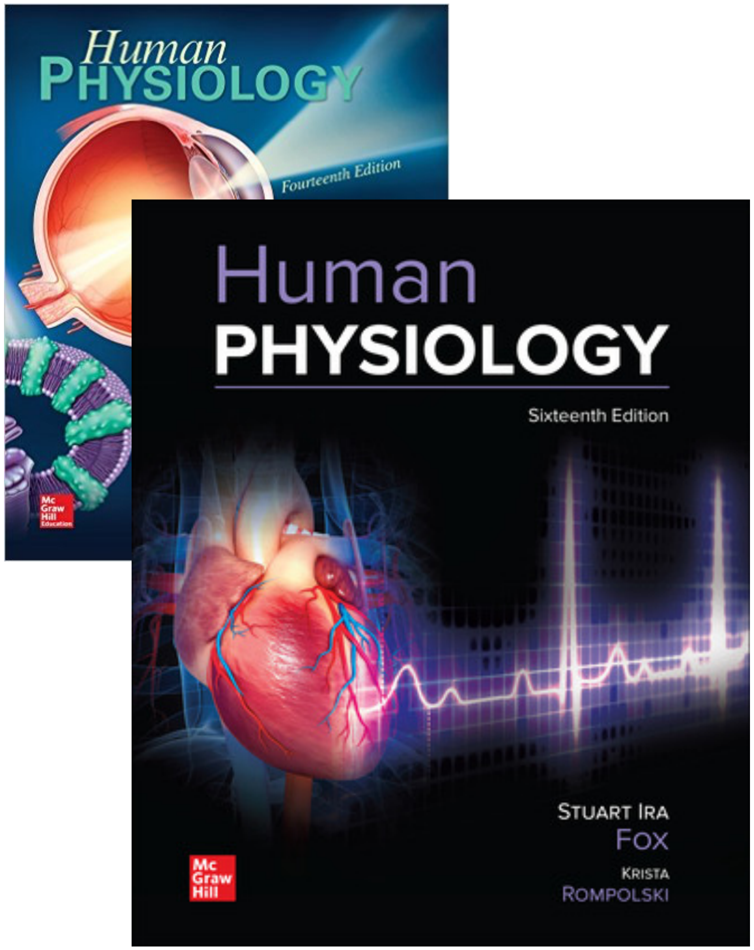
Professor: Dr. Tom Houpt
Email: houpt@bio.fsu.edu
Office Hours: 2067 King Building, Thurs, noon to 2pm (or by appointment)

Teaching Assistant: Marena Bass
Email: mnb11d@bio.fsu.edu
Office Hours: 3022 King Building, Friday, 3-4pm (or by appointment)

Email using your FSU-issued account! Other accounts (hotmail, google) get filtered to spam!

Textbook
Human Physiology, 13th - 16th edition, by Stuart Ira Fox

FSU course-website
Assignments, lecture outlines, handouts, and practice exams will be posted on Canvas.


Human
PHYSIOLOGY
Fourteenth Edition
Human
PHYSIOLOGY
Sixteenth Edition
STUART IRA
FOX
KRISTA
ROMPOLSKI
Mc
Graw
Hill

TOP HAT

Canvas
& http://houptlab.org/courses/humanphys

Download lectures in advance!

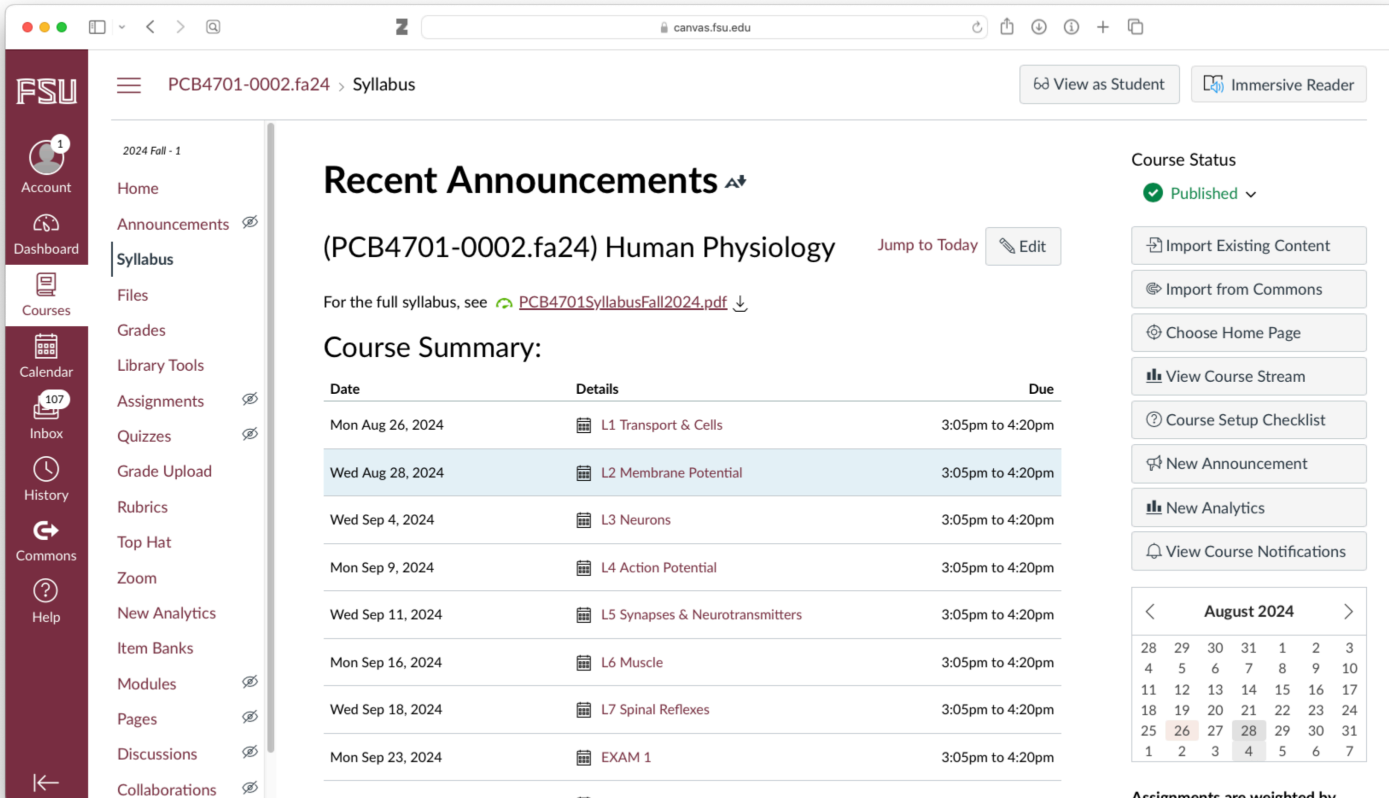
Assignments, lecture outlines, handouts, and practice exams will be posted on Canvas.

Syllabus
Syllabus and course descripton

Course Library
Powerpoint/PDF of Lecture Slides will be posted on Canvas 1-2 days in advance

Assignments
Quizzes (1 / chapter) will be posted under Assignments, and will be completed as "on-line" quizzes. Due before each exam.

Grade Center
Grades will be posted in the Canvas grade center, although the professor has the master spreadsheet of grades.


canvas.fsu.edu
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Account
Dashboard
Courses
Calendar
107
Inbox
History
Commons
Help
PCB4701-0002.fa24 › Syllabus
View as Student
Immersive Reader
2024 Fall - 1
Home
Announcements
Syllabus
Files
Grades
Library Tools
Assignments
Quizzes
Grade Upload
Rubrics
Top Hat
Zoom
New Analytics
Item Banks
Modules
Pages
Discussions
Collaborations
Recent Announcements
(PCB4701-0002.fa24) Human Physiology
Jump to Today
Edit
For the full syllabus, see PCB4701SyllabusFall2024.pdf
Course Summary:
Date
Details
Due
Mon Aug 26, 2024
L1 Transport & Cells
3:05pm to 4:20pm
Wed Aug 28, 2024
L2 Membrane Potential
3:05pm to 4:20pm
Wed Sep 4, 2024
L3 Neurons
3:05pm to 4:20pm
Mon Sep 9, 2024
L4 Action Potential
3:05pm to 4:20pm
Wed Sep 11, 2024
L5 Synapses & Neurotransmitters
3:05pm to 4:20pm
Mon Sep 16, 2024
L6 Muscle
3:05pm to 4:20pm
Wed Sep 18, 2024
L7 Spinal Reflexes
3:05pm to 4:20pm
Mon Sep 23, 2024
EXAM 1
3:05pm to 4:20pm
Course Status
Published
Import Existing Content
Import from Commons
Choose Home Page
View Course Stream
Course Setup Checklist
New Announcement
New Analytics
View Course Notifications
August 2024
Assignments are weighted by

http://houptlab.org/courses/humanphys/

houptlab.org/courses/humanphys/

Human Physiology Summer 2018

Houpt Lab

Neuroscience · Biological Science
The Florida State University

Home Wiki Research People Papers Resources Courses Software

PCB 4701 Human Physiology Summer 2018

Course Syllabus as PDF

Lectures

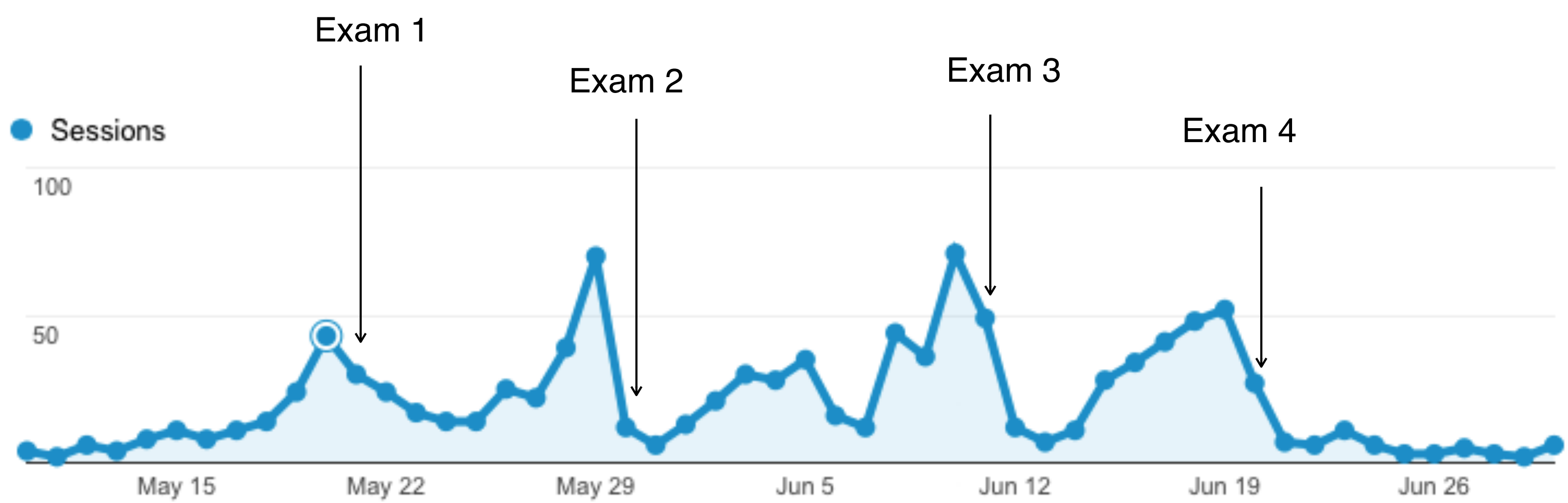
Recordings for use only by enrolled FSU students. © T. Houpt Ph.D. Figures shown are copyright by their respective owners.

Section 1 : Neurons and Muscle

#	Date		Topic	PDF	PPT	Recording
1	Mon	May 14	**Transport**	PDF	PPT	MP4
2	Tue	May 15	**Membrane Potential**	PDF	PPT	MP4
3	Wed	May 16	**Neurons**	PDF	PPT	MP4
4	Thu	May 17	**Action Potential**	PDF	PPT	MP4
5	Fri	May 18	**Synapses and Neurotransmitters**	PDF	PPT	MP4
6	Mon	May 21	**Muscle**	PDF	PPT	MP4
7	Tue	May 22	**Spinal Reflex**			MP4

Wednesday, May 23: Exam 1 covers Lectures 1-7

Lecture recording downloads per day



Grade Determination

TopHat participation (4% of final grade)

Beginning on the third day of class, periodic quizzes or discussion points will be raised in class using Top Hat. Because these in-class questions are designed to help track your understanding of the lecture, you won't be graded on your correct/incorrect responses -- but you will get credit just for participating. **Wednesday Monday September 4**

Weekly Quizzes/Problem Sets (12% of final grade)

Exams (84% of final grade)

Date	% of Final Grade	Material Covered
23-Sep Monday	21%	Lectures 1-7
16-Oct Wednesday	21%	Lectures 8-13
6-Nov Wednesday	21%	Lectures 14-18
12-Dec Thursday 3pm	21%	Lectures 19-24

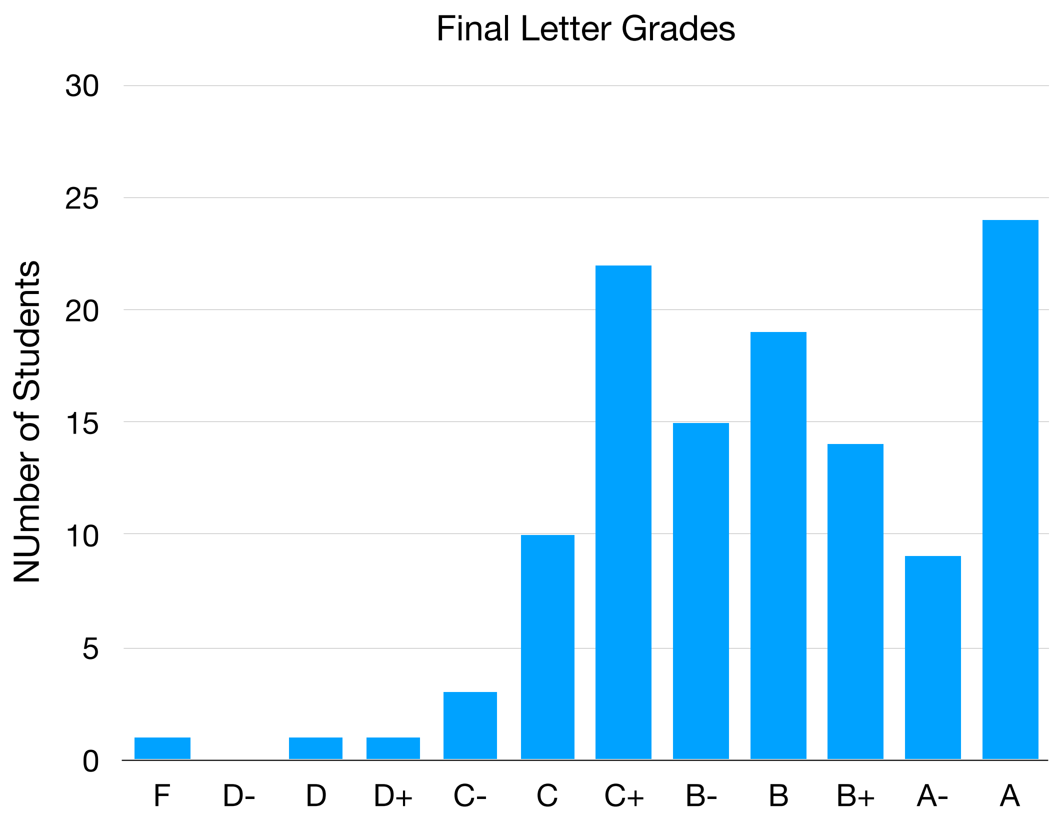
Grade Assignment

Grades will be assigned as follows:

A	100-93
A-	92-90
B+	89-87
B	86-83
B-	82-80
C+	79-77
C	76-73
C-	72-70
D+	69-67
D	66-63
D-	62-60
F	59-0

No curve, but I throw out bad questions on each exam.

Human Physiology



Average = 84%

Make-Up Examinations
Any anticipated conflict with the hour examination (weddings, field trips, family obligations, etc.) must be discussed with the instructor during the first week of classes, so that alternate arrangements for taking the examination(s) can be made in advance. **After the first week of classes, only legitimate emergencies will be accepted as valid excuses.**

A make-up exam may be arranged if: (1) the student contacted the instructor **prior** to the examination (houpt@bio.fsu.edu) and the student documents the fact that a legitimate emergency will prevent her/him from taking the examination - -if the instructor cannot be reached, a message must be left with the departmental office at 644-3700; or (2) the student documents the fact that a legitimate emergency prevented her/him from taking the examination (for example, a written notice from the Health Center indicating the student could not take the exam on the scheduled date) and contacts the instructor within 2 days after the exam date (if the instructor cannot be reached, a message must be left with the departmental office at 644-3700). If the above conditions are not met, the student will receive a "0" for the missed examination.

University Attendance Policy
Excused absences include documented illness, deaths in the family and other documented crises, call to active military duty or jury duty, religious holy days, and official University activities.Consideration will also be given to students whose dependent children experience serious illness.

Academic Honor Policy
Students are responsible for reading the Academic Honor Policy and for living up to their pledge to "...be honest and truthful and...[to] strive for personal and institutional integrity at Florida State University." (Florida State University Academic Honor Policy, found at http://dof.fsu.edu/honorpolicy.htm.)

Americans With Disabilities Act
Students with disabilities needing academic accommodation should: (1) register with and provide documentation to the Student Disability Resource Center; and (2) bring a letter to the instructor indicating the need for accommodation and what type. This should be done during the first week of class.This syllabus and other class materials are available in alternative format upon request

Free Tutoring from FSU
On-campus tutoring and writing assistance is available for many courses at Florida State University. For more information, visit the Academic Center for Excellence (ACE) Tutoring Services' comprehensive list of on-campus tutoring options at https://ace.fsu.edu/tutoring or contact tutor@fsu.edu.

CONFIDENTIAL CAMPUS RESOURCES:
Various centers and programs are available to assist students with navigating stressors that might impact academic success. These include the following:

Victim Advocate Program
University Center A, Rm. 4100
(850) 644-7161
Available 24/7/365
Office Hours: M-F 8-5
https://dsst.fsu.edu/vap

Counseling and Psychological Services
Askew Student Life Center, 2nd floor
942 Learning Way
(850) 644-8255
https://counseling.fsu.edu/

Human Physiology PCB 4701 Topics

Transport & Cells
Neurons & Synapses
Muscle
Nervous System
Sensory Physiology
Endocrinology
Blood, Heart, Circulation
Respiratory Physiology
Gastrointestinal Physiology
Renal Physiology

Human Phys Lectures 01 & 02
Cells and Transport across Membranes

Fluid Compartments of the Body

Transport across the Plasma Membrane

Diffusion and Osmosis

Carrier Mediated Transport

Membrane Potential

Cell Signaling

Human Phys PCB4701

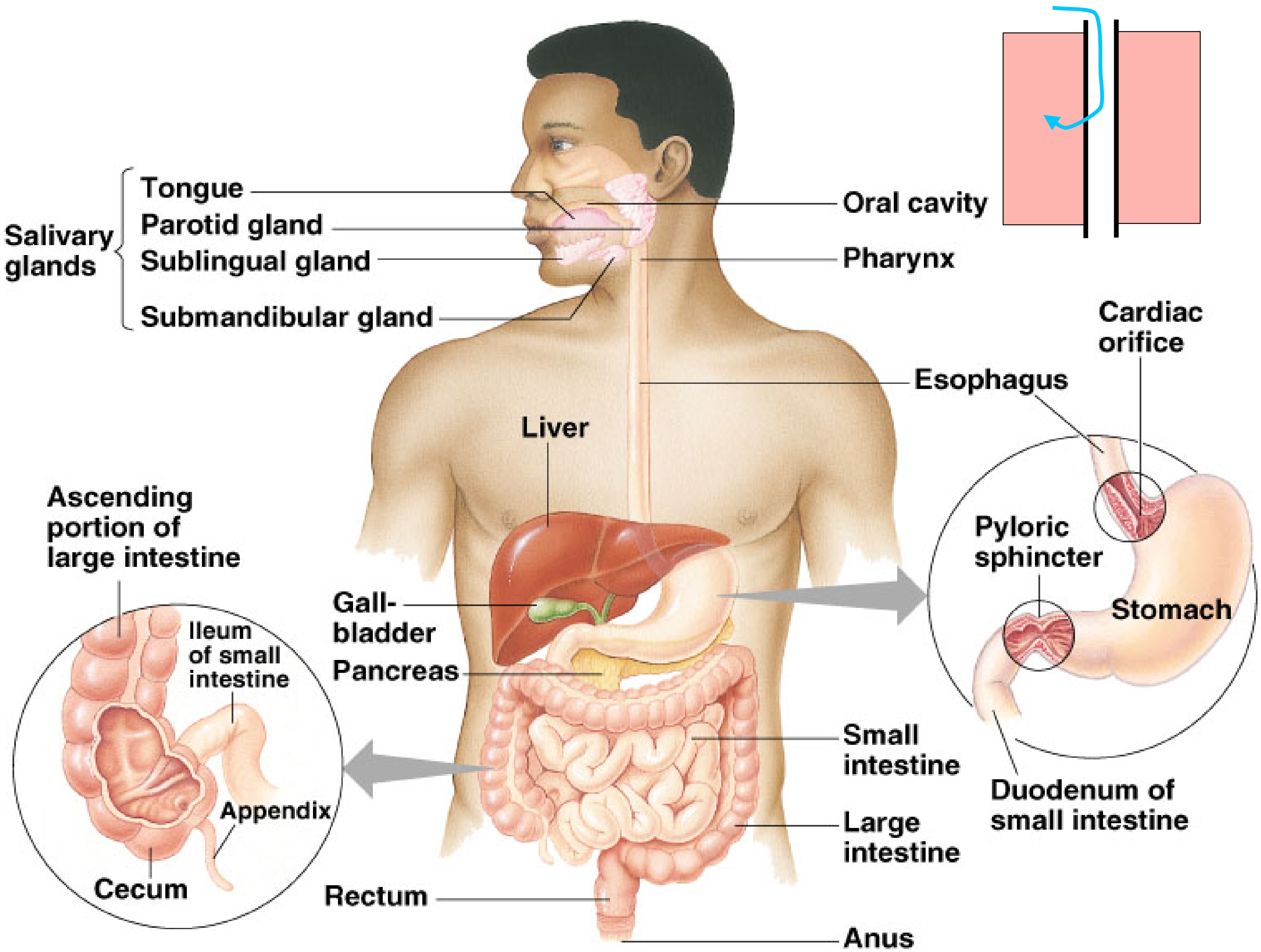
Transport
Fox Chapter 6 pt 1

Compartments of the Body

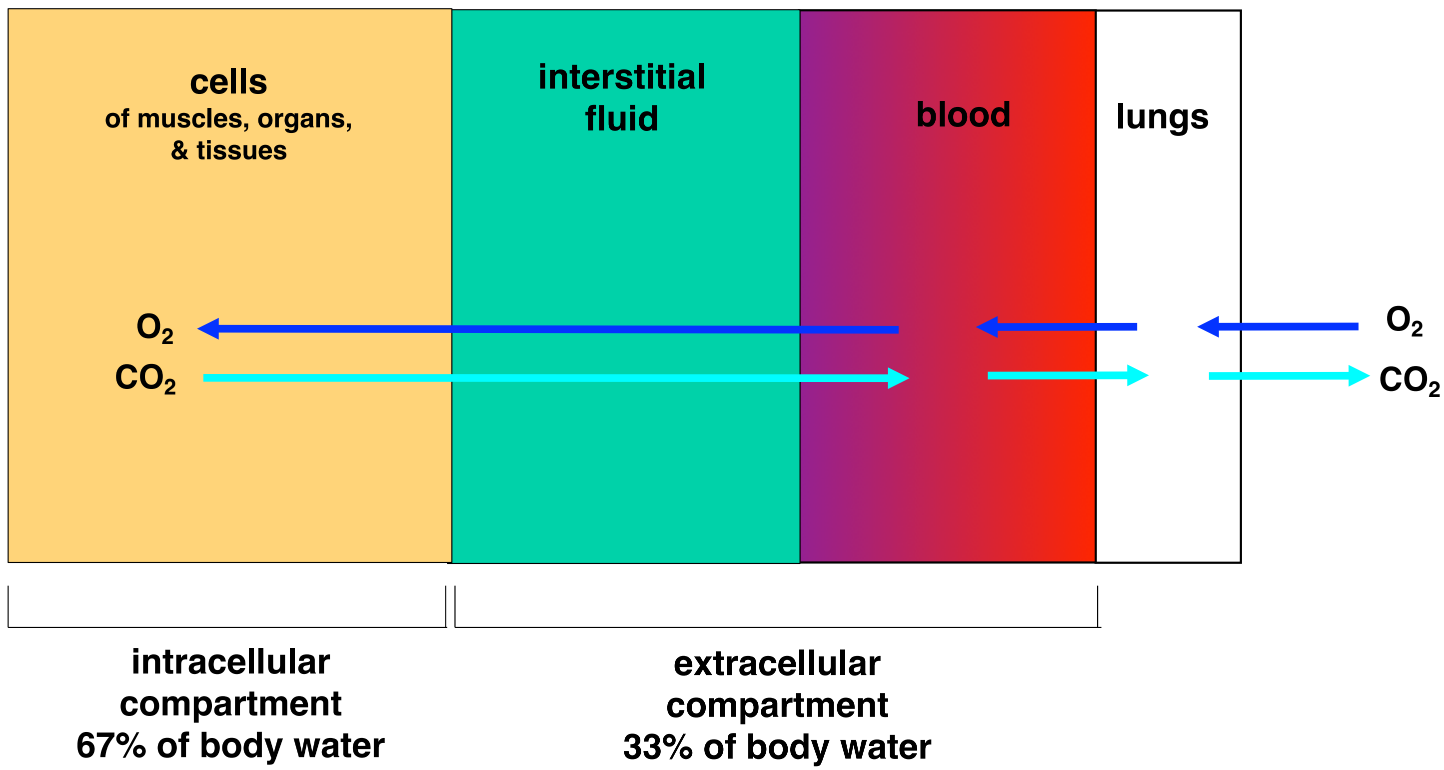
The body can be divided up into conceptual "compartments" :
extracellular vs. intracellular compartments
interstitial fluid vs. blood plasma

Compartments are separated by physical barriers (e.g. linings of blood vessels, lining of lungs, lining of GI tract, extracellular matrix)

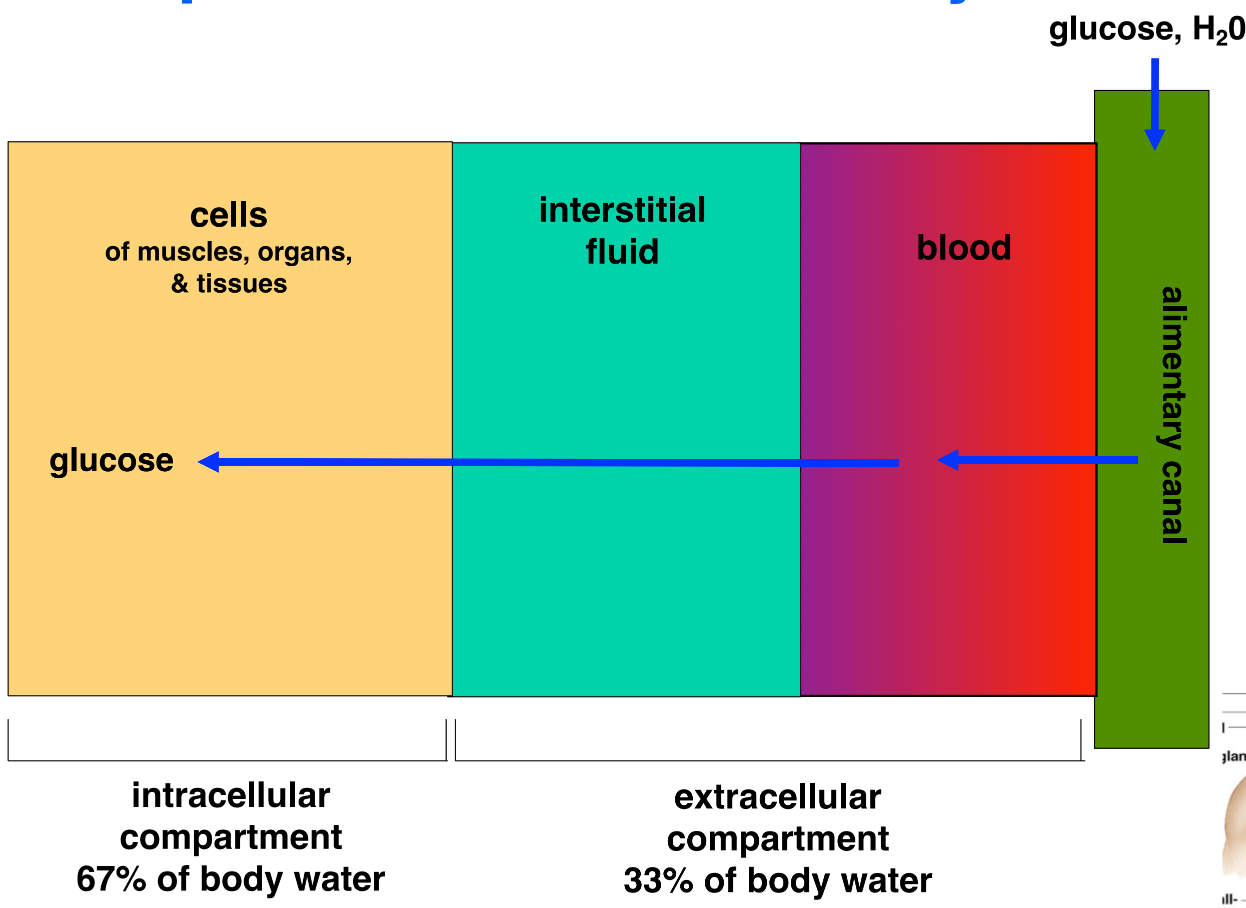
Circulatory system transports O_2 and water-soluble chemicals between compartments (e.g. from lungs to tissues, or from gut to tissues)

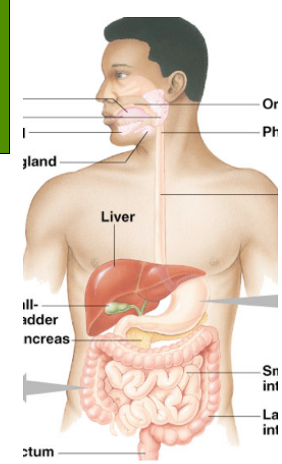

Salivary glands
Tongue
Parotid gland
Sublingual gland
Submandibular gland
Oral cavity
Pharynx
Esophagus
Cardiac orifice
Liver
Ascending portion of large intestine
Gall-bladder
Pancreas
Pyloric sphincter
Stomach
Ileum of small intestine
Appendix
Cecum
Small intestine
Large intestine
Duodenum of small intestine
Rectum
Anus

“Compartments” of the Body

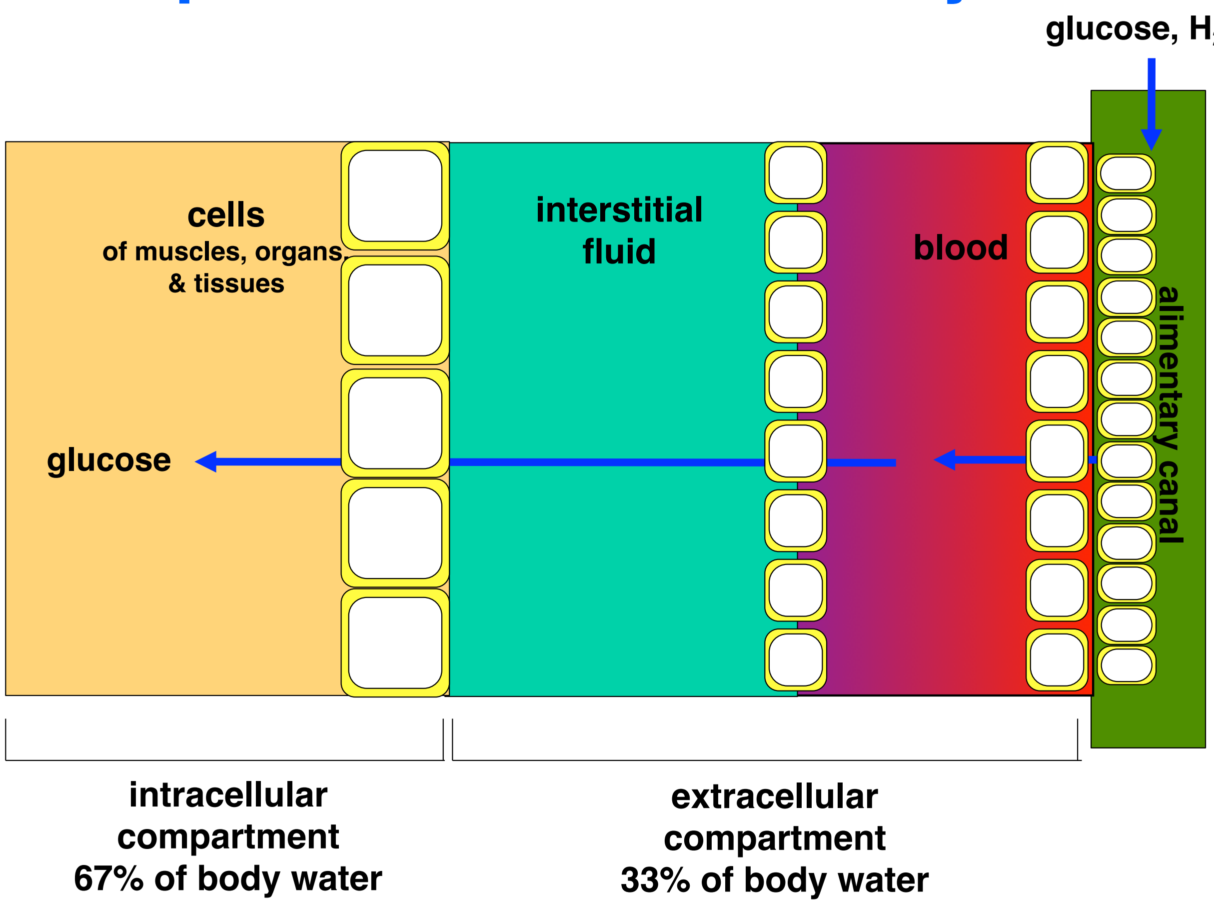


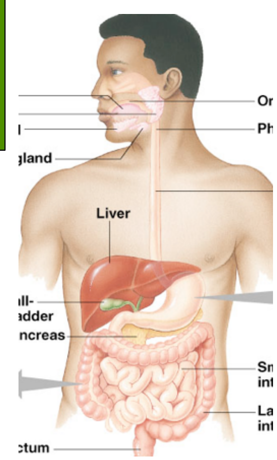
“Compartments” of the Body





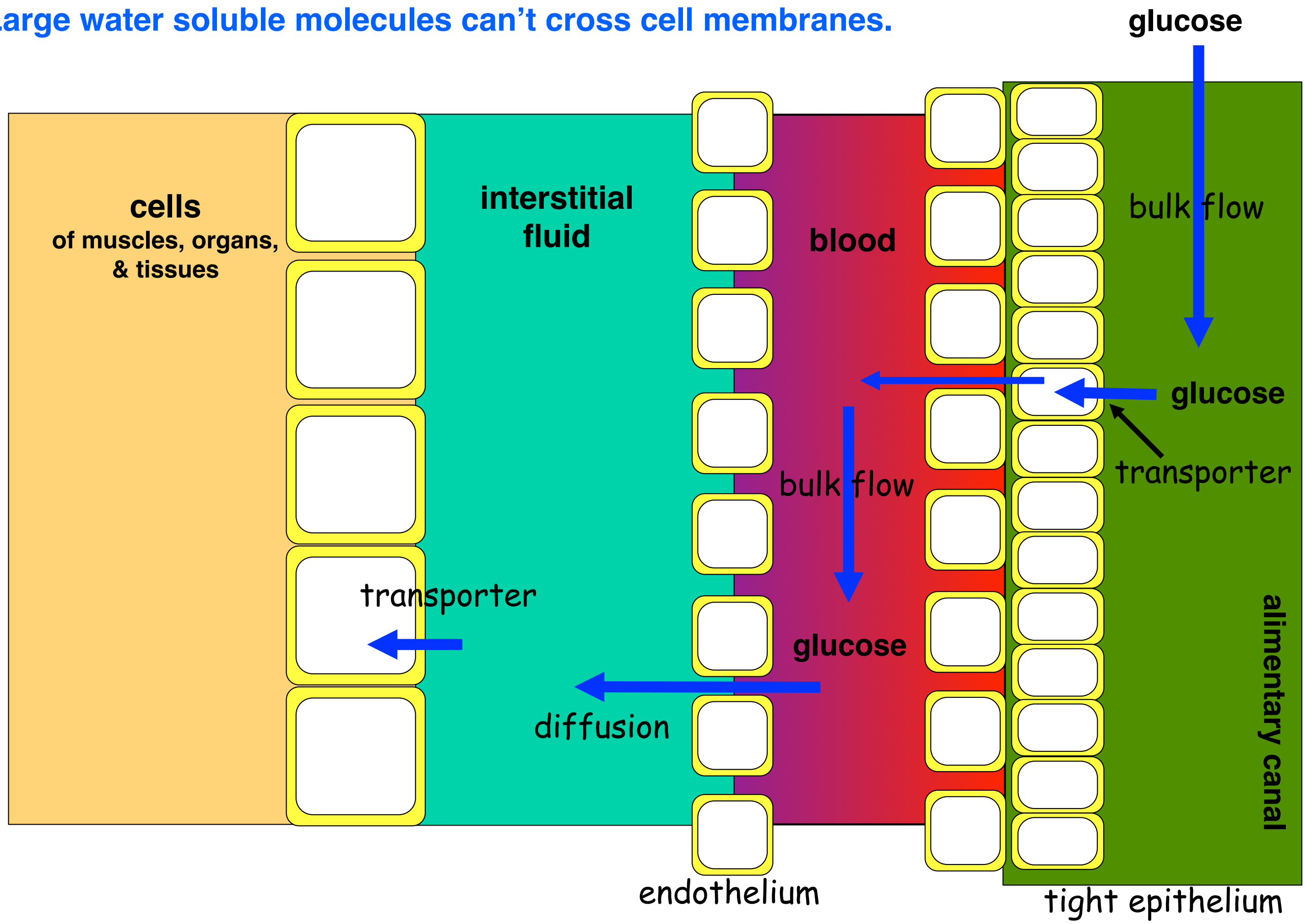
“Compartments” of the Body

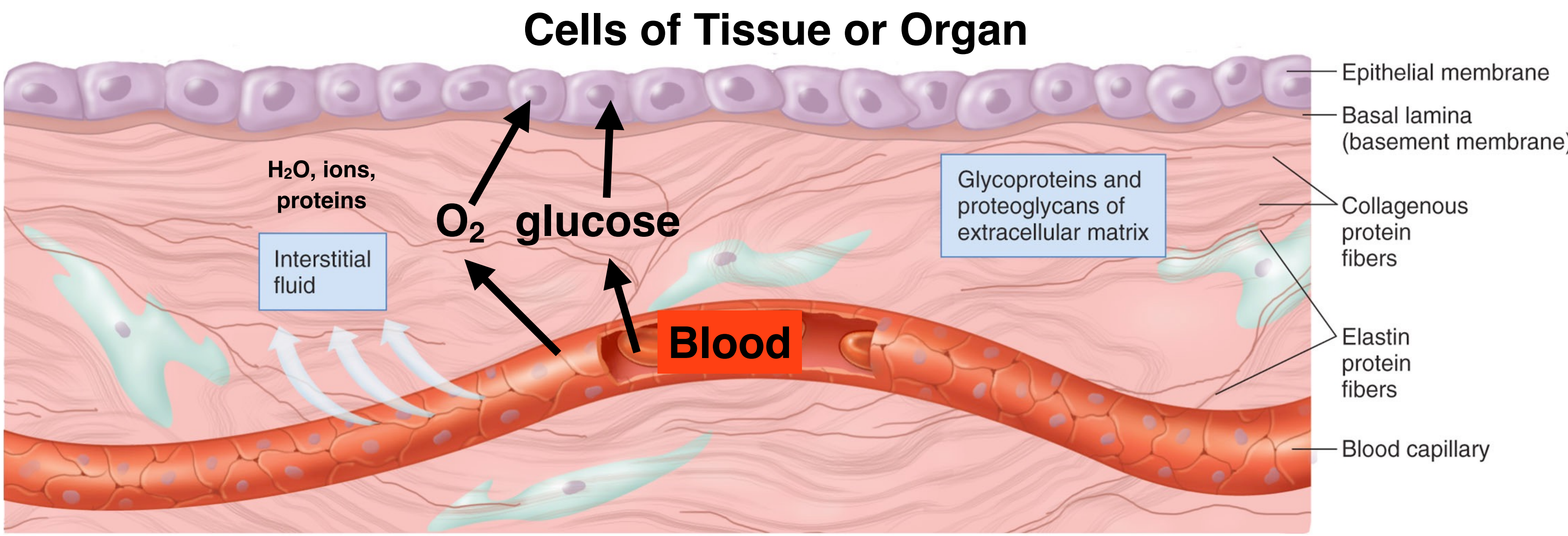




Transport between compartments requires bulk transport, diffusion, and cell membrane transport

Large water soluble molecules can't cross cell membranes.





what prevents movement of chemicals?
how do chemicals move from in/out of cells?

glyco- *associated with glucose and/or polysaccharides*

glycoproteins have polysaccharide side chains

Fox Figure 6.1

Plasma Membrane of cells

selectively permeable phospholipid bilayer

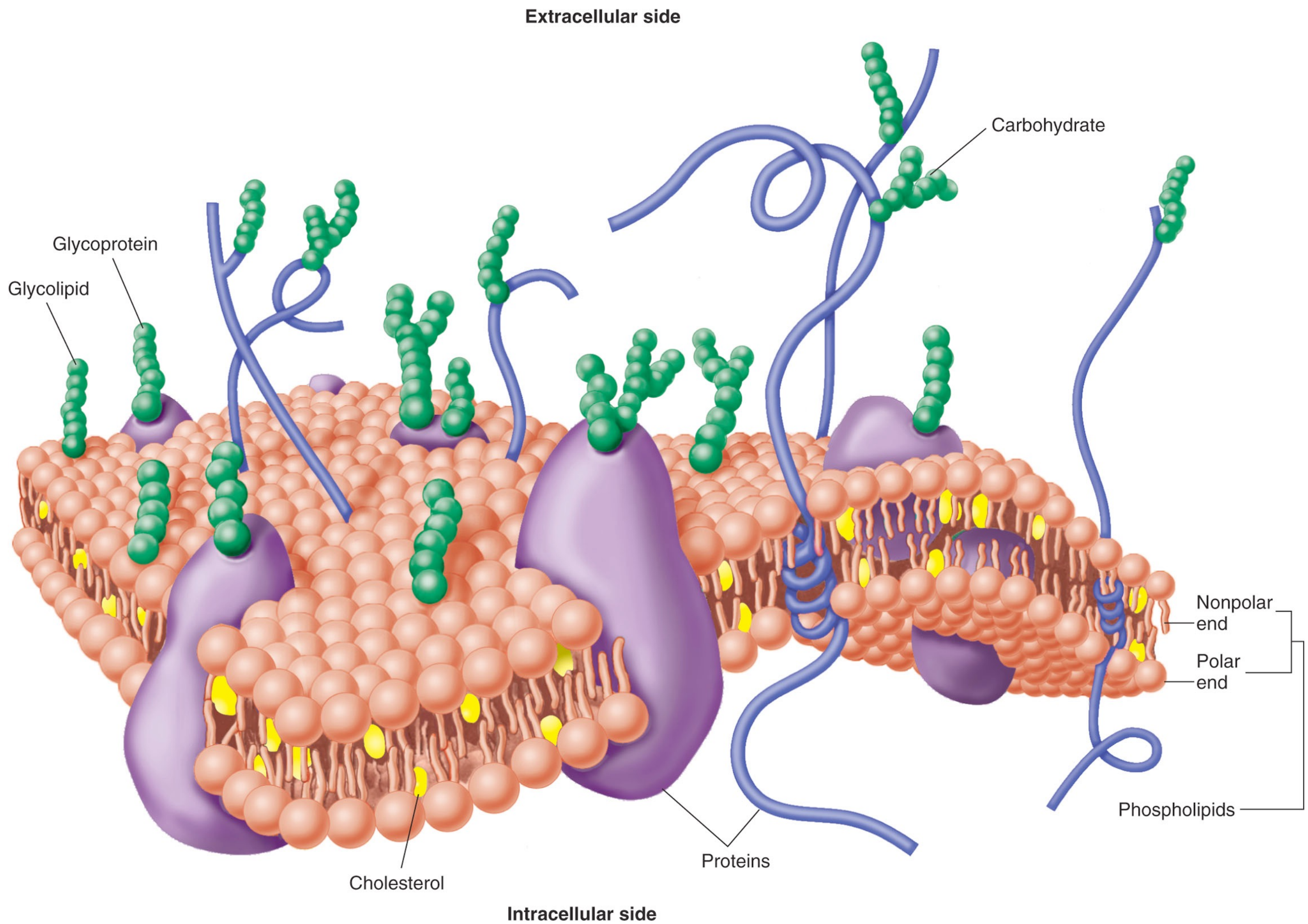
Barrier to large, polar molecules, e.g. proteins, nucleic acids

Permeable to many smaller molecules

Mechanisms of Transport across membrane:

- Simple Diffusion
  - lipid-soluble molecules
  - ions through channel proteins
  - osmosis - diffusion of water through aquaporin channels
- Carrier-Mediated Transport
  - facilitated diffusion
  - active transport

Plasma Membrane



Fox Figure 3.2

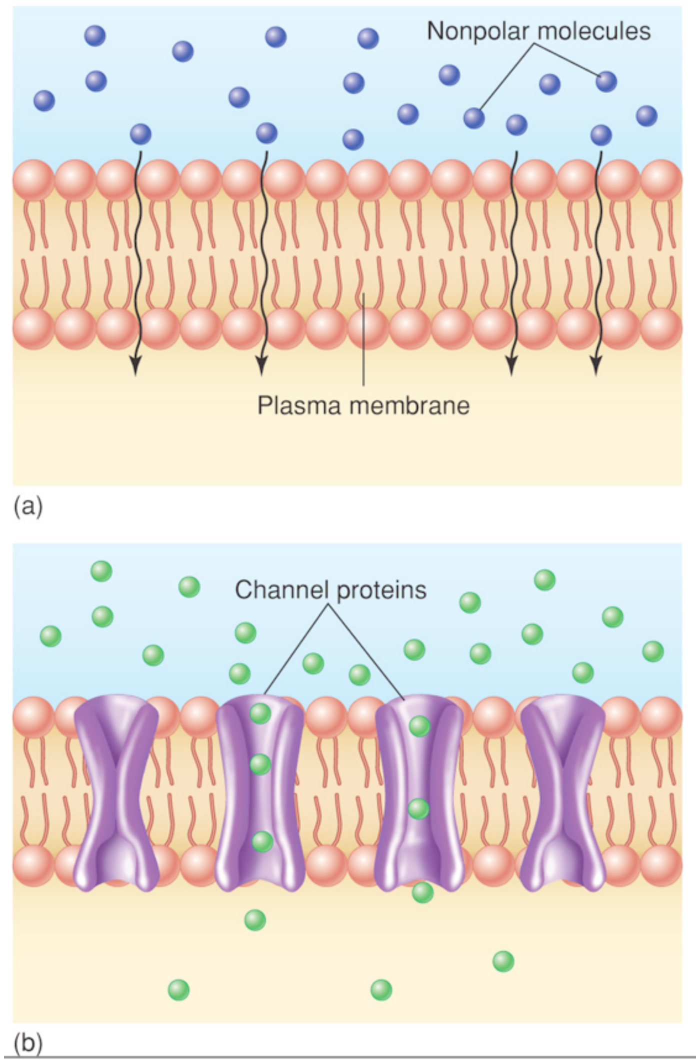
Non-Carrier Mediated Transport

Simple Diffusion across Membrane
(lipids, gases)

Diffusion of ions through **ion channel proteins**

Osmosis: diffusion of water through
aquaporin channels across membrane

Note: because diffusion moves molecules down a concentration gradient, no extra energy is required to transport these molecule.



(a)

(b)

Diffusion

Solution = solvent (water) and solute (dissolved molecules)

Due to random movement (thermal energy), solute molecules will show **net** movement from region of high concentration to region of low concentration; solute **moves down concentration gradient**.

Rate of Diffusion:

- increases with temperature
- increases with concentration gradient
- increases with surface area of membrane
- decreases with distance

Diffusion is only efficient at 100 μm or less, so all tissues of body within 100 μm of blood capillary.

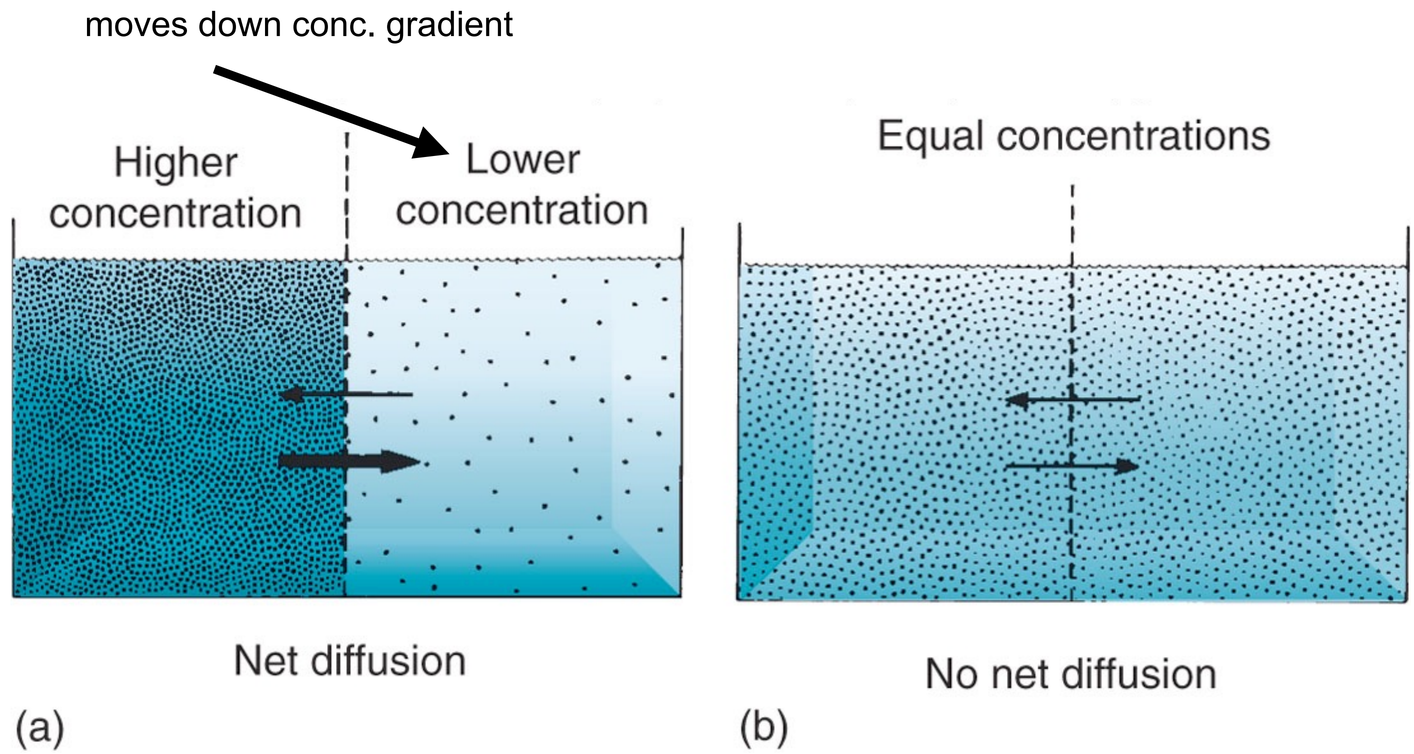
if the solute molecules can penetrate the membrane
then diffusion can occur across the membrane, e.g.

- lipids
- small gas molecules (O_2, CO_2)
- ions through protein channels in the membrane.

$$\textit{Diffusion Flux} = -D\,\frac{d\Phi}{dx}$$

D (diffusion coefficient) is proportional to the squared velocity of the diffusing particles, which depends on the temperature, viscosity of the fluid and the size of the particles according to the Stokes-Einstein relation.

Φ = concentration of the solute, so $d\Phi/dx$ is the concentration gradient.



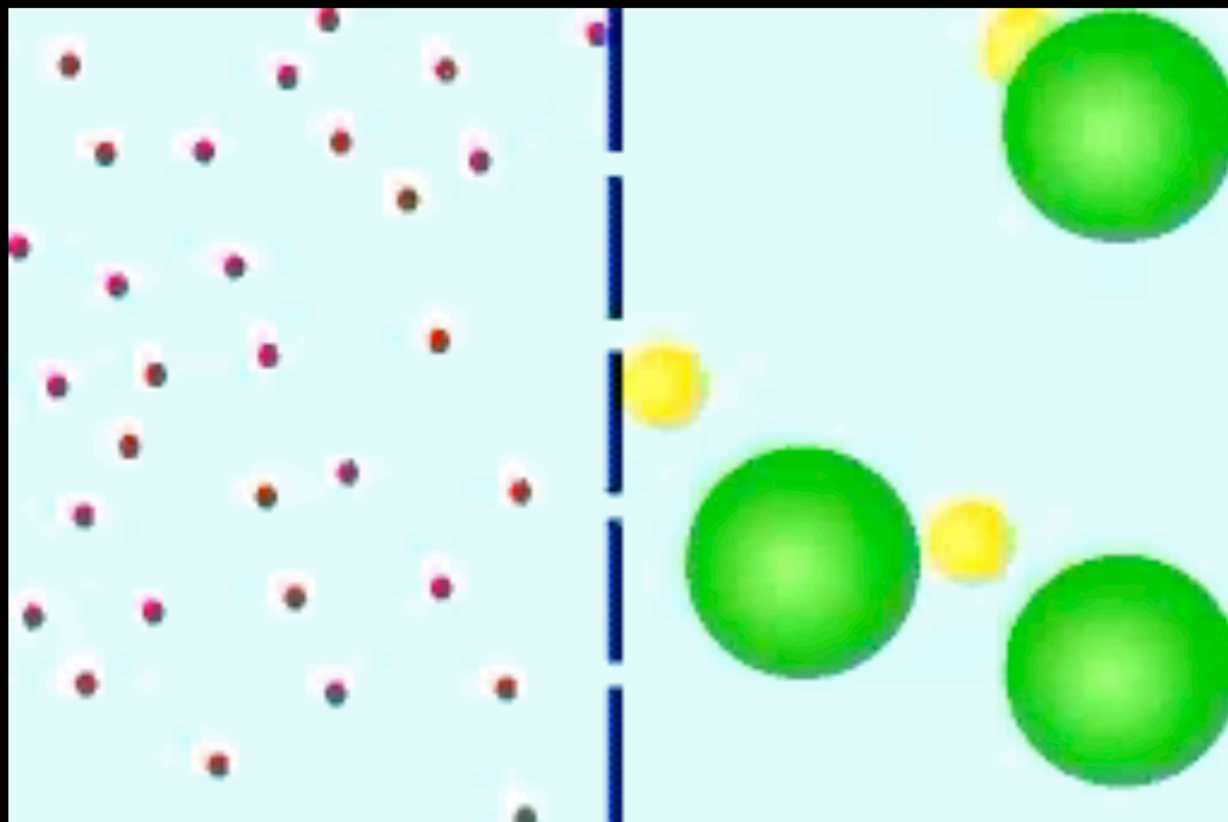
Rate of Diffusion:

constant in mammals ->
- increases with temperature
- increases with concentration gradient
- increases with surface area of membrane

<- exploit or overcome

keep within 100 μm ->
- decreases with distance

Fox Figure 6.3



- Rate of Diffusion increases with surface area of membrane that solute is diffusing across

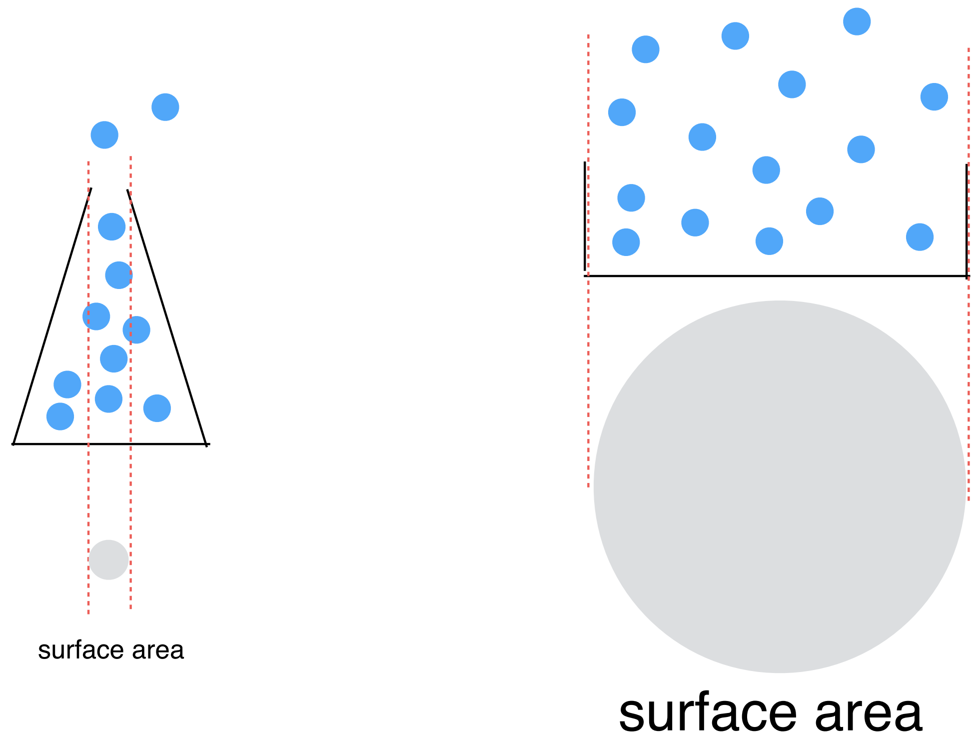
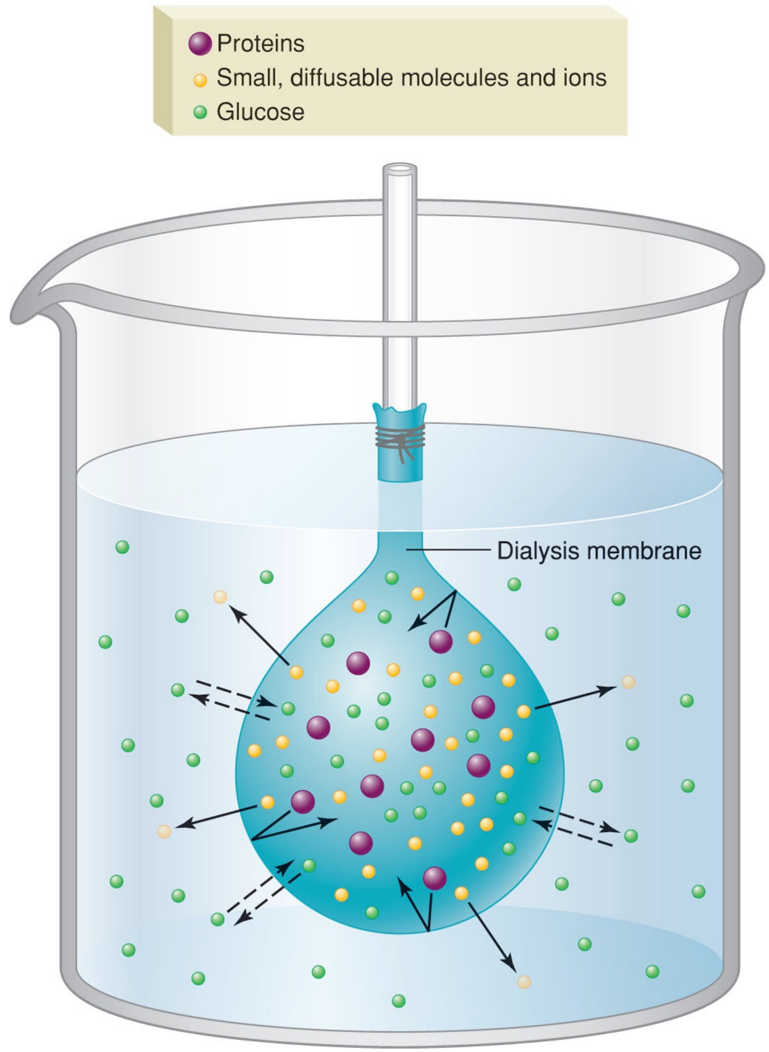
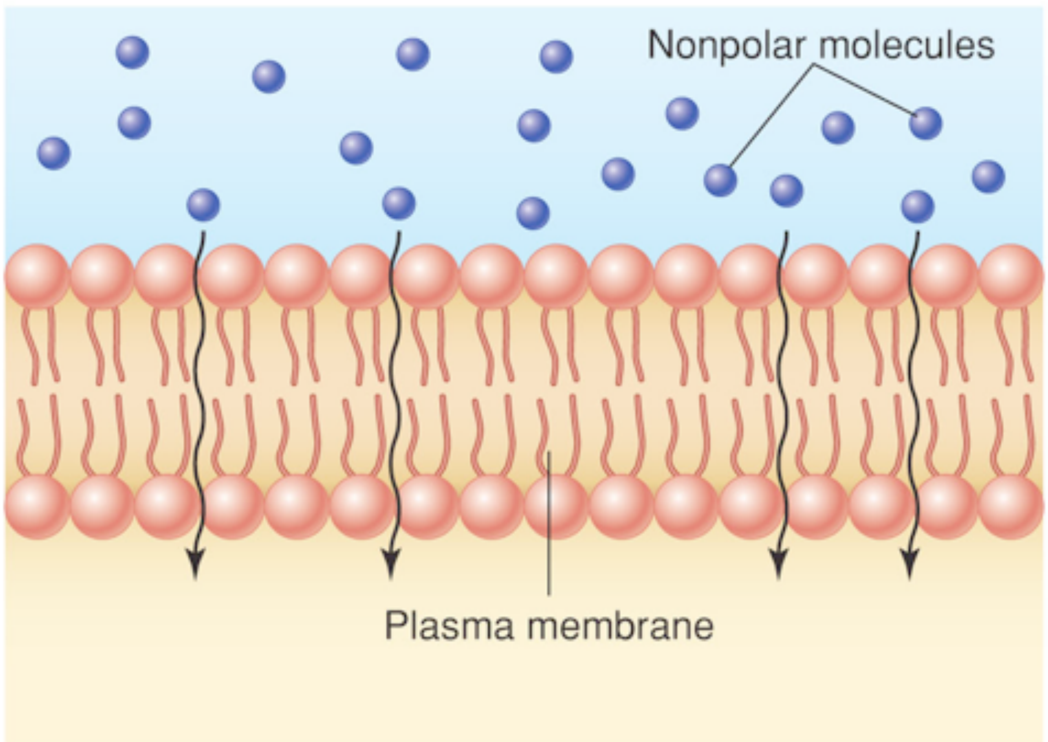


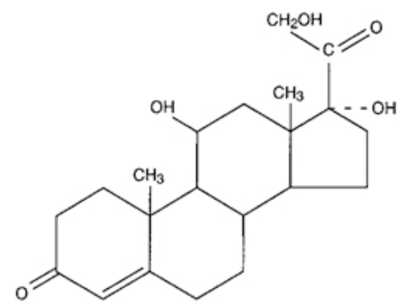
Figure 6.4

Diffusion can occur across a semipermeable membrane ***if the solute molecules can penetrate the membrane***



Nonpolar molecules (e.g. lipids, steroids) can diffuse through phospholipid bilayer

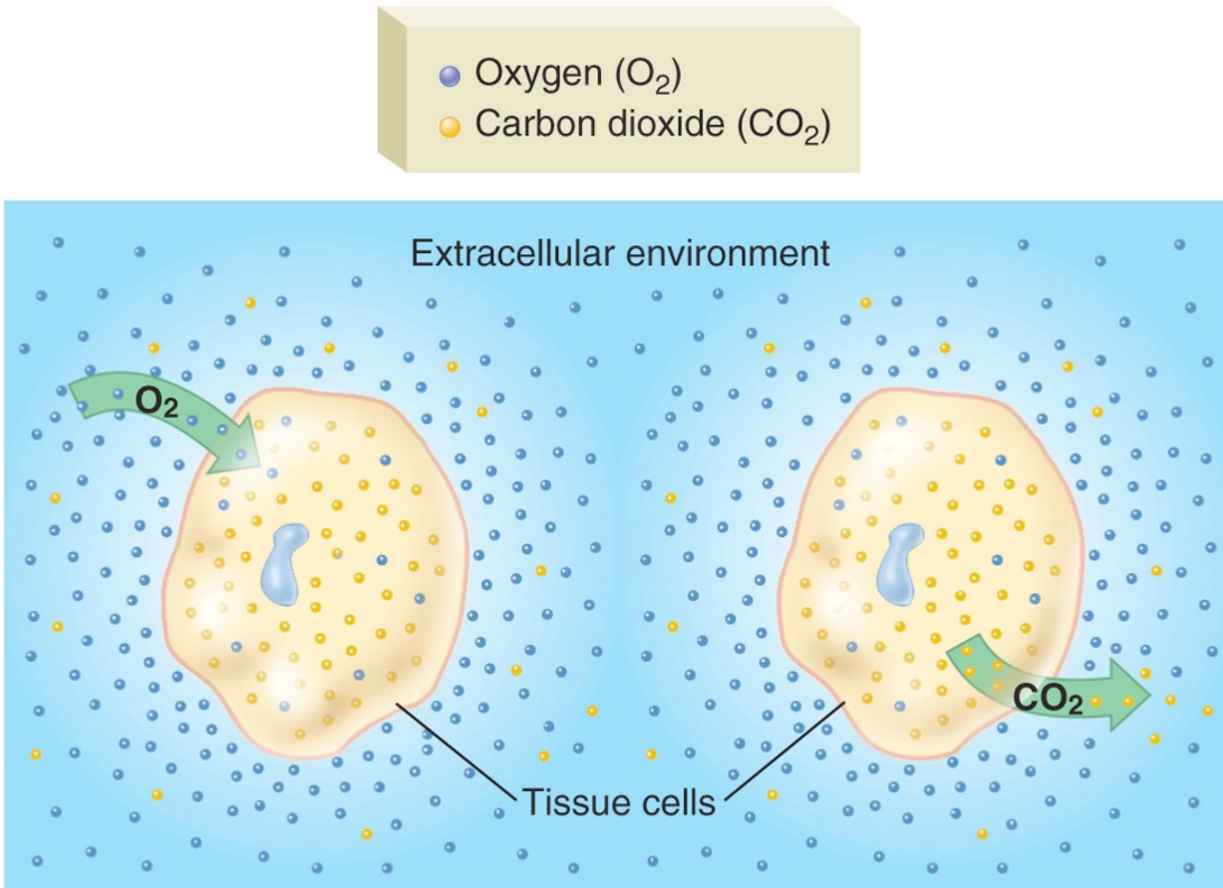




e.g. cortisol

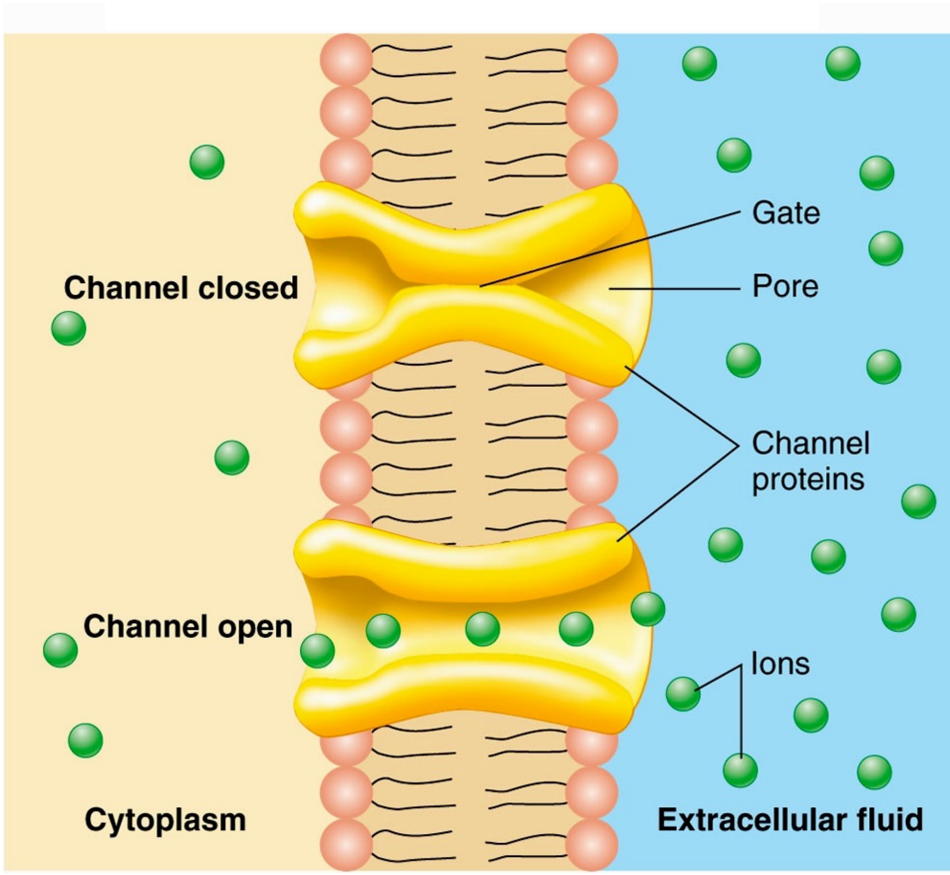
Small gas molecules (O_2, CO_2) can diffuse across cell membrane:

O_2 from outside to inside cell; CO_2 from inside to outside of cell



Fox Figure 6.5

Ions can move down concentration gradient through protein channels in the membrane (if the channels are open).



Fox Figure 6.6

Osmosis

cells cannot pump H_2O directly!

Diffusion of water across a semipermeable membrane, e.g. through **aquaporin channels** in plasma membrane.

Water moves from low solute concentration solution to high solute concentration solution (i.e. water diffuses from high water concentration to low water concentration)

Water will diffuse by osmosis across the membrane until solute concentration is the same on both sides of the membrane (or until physical pressure stops the flow)

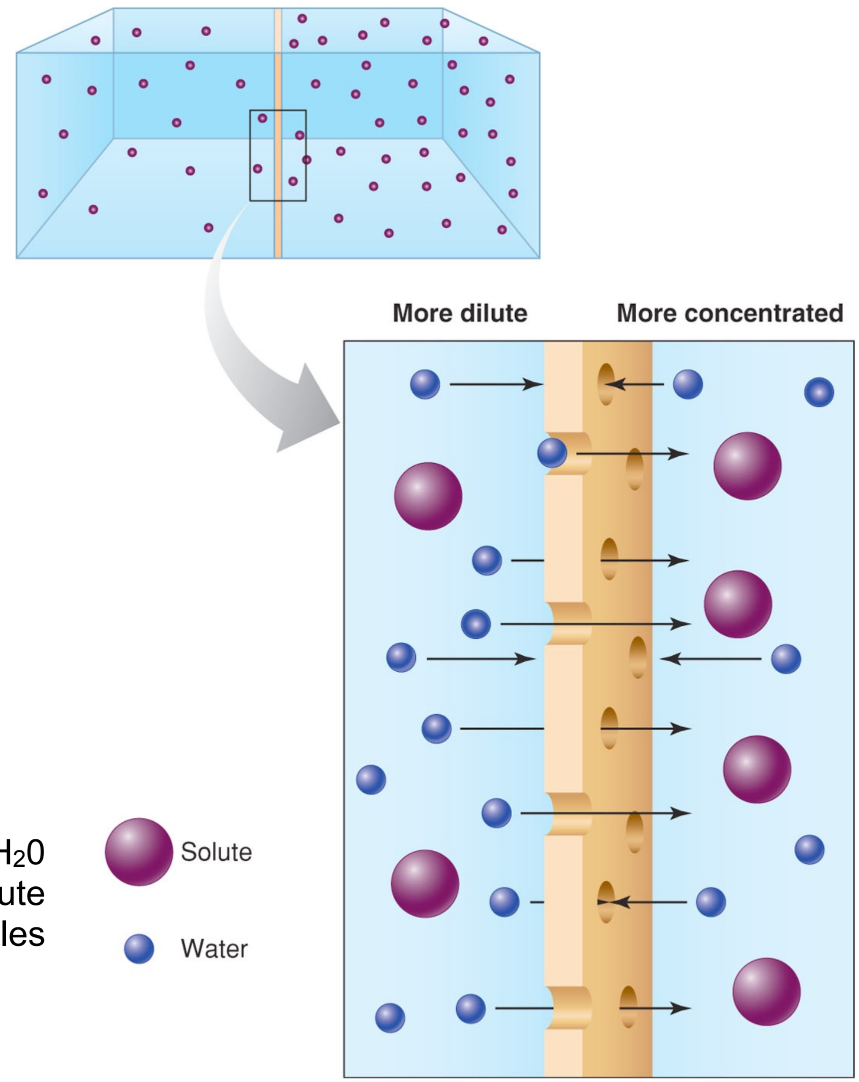
Osmotic Pressure is how strongly a concentrated solution pulls water by osmosis across the membrane.

Pure Water: osmotic pressure = 0
Equal osmotic concentration on each side: **isotonic**
less concentrated solution: lower osmotic pressure = **hypotonic**
More concentrated solution: higher osmotic pressure = **hypertonic**

Osmo- to push.
iso- same, **hypo-** under/less than, **hyper-** above/more than, **-tonic** pressure

Osmosis

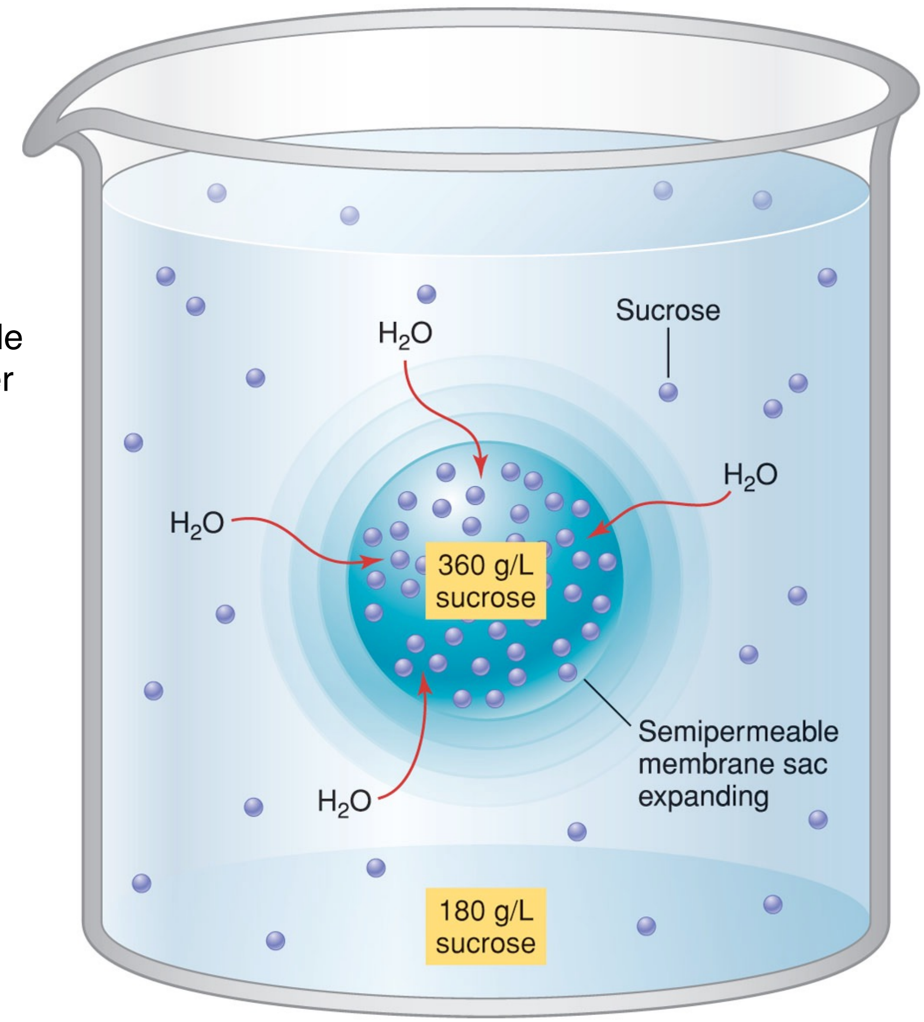
Diffusion of **water** across a semipermeable membrane from **less** concentrated solution to **more** concentrated solution



Membrane permeable to small H_20 molecules, but not large solute molecules

Fox Figure 6.7

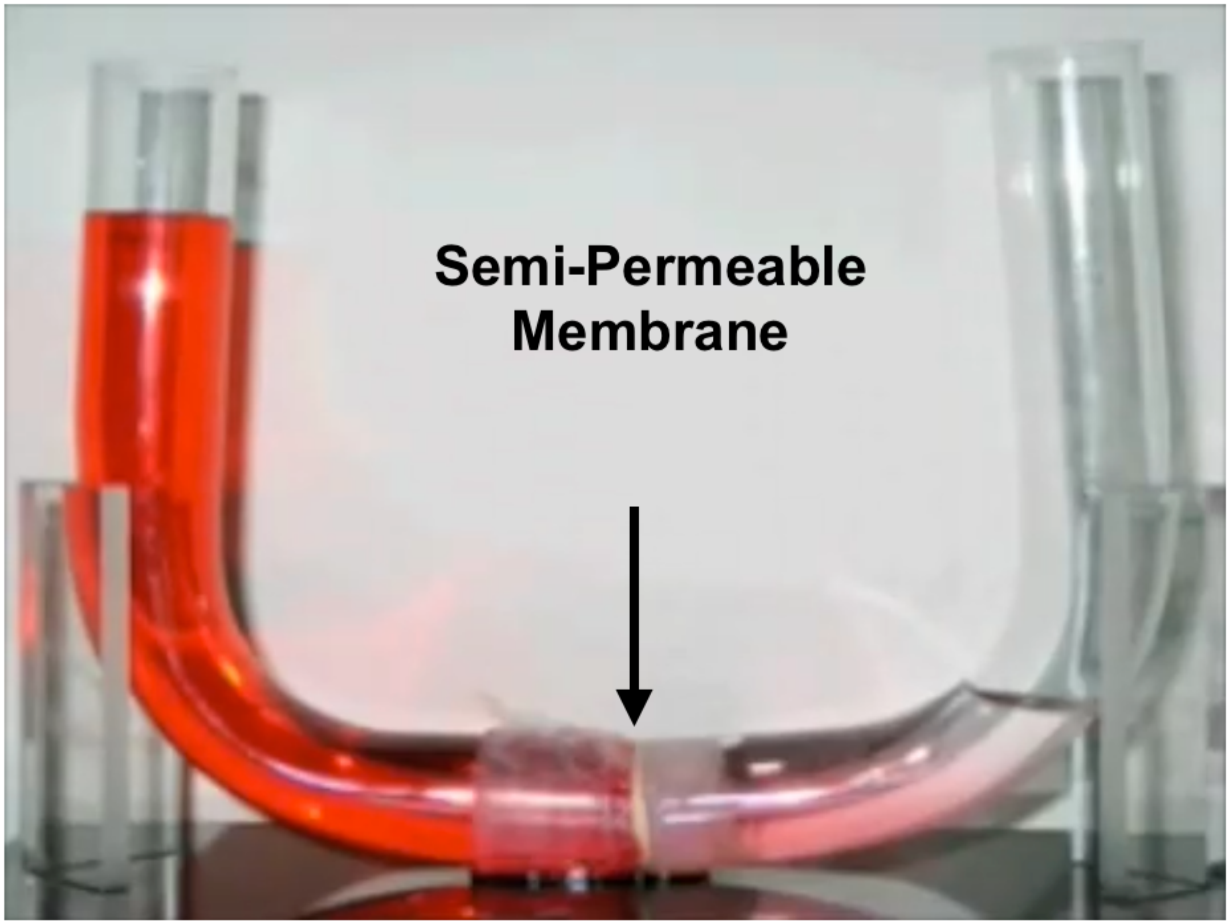
Osmosis will cause semipermeable membrane sac to expand as water moves from less concentrated to more concentrated solution



Fox Figure 6.8

Osmosis in a U-Tube

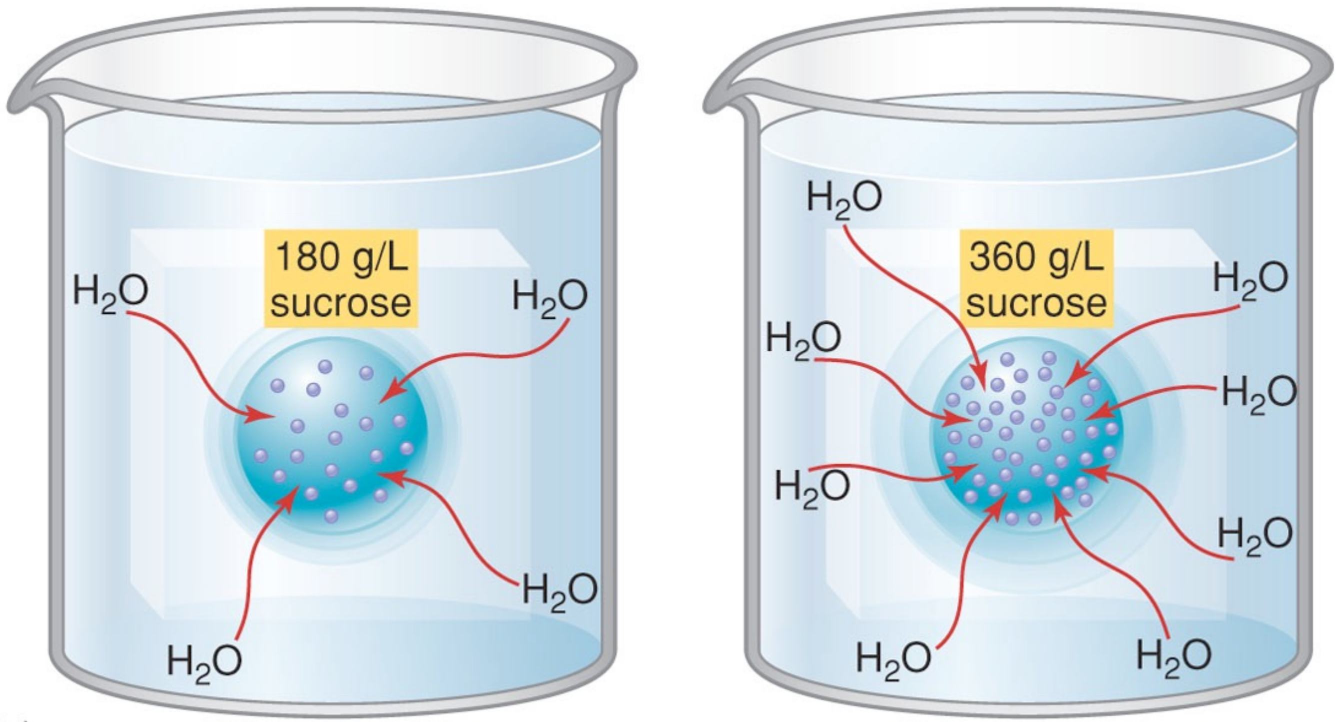
http://www.youtube.com/watch?v=GbudKs-49jo



Sucrose solution
(2 M)

water
(O M)

Higher concentration solution exerts greater osmotic pressure (draws in more water, faster)

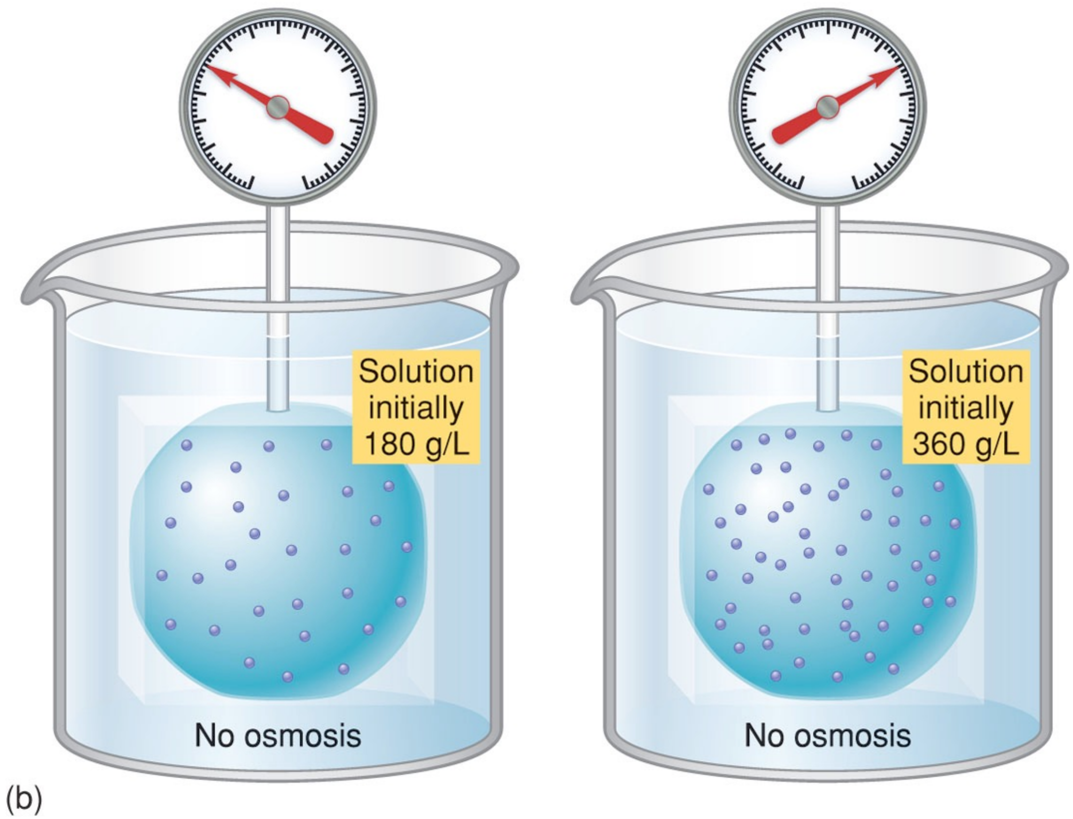


(a)

Fox Figure 6.9a

After cell swells to maximum possible size, can measure **osmotic pressure** exterted by movement of water into the cell: higher concentration exerts a greater drawing power on water

$$\Pi = c_{solutes} RT$$



Fox Figure 6.9b

Osmolarity vs Molarity

Osmotic concentration of a solution is determined by number of **particles**, not concentration of compound.

NaCl in solution dissociates into 2 particles (Na & Cl), so 1 M NaCl solution has **2x** the osmotic concentration as 1 M glucose.

Osmotic concentration is measured in **Osmolarity (Osm)**.
(number of particles in moles / liter solution)

Osmosis is diffusion of water from:
low Osmolarity to **high** osmolarity.

Remember: Particles Suck!

Osmolarity vs Molarity

Molarity (m):

number of <u>compound molecules</u> per liter of solution

1 M glucose = 1 mole (6 x 10^{23}) glucose molecules / liter

1 M NaCl = 1 mole (6 x 10^{23}) NaCl molecules / liter

Osmolarity (Osm):

number of <u>solute</u> <u>particles</u> per liter

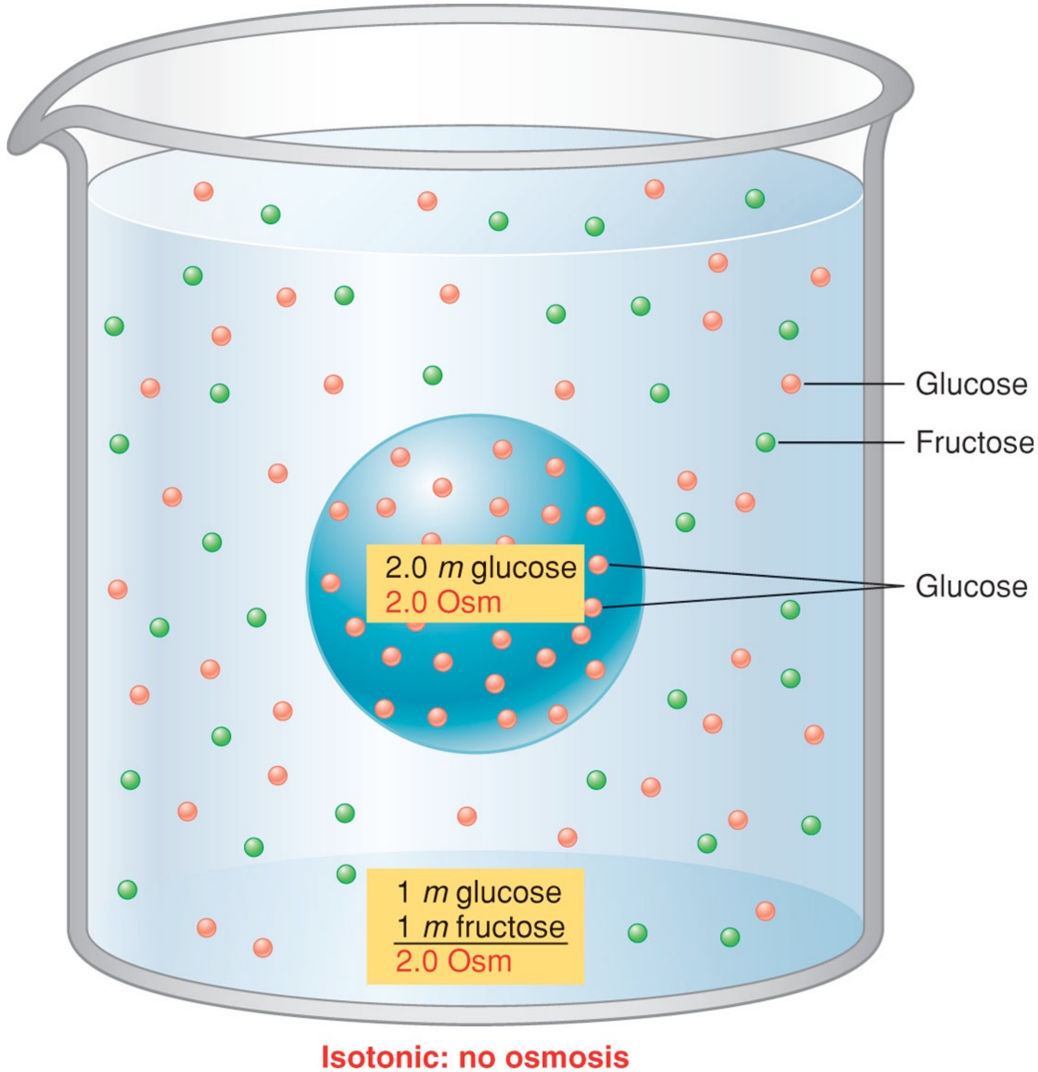
1 M glucose = 1 mole glucose / liter = 1 osmole /liter = 1 Osm

1 M NaCl = 1 mole Na & 1 mole Cl / liter = 2 osmoles /liter = 2 Osm

1 M glucose, 1 M fructose = 1 mole fructose & 1 mole glucose / liter

= 2 osmoles/liter = 2 Osm

Figure 6.11


Glucose
Fructose
2.0 m glucose
2.0 Osm
Glucose
1 m glucose
1 m fructose
2.0 Osm
Isotonic: no osmosis

Homeostasis: Osmotic Regulation

Body tries to maintain constant osmotic concentration of 0.3 Osm for both intracellular and extracellular fluids

(solute molecules may be different in different compartments, but osmotic concentration, the number of particles/liter, is kept constant)

<u>intra</u>cellular potassium [K] & anions = 0.3 Osm

<u>extra</u>cellular sodium [Na] & anions = 0.3 Osm

homeo- *the body*

stasis- *to keep constant*

Concentration of Blood Plasma

Ion	**Concentration (1 mM = 0.001 M)**
Na +	150 mM
K+	5 mM
Ca++	5 mM
Cl -	105 mM
$HC0_3$ -	25 mM
Proteins (-)	35 mM

Osmolarity of blood = ~ 0.3 Osm

Body tries to maintain this osmotic concentration of blood.

if [NaCl] is too high, then animal will try to dilute blood with water.

Isotonic Saline

0.15 M NaCl

= 0.9% NaCl

= Physiological saline

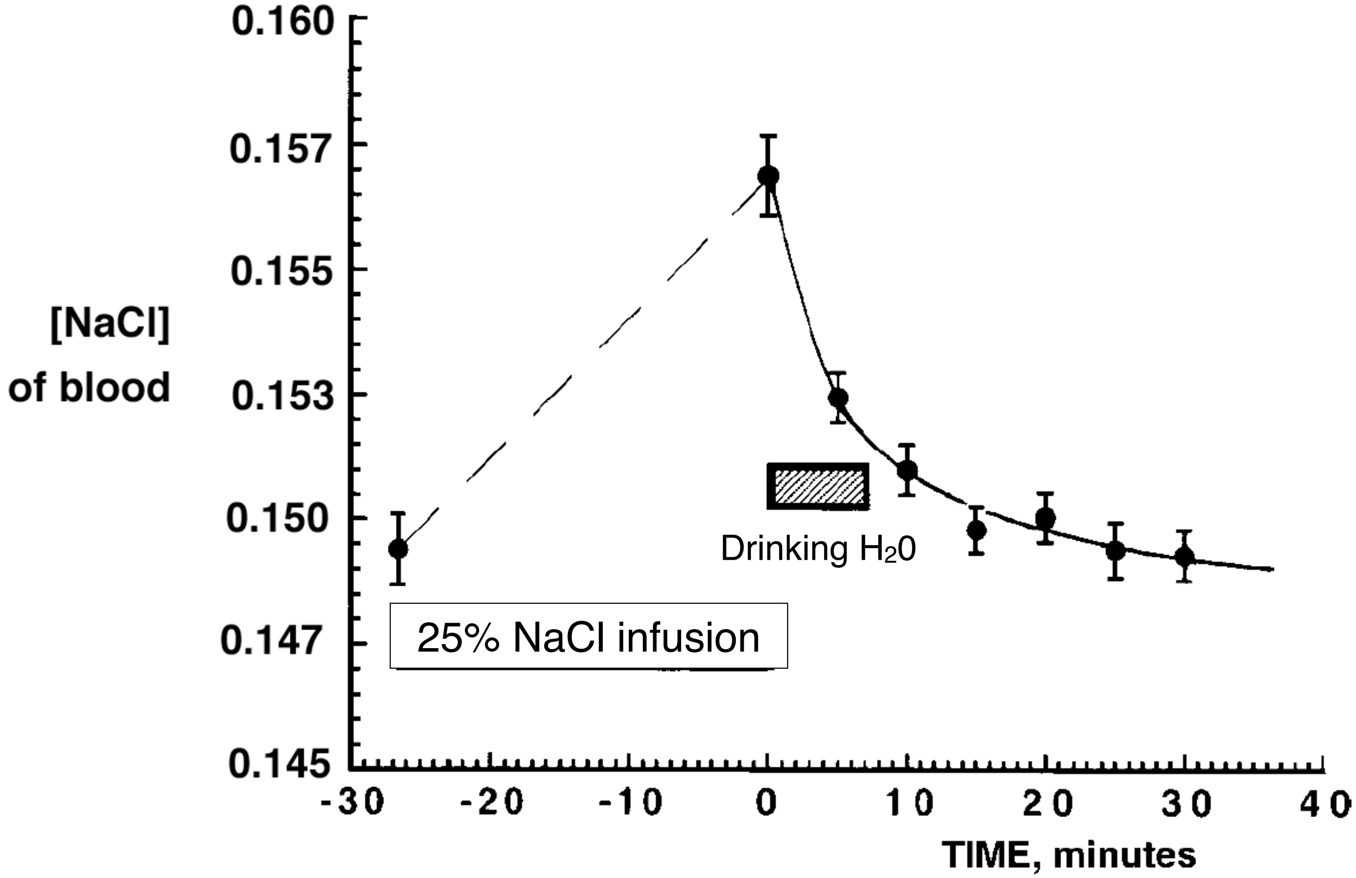
= Concentration of NaCl in mammalian blood

Animals tries to maintain this concentration of NaCl.

if [NaCl] is too high, then animal will try to dilute blood with water.

Also important, because water is toxic to tissues!

Elevated [NaCl] in blood above 0.15 M causes drinking in pigs



Osmolarity of Intravenous Fluids

IV fluids must be same osmotic concentration as blood;
pure water is toxic to tissues!

Isotonic Saline

0.9% NaCl

= 0.9 g NaCl / 100 ml H_20

= 0.15 M NaCl

= 0.15 M Na^+ & 0.15 M Cl^-

= 0.3 M particles

= 0.3 Osmoles

= 0.3 Osm

5% Dextrose

5% glucose

= 5 g glucose / 100 ml H_20

= 0.3 M glucose

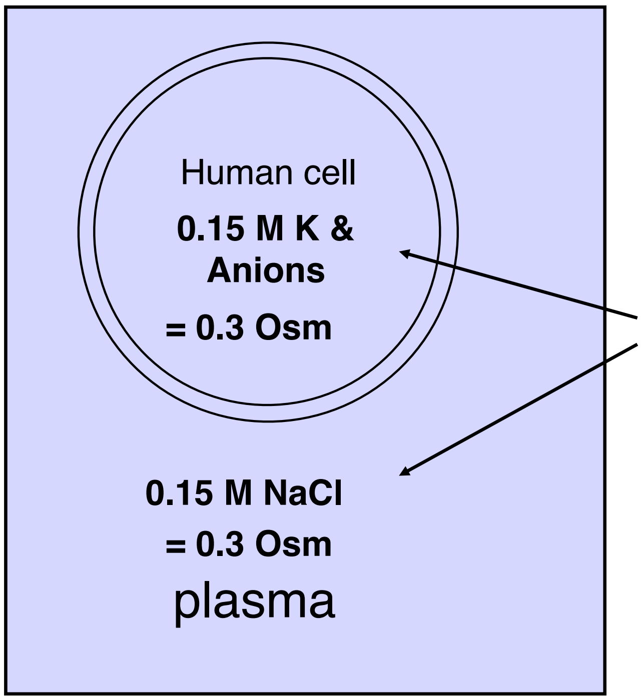
= 0.3 M particles

= 0.3 Osmoles

= 0.3 Osm

Osmosis

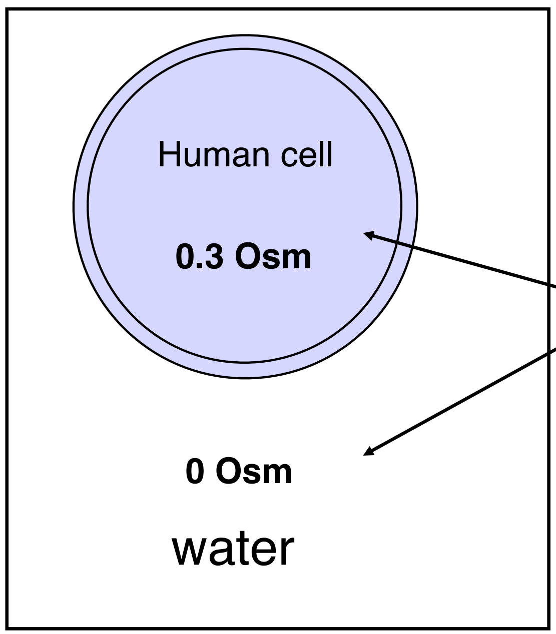
Water moves across membrane from ***less*** concentrated to ***more*** concentrated solutions



same concentration inside cell as outside cell, so no movement of H_20

Osmosis

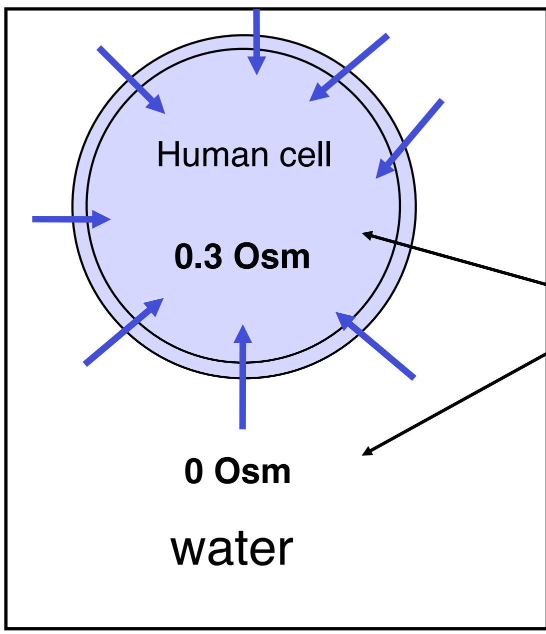
Water moves across membrane from ***less*** concentrated to ***more*** concentrated solutions



more concentrated
inside cell,
so H_20 moves into cell

Osmosis

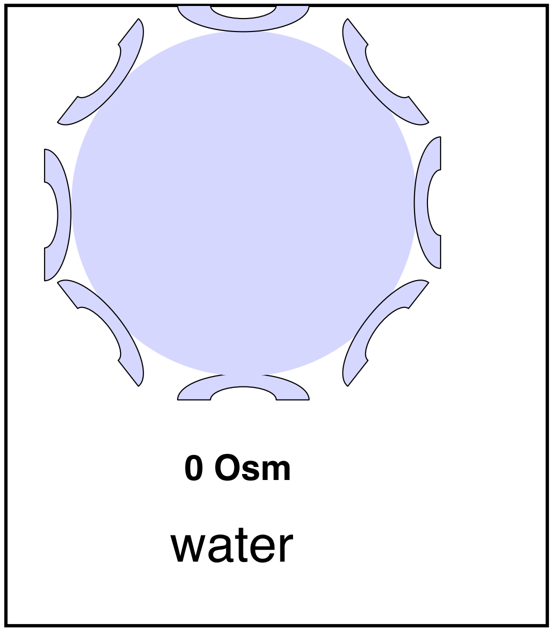
Water moves across membrane from ***less*** concentrated to ***more*** concentrated solutions



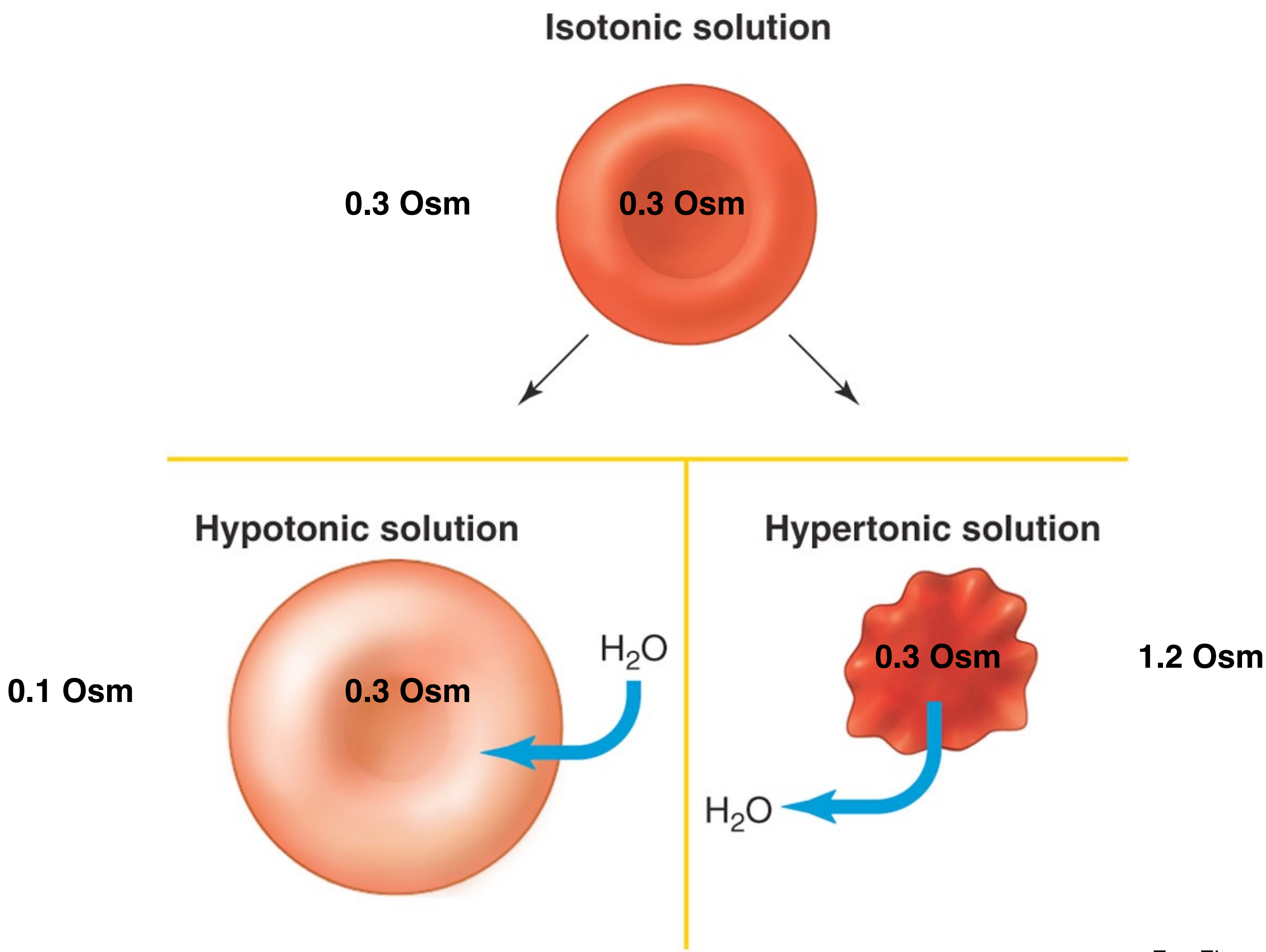
more concentrated
inside cell,
so H_20 moves into cell

Osmosis

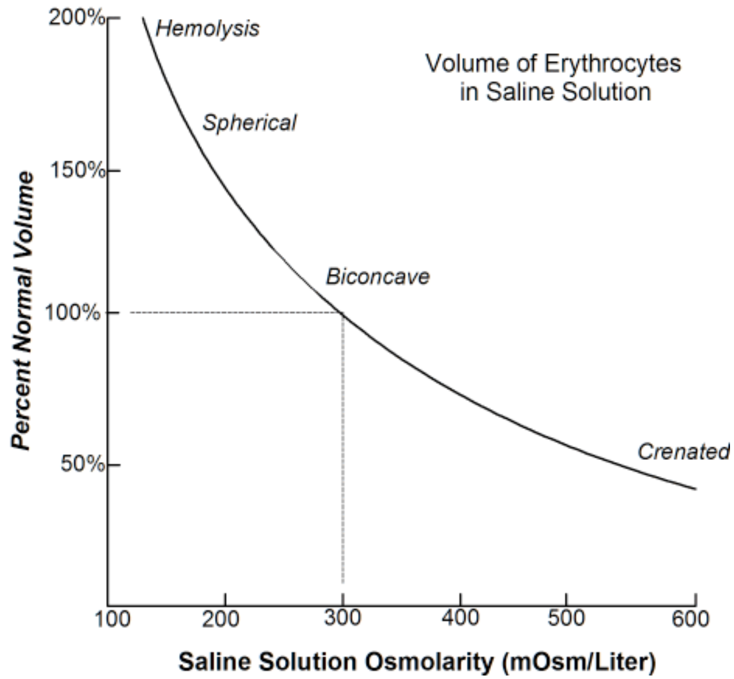
Water moves across membrane from ***less*** concentrated to ***more*** concentrated solutions

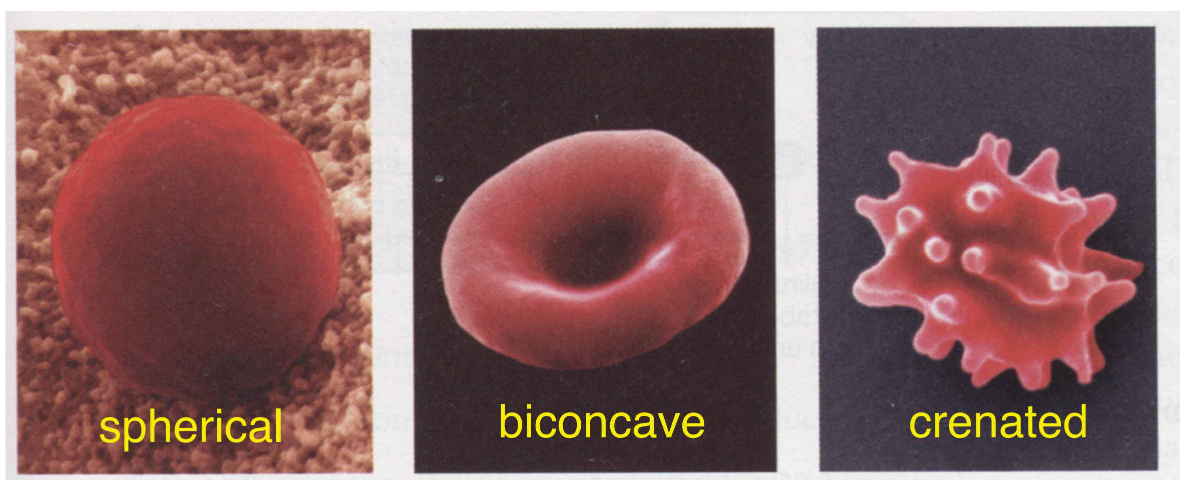


H_20 moves into cell, causing cell to swell and burst (lyse)



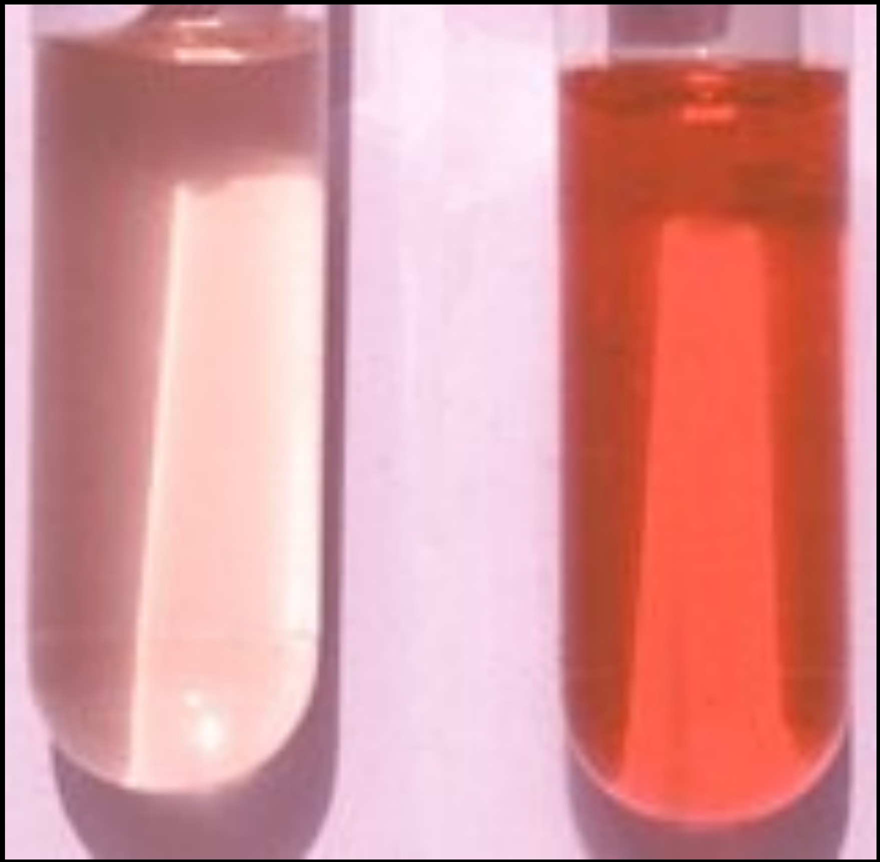
Fox Figure 6.13





http://www.acbrown.com/neuro/Lectures/Mmbr/NrMmbrWatr.htm

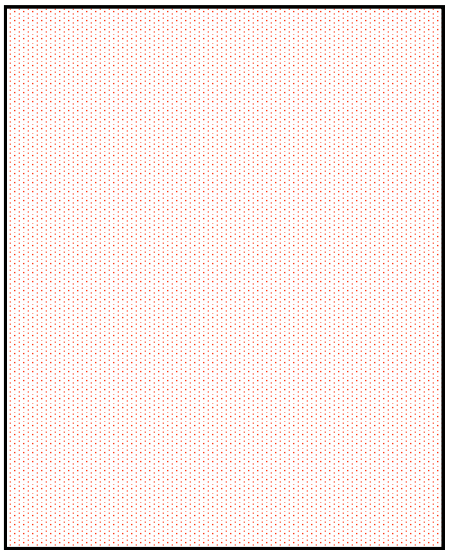
Blood diluted with:



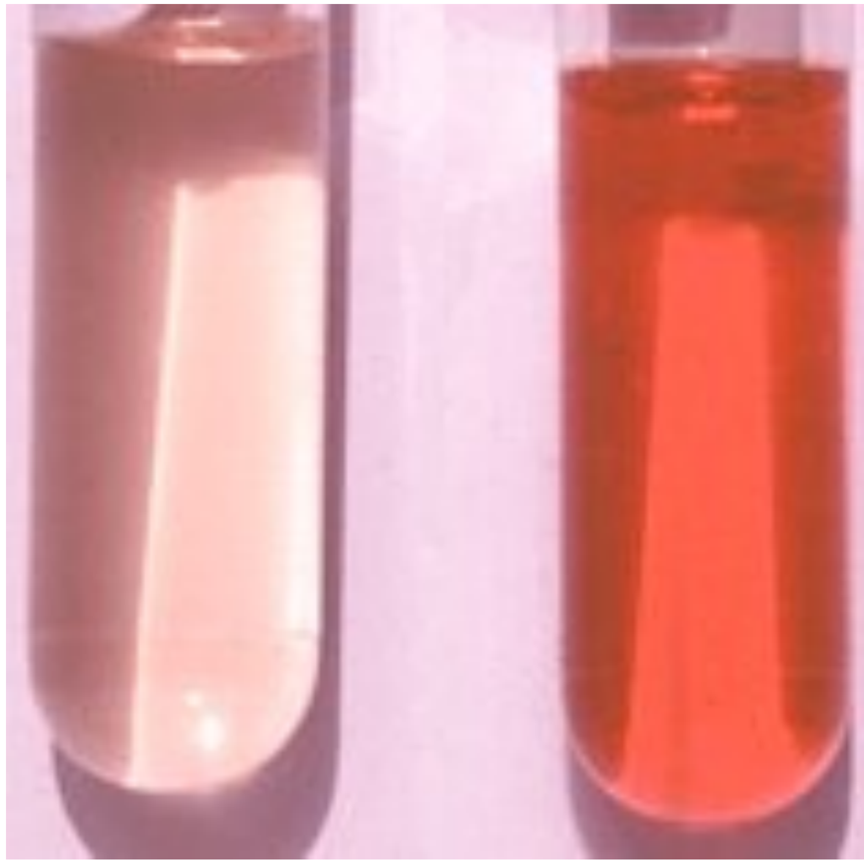
H20 0.15M NaCl

example 13g

Blood + Water



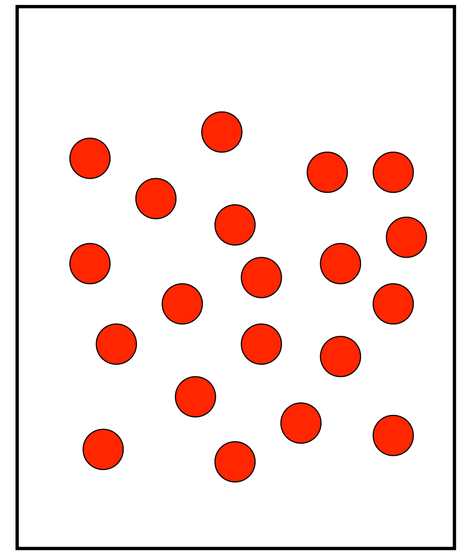
No intact cells to scatter light, but hemoglobin in the water still looks pink.



H20

0.15M NaCl

Blood + Saline



Intact red blood cells scatter light, so looks milky red

Osmolarity vs Molarity

Osmotic concentration of a solution is determined by number of **particles**, not concentration of compound.

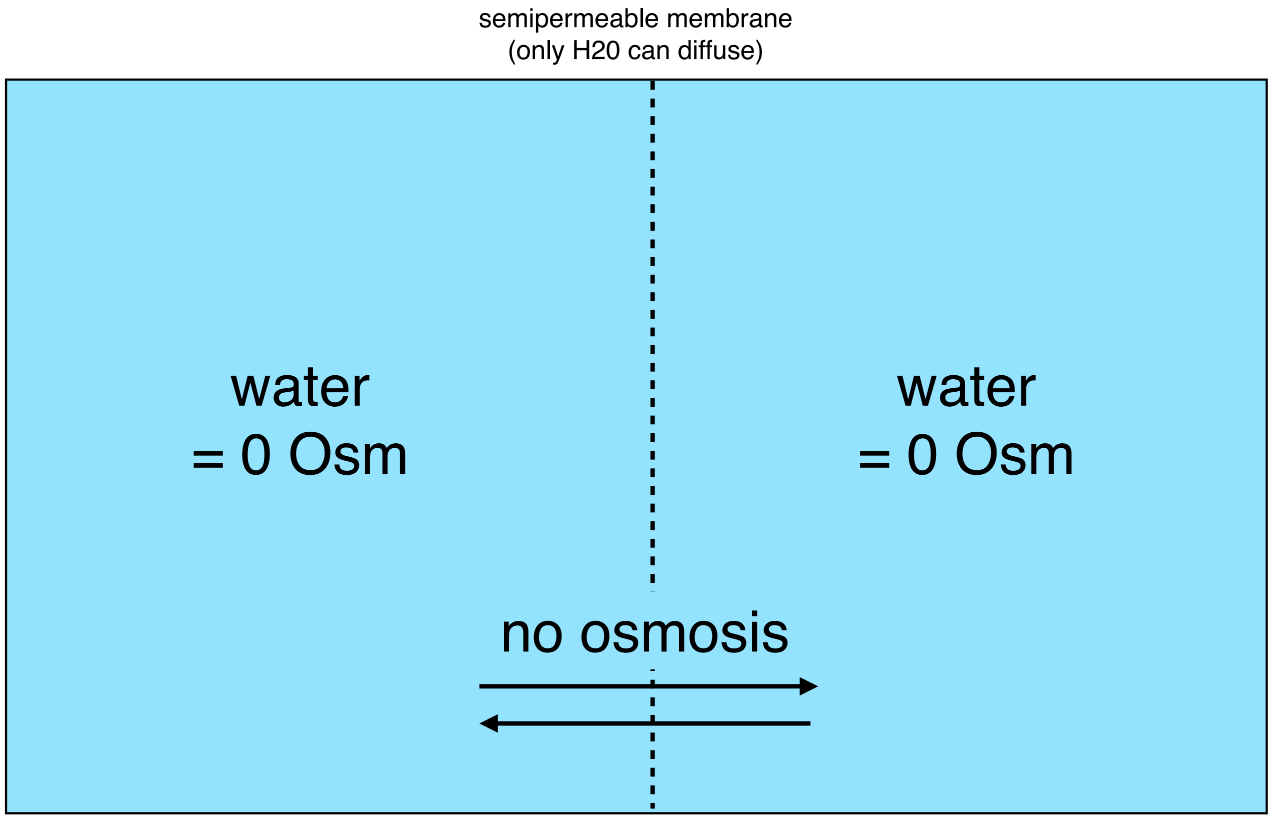
NaCl in solution dissociates into 2 particles (Na & Cl), so 1 M NaCl solution has **2x** the osmotic concentration as 1 M glucose.

Osmotic concentration is measured in **Osmolarity (Osm)**.
(number of particles in moles / liter water)

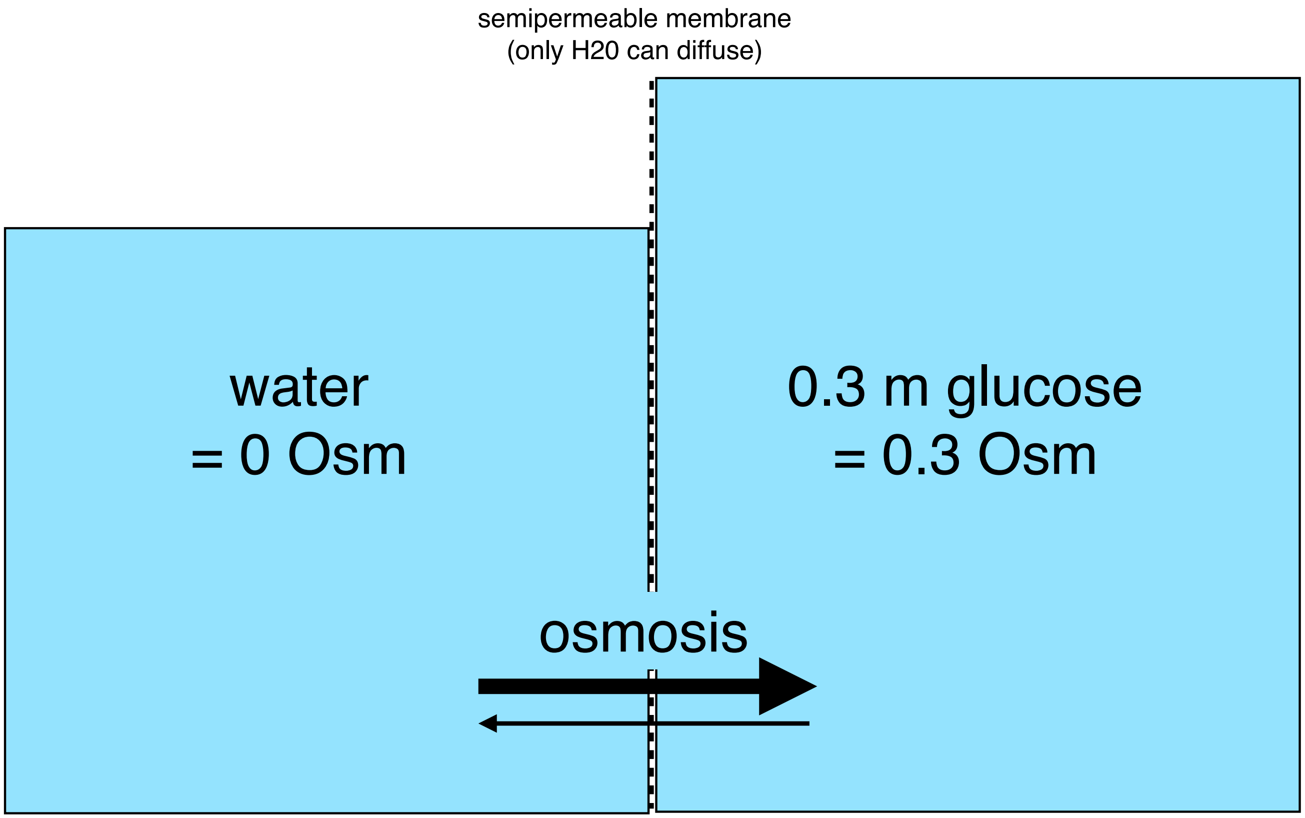
Osmosis is diffusion of water from:
low Osmolarity to **high** Osmolarity.

Remember: Particles Suck!

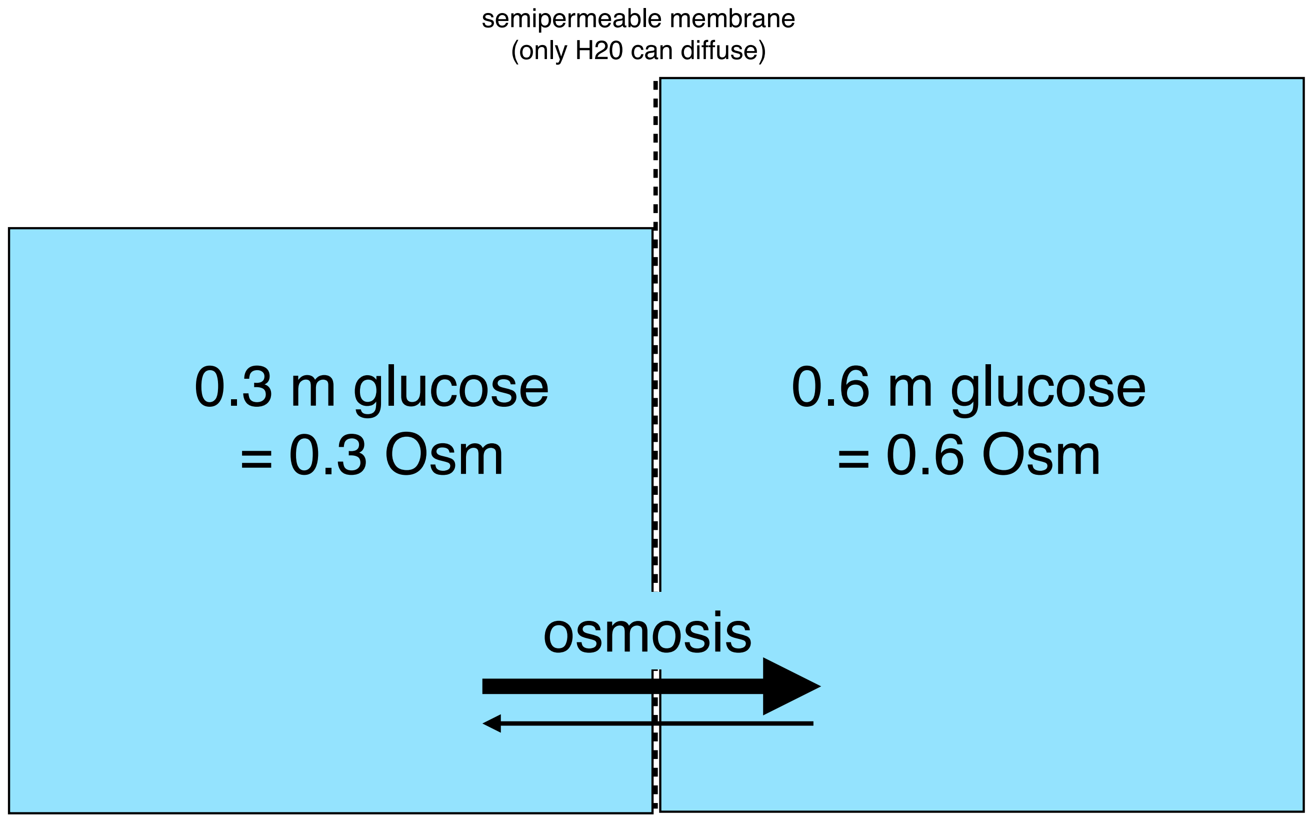
Osmolarity Examples



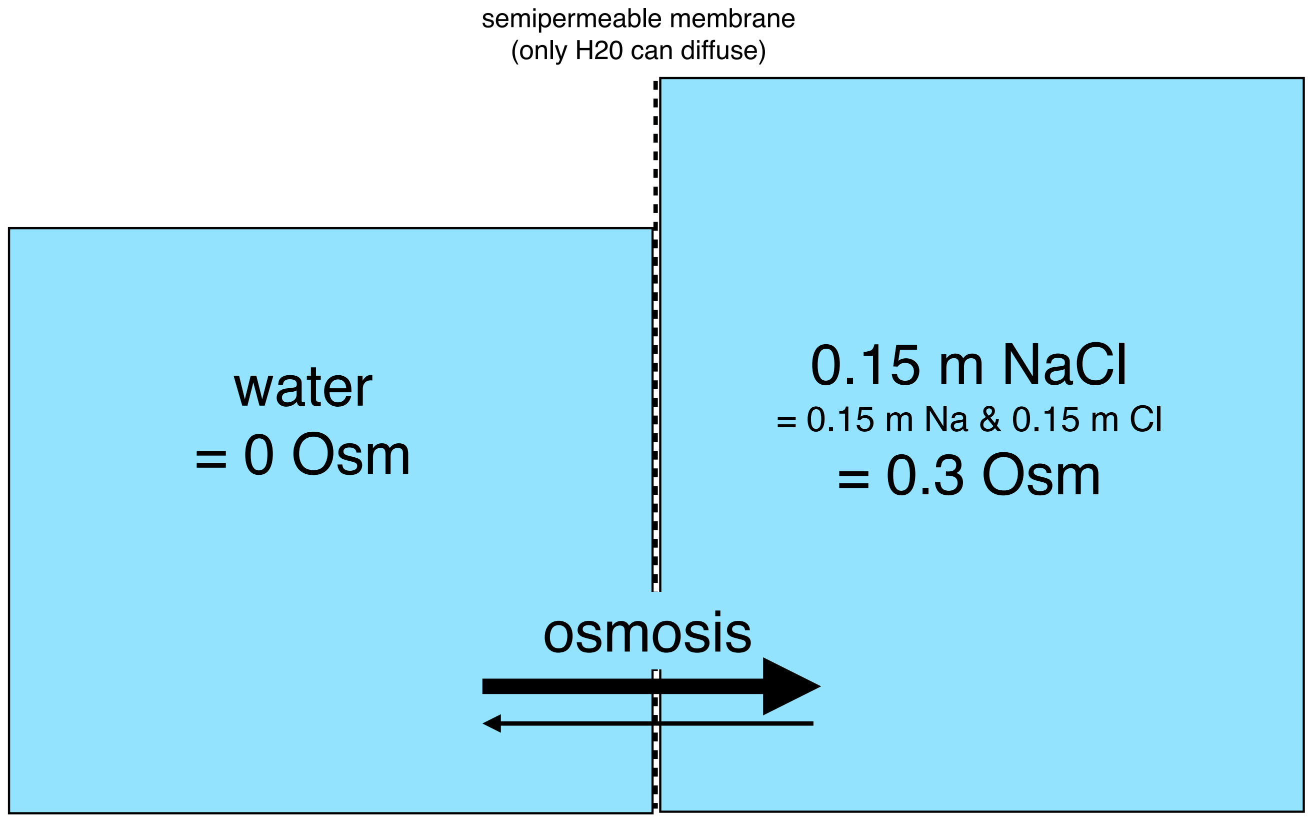
Osmolarity Examples



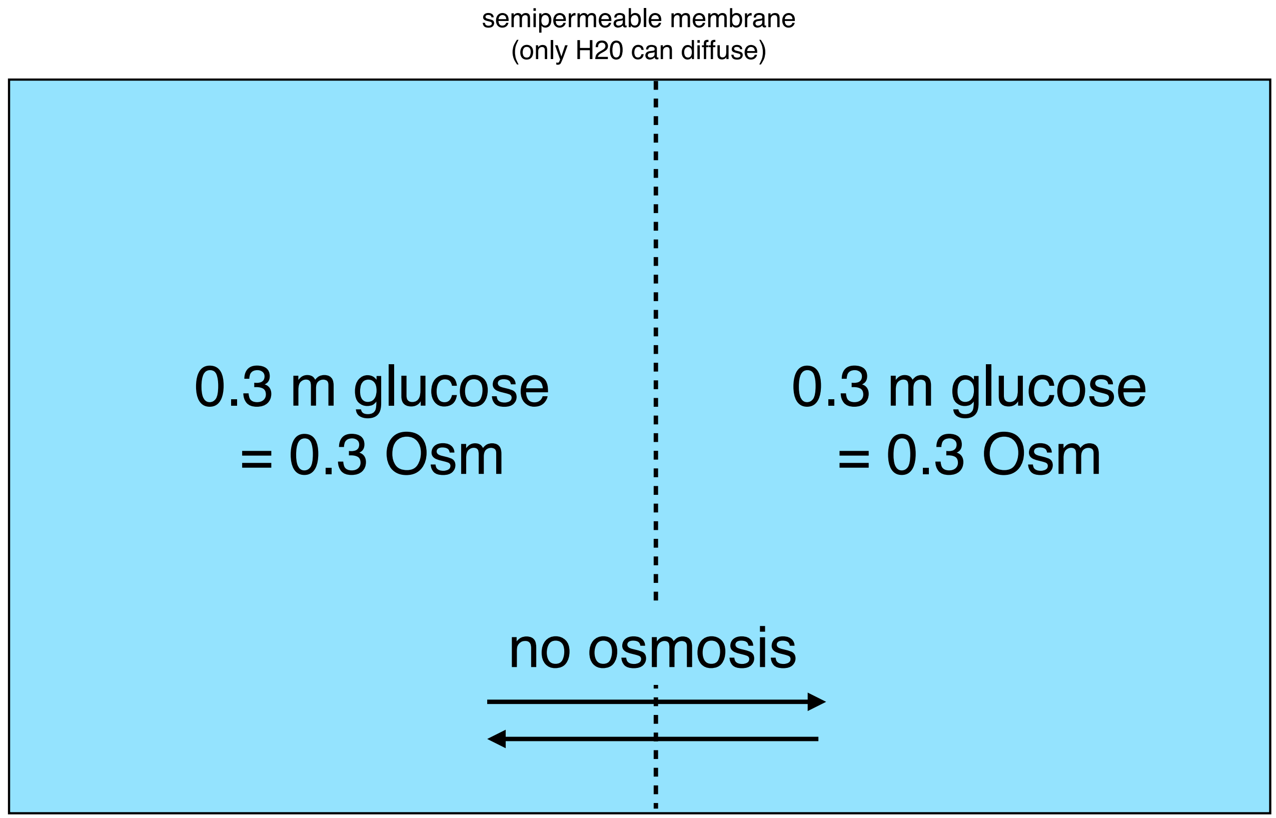
Osmolarity Examples



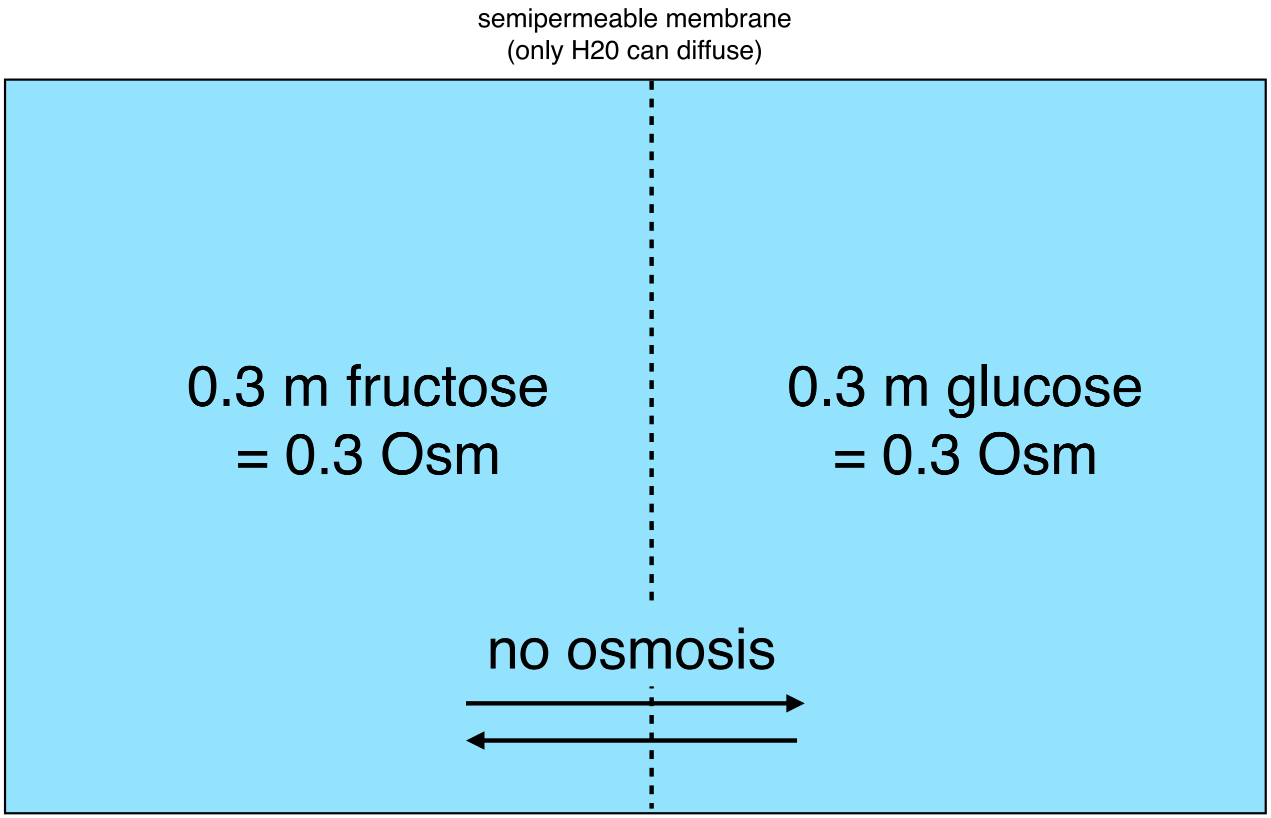
Osmolarity Examples



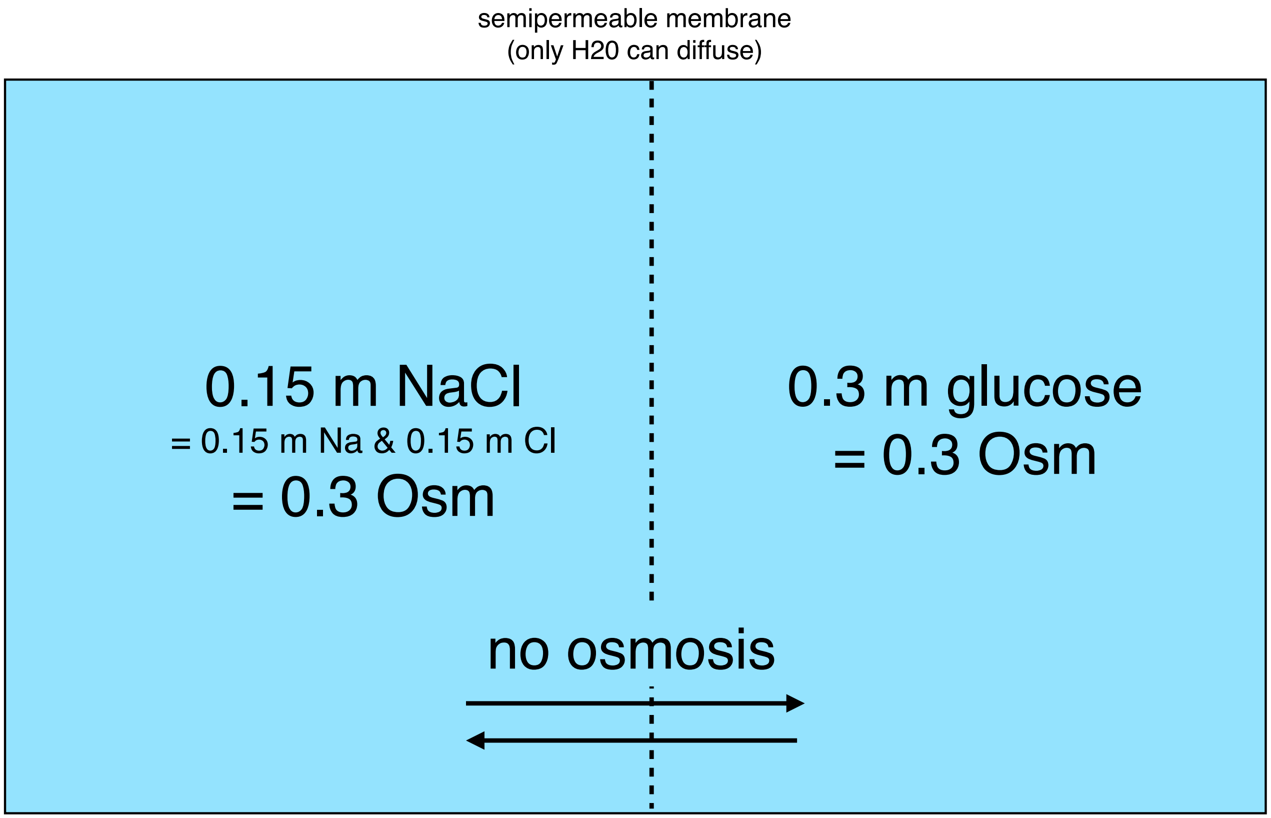
Osmolarity Examples



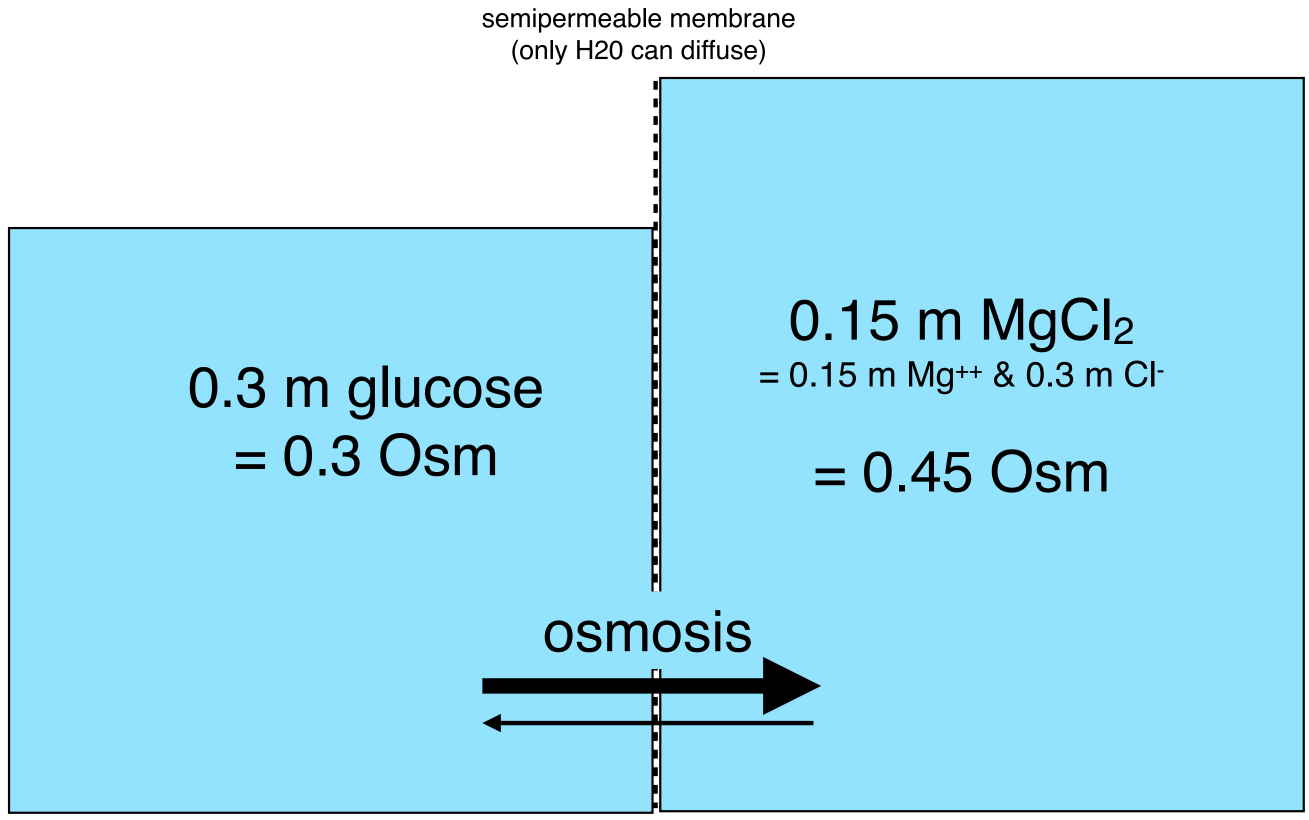
Osmolarity Examples



Osmolarity Examples



Osmolarity Examples



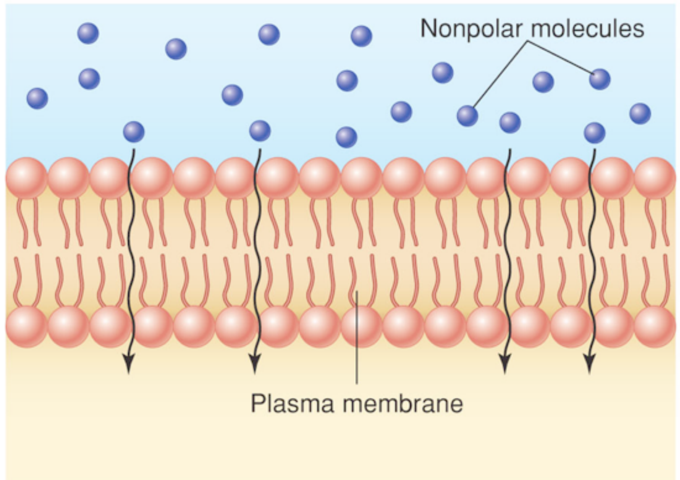
Non-Carrier Mediated Transport

Simple Diffusion across Membrane (lipids, gases)

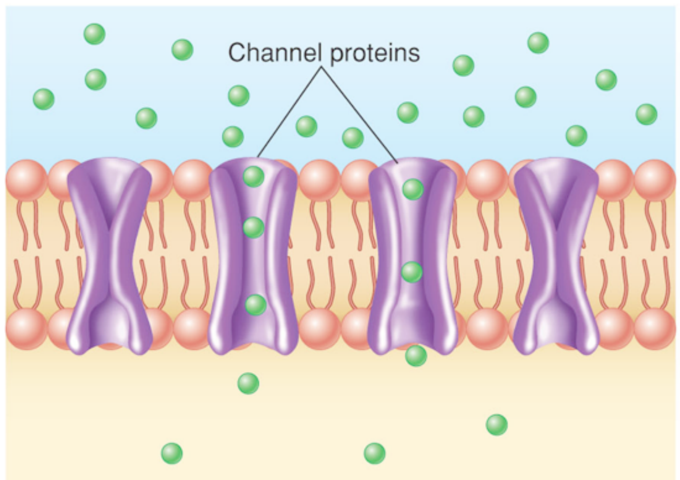
Diffusion of ions through **ion channel proteins**

Osmosis: diffusion of water through aquaporin channels across membrane

Note: because diffusion moves molecules down a concentration gradient, no extra energy is required to transport these molecule.



(a)



(b)

Carrier-Mediated Transport

Mediated by **carrier proteins** that span the plasma membrane.

Properties of Carrier Mediated Transport

1. **specificity** for a specific molecule
2. limited number of transporters can be **saturated**, with a max transport rate (**Tm**)
3. Closely related molecules can **compete** for transporters on the cell surface

(different cell types express different transporters)

Facilitated Diffusion

Transported molecule is moved down its concentration gradient.
Does not require extra energy from the cell (uses potential energy of concentration gradient).

Primary Active Transport

Membrane carrier protein is an **ATPase** that breaks down ATP to release energy.
Energy is used to transport molecule **against** its concentration gradient (up the gradient, requires energy).

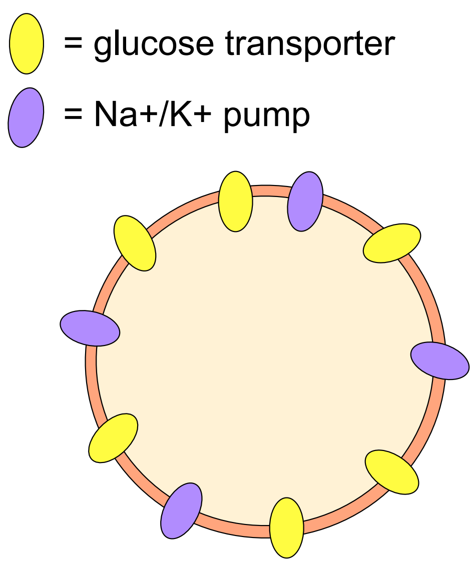
Coupled Active Transport

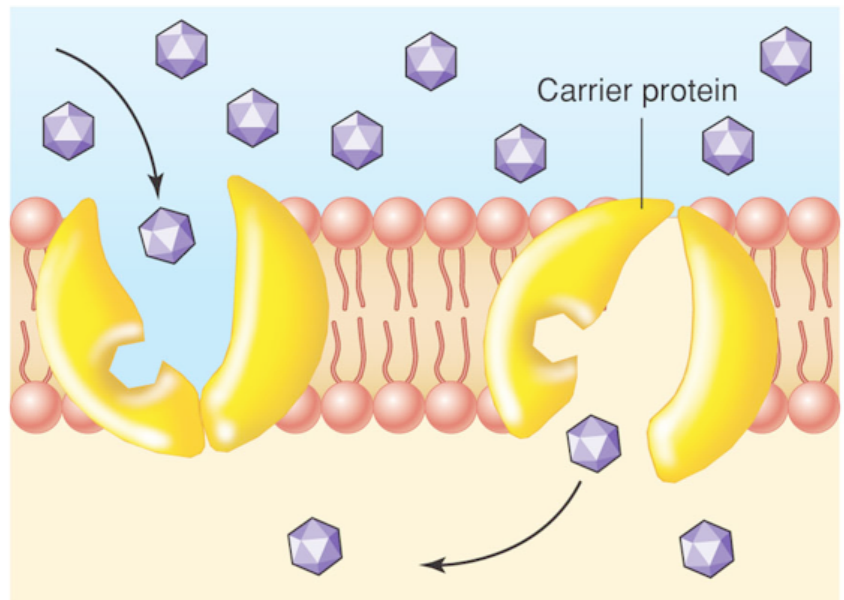
Cell uses energy to establish steep concentration gradient for molecule 1.
Co-transporter allows molecule 1 to move **down** concentration gradient.
Couples energy of first molecule to co-transport molecule 2 **up** its gradient.

Carrier Mediated Transport

Mediated by **carrier proteins** that span the plasma membrane.

Multiple types of transporters on every cell, depending on cell type.



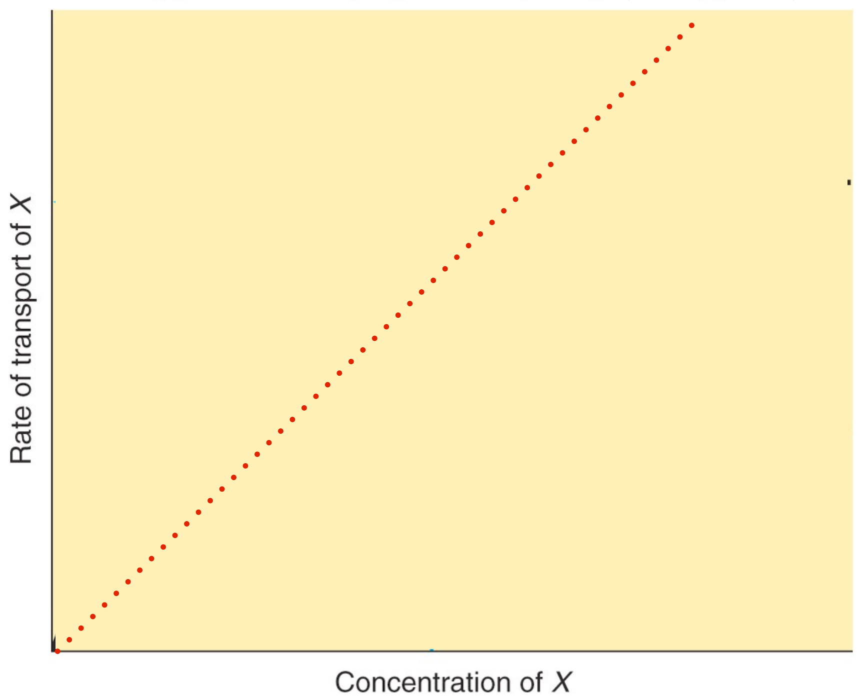


(c)

Fox Figure 6.2

Properties of Carrier Mediated Transport

Non-saturable transport = simple diffusion



1. Each type of carrier protein has **specificity** for a specific molecule: e.g. glucose transporters transport glucose, but not fructose.

2. Because there is a limited number of carrier proteins on the cell surface, carrier transport can be **saturated**, with a maximum rate of transport (**Tm**) at high concentrations of the transported molecules**.**

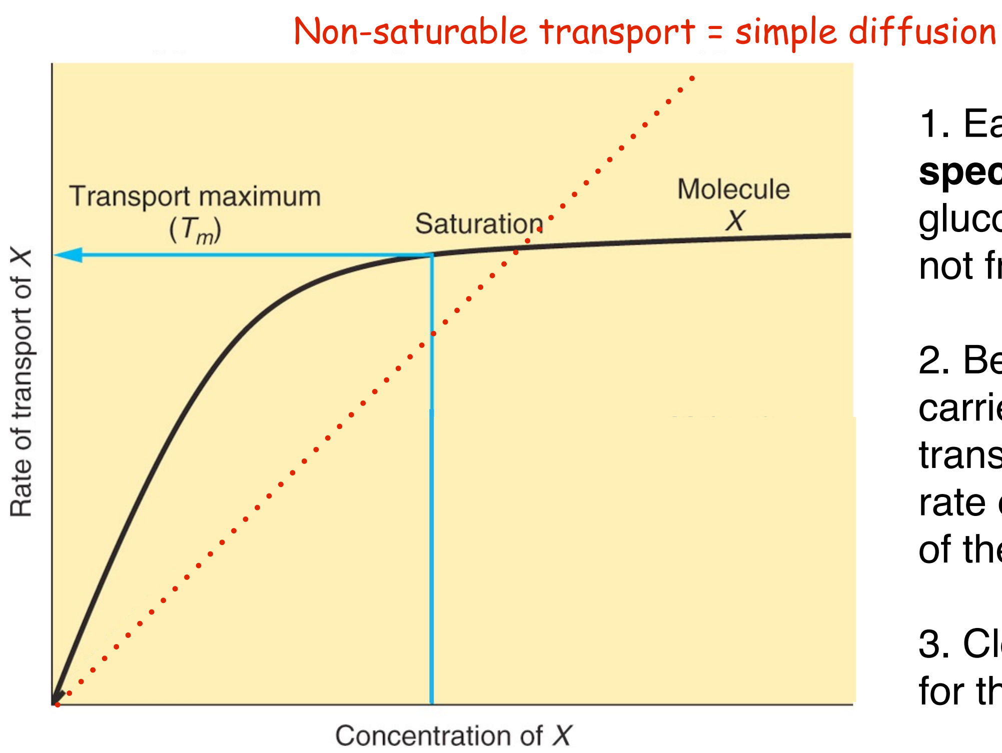
3. Closely related molecules can **compete** for the carrier proteins on the cell surface

(different cell types express different transporters)

(molecules X and Y compete for same transporter, so less X transported if Y is also present)

Fox Figure 6.15

Properties of Carrier Mediated Transport



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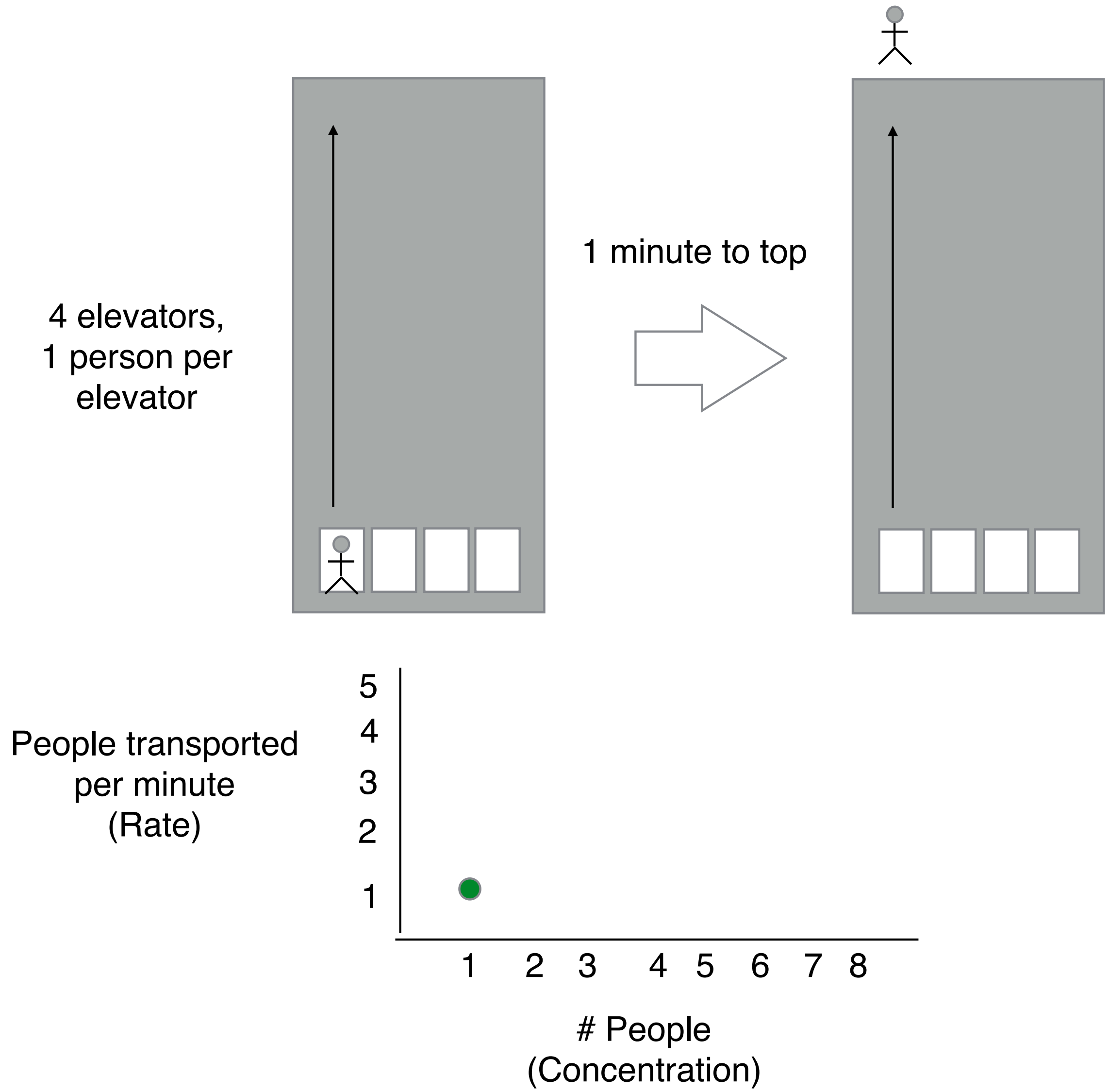
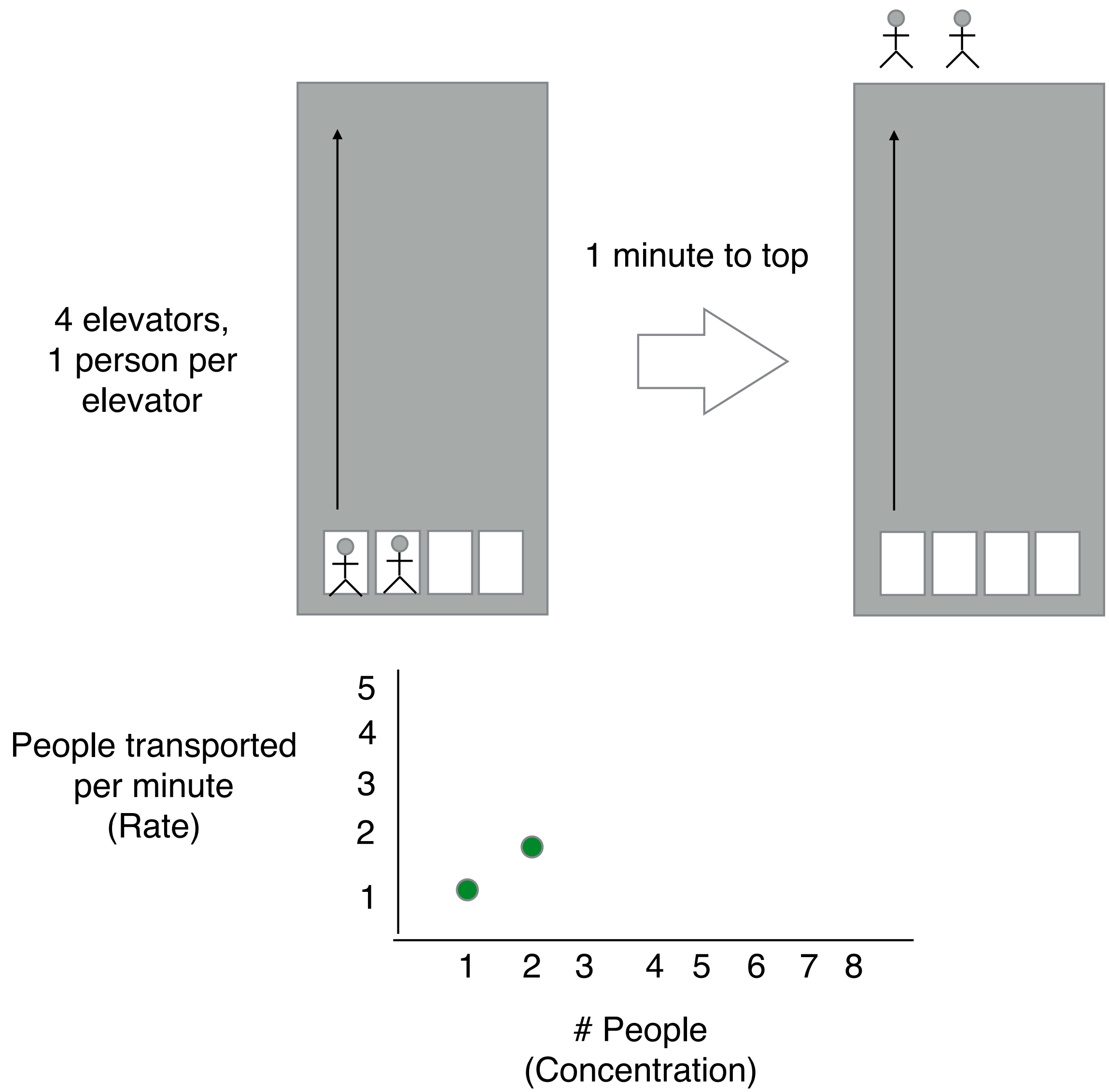
Fox Figure 6.15


4 elevators,
1 person per
elevator
1 minute to top
People transported
per minute
(Rate)
5
4
3
2
1
1
2
3
4
5
6
7
8
People
(Concentration)



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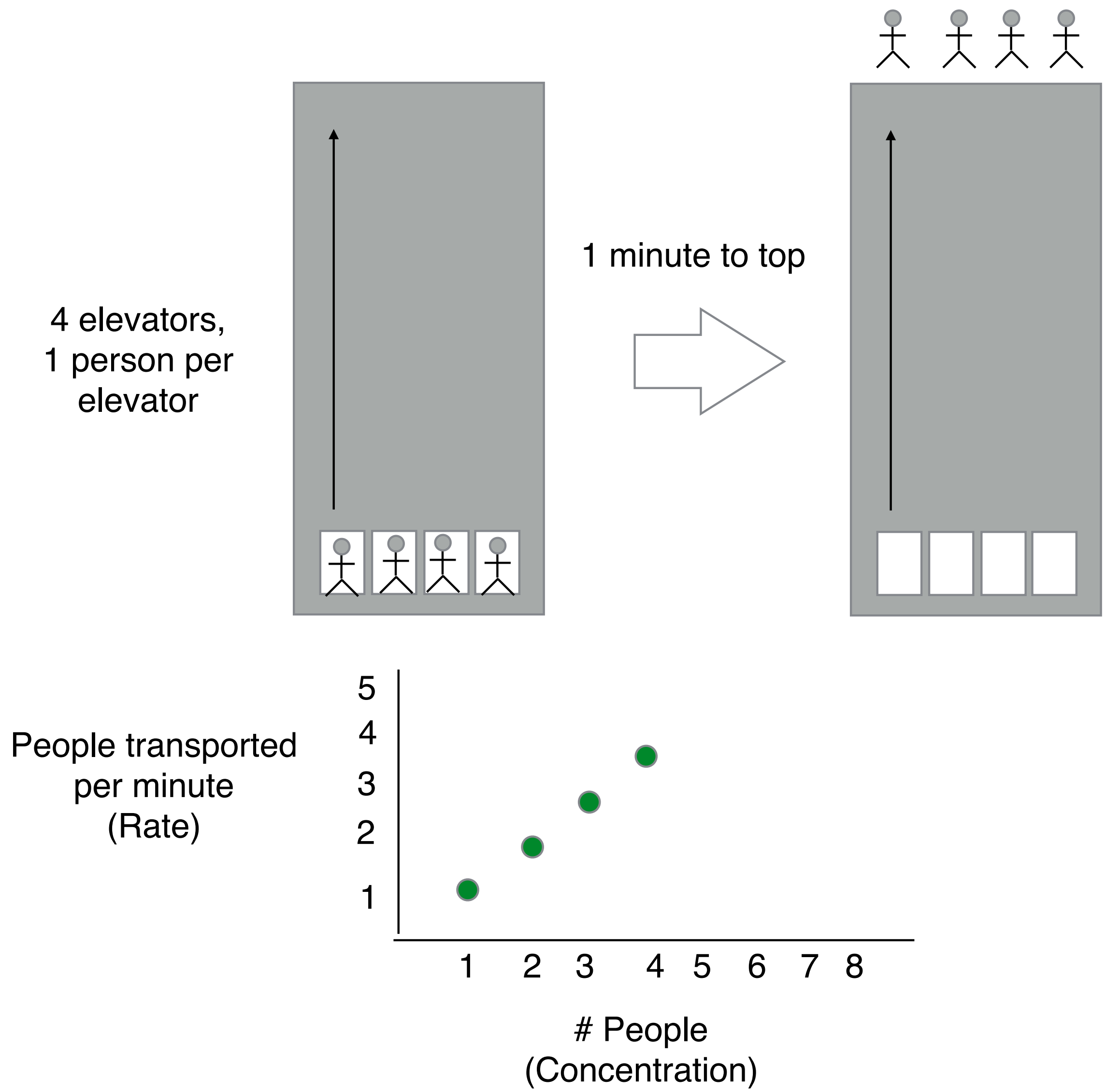

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1 minute to top
People transported
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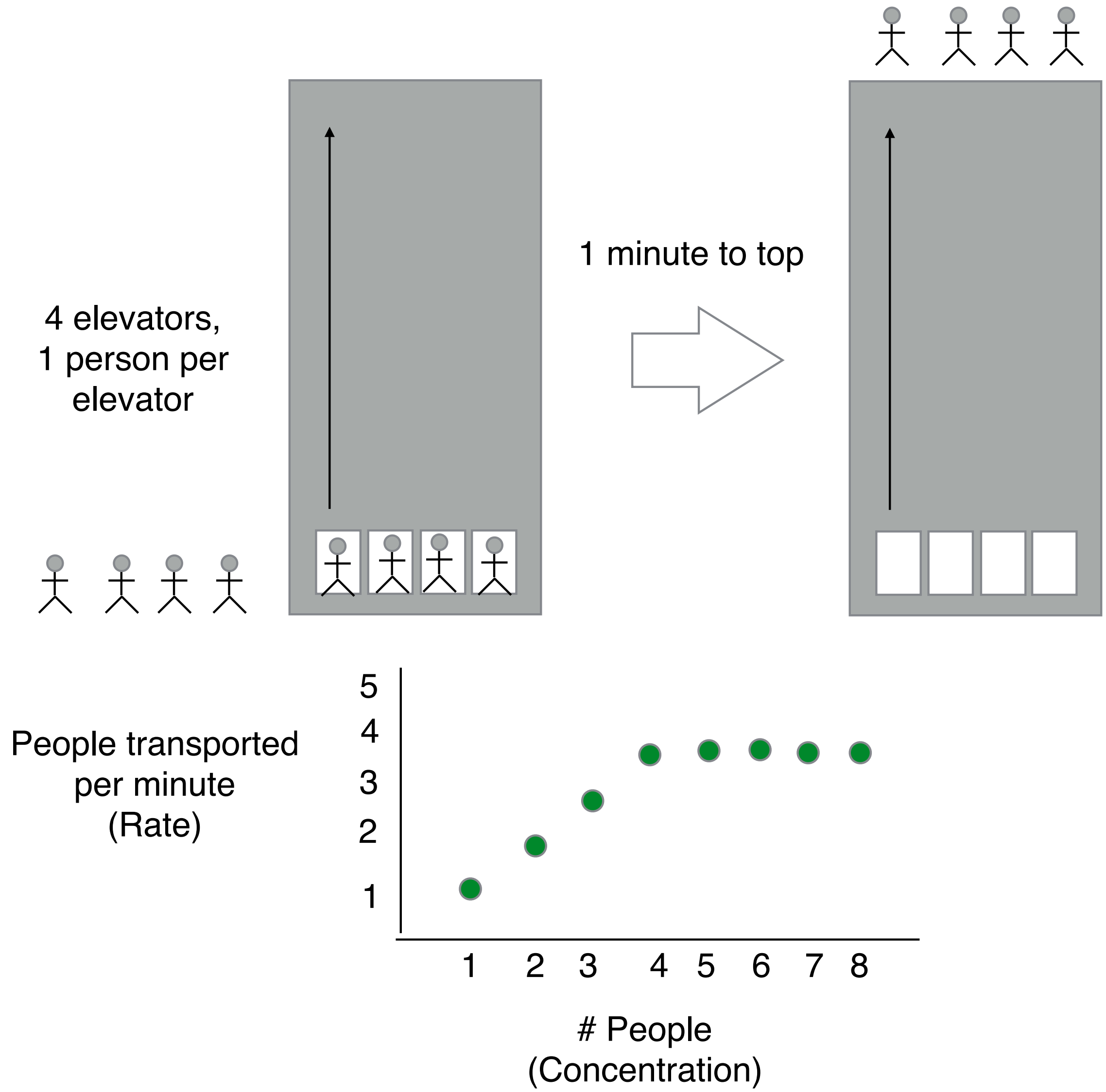
(Rate)
5
4
3
2
1
1 2 3 4 5 6 7 8
People
(Concentration)



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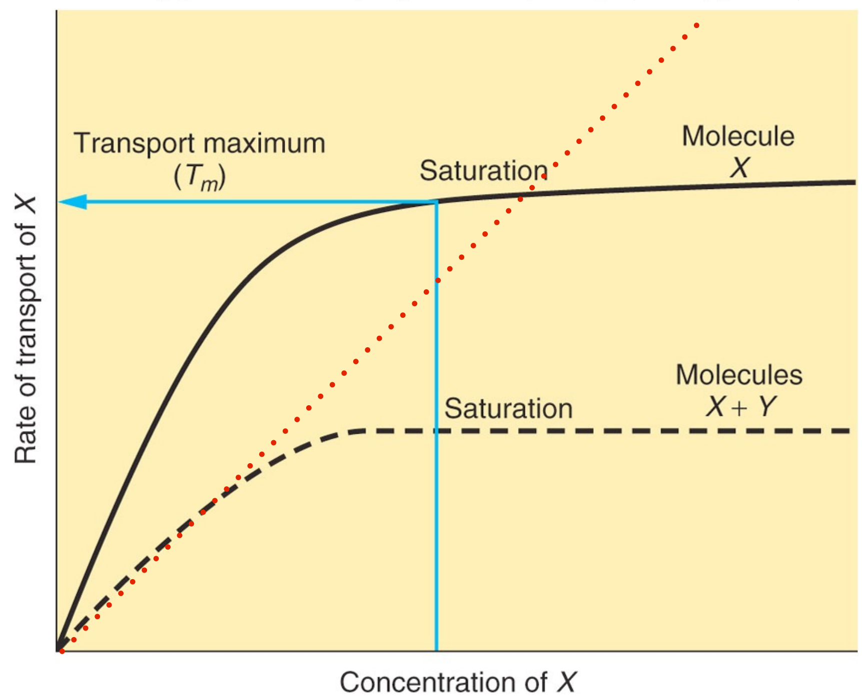
per minute
(Rate)
5
4
3
2
1
1 2 3 4 5 6 7 8
People
(Concentration)

Properties of Carrier Mediated Transport

Non-saturable transport = simple diffusion



1. Each type of carrier protein has **specificity** for a specific molecule: e.g. glucose transporters transport glucose, but not fructose.

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3. Closely related molecules can **compete** for the carrier proteins on the cell surface

(different cell types express different transporters)

(molecules X and Y compete for same transporter, so less X transported if Y is also present)

Fox Figure 6.15

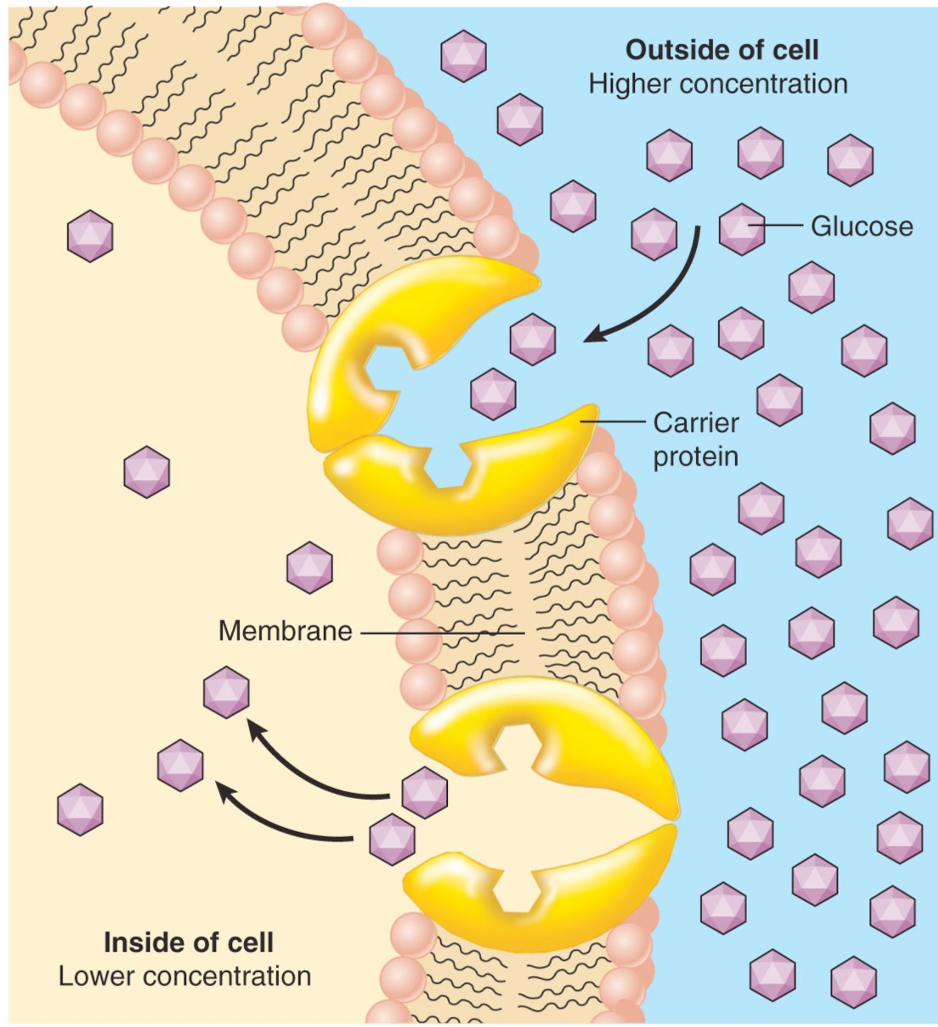
Facilitated Diffusion

Transported molecule is moved down its concentration gradient.

Does not require extra energy from the cell (uses potential energy of concentration gradient).

GLUT *- glucose transporter*

y

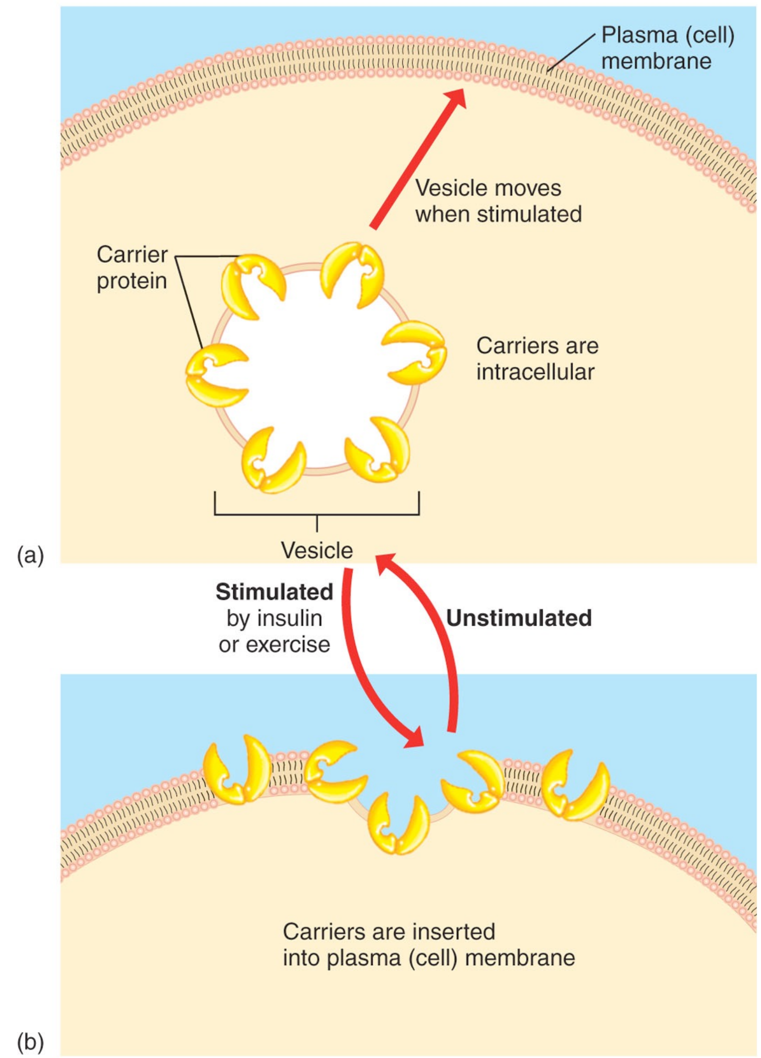


Fox Figure 6.16

Facilitated Diffusion

Because facilitated diffusion requires using a limited number of transporters, transport can be **regulated** by increasing or decreasing the number of transporters.

Example: the hormone insulin causes a drop in blood glucose by increasing GLUTs on the surface of muscle, liver, and fat cells; causing these cells to take up more glucose.



Fox Figure 6.17

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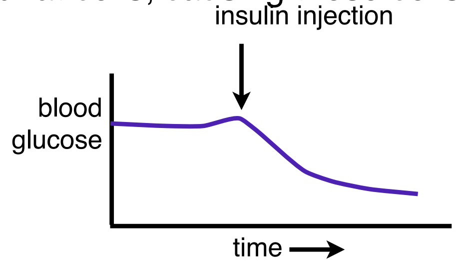
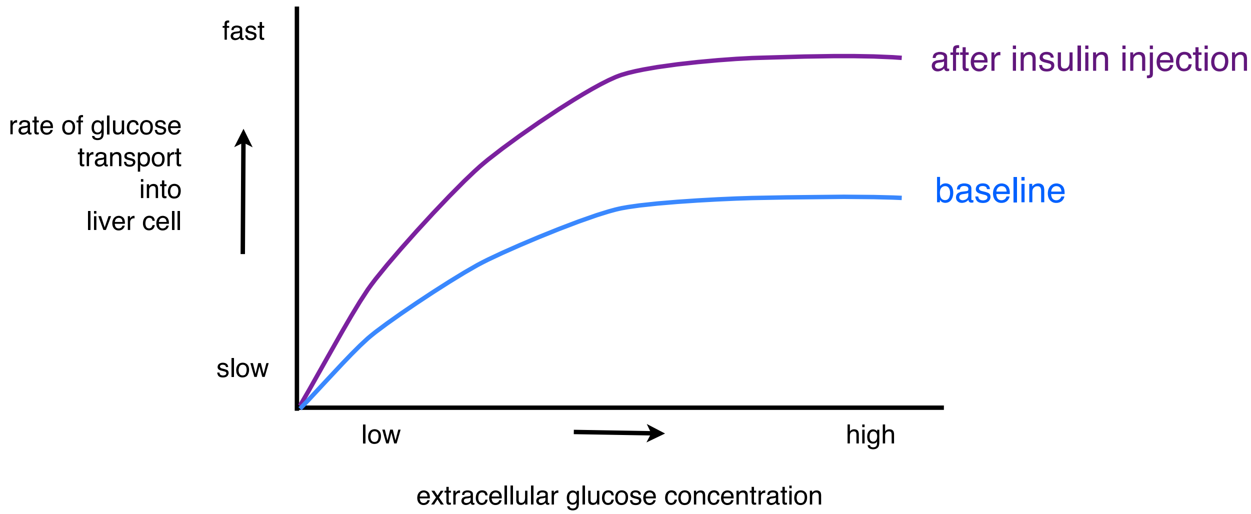


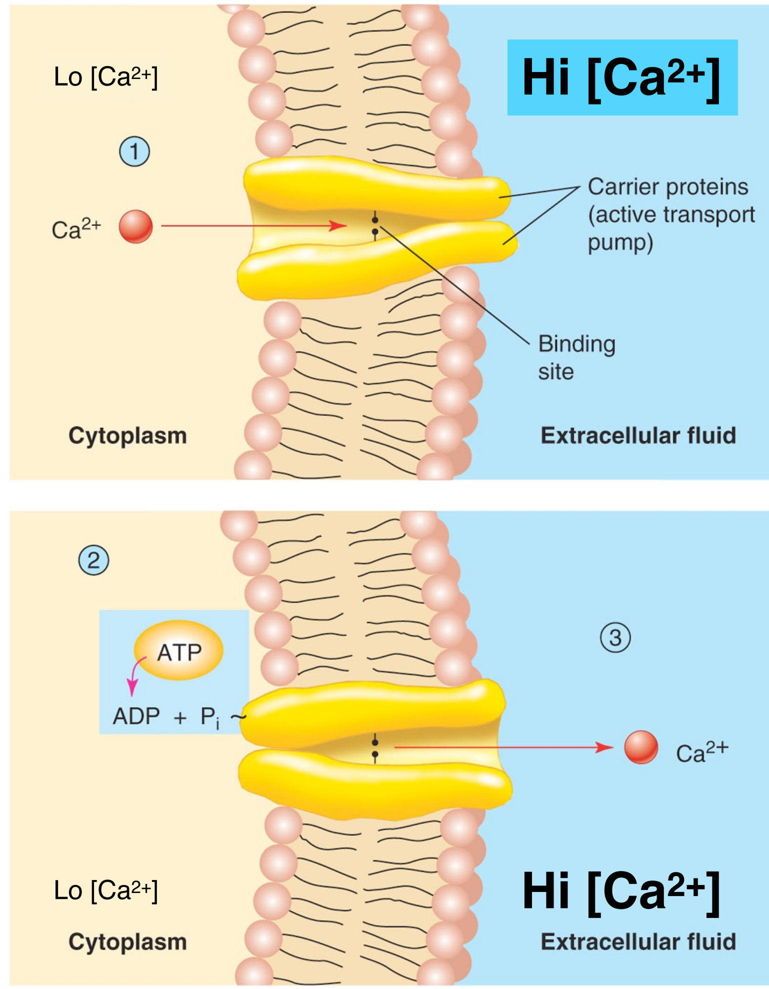


Glucose transport is still saturated (because a finite number of trasporters), but with more transporters insulin-stimulated tissue can take up more glucose.

Primary Active Transport

Membrane carrier protein is an **ATPase** that breaks down ATP to release energy.

Energy is used to transport molecule **against** its concentration gradient (up the gradient, requires energy).



Ca^{2+} ATPase Pump:
Hydrolysis of ATP and release of ADP causes conformational change in transporter, releasing Ca^{2+} outside the cell.

Fox Figure 6.18

Primary Active Transport

Most cells maintain a steep Na+ and K+ gradient across their membranes.

Na^+/K^+ ATPase Pump:

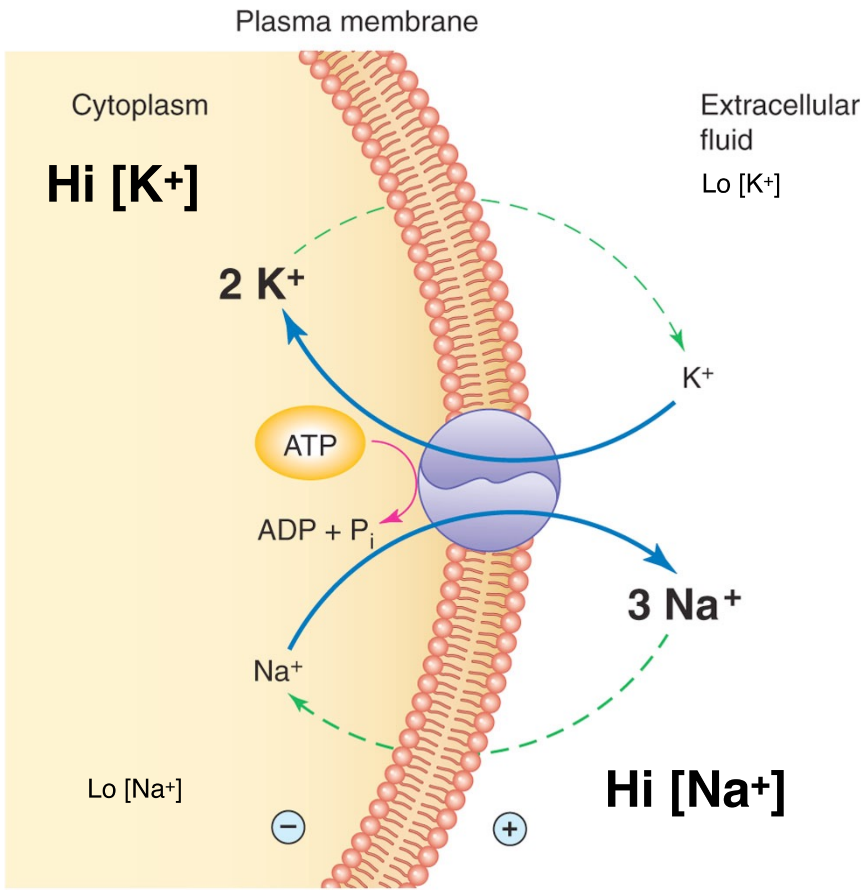
3 Na^+ ions bind to inside of carrier protein

ATP is hydrolyzed.

Release of ADP moves 3 Na^+ to outside of cell.

Release of P_i moves 2 K^+ to inside of cell.

Summary: 3 Na^+ out, 2 K^+ in for every 1 ATP molecule.



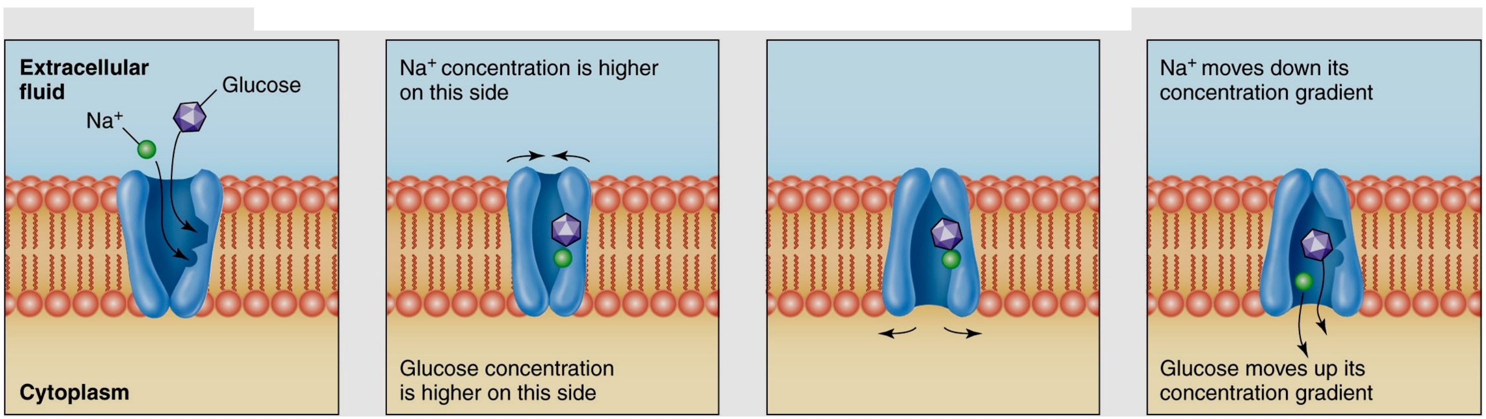
Fox Figure 6.19

Secondary Active Transport (Coupled Transport)

Cell uses energy to establish steep concentration gradient for molecule 1.
e.g. use NA^+/K^+ ATPase pump to set high Na+ outside of cell

Co-transporter allows molecule 1 to move **down** concentration gradient.

Couples energy of first molecule to co-transport molecule 2 **up** its gradient.
e.g. concentrate glucose inside cell



Fox Figure 6.20

Cotransport or **symport**: both molecules move in same direction
(e.g. Na^+ & glucose move into cell.)
Countertransport or **antiport**: molecules move in opposite directions
(e.g. one moves into cell, other moves out of cell.)


Mythbusters- Barrel of Bricks | MiniMyth
BaRREL oF BRicks

Secondary Active Transport (Coupled Transport)

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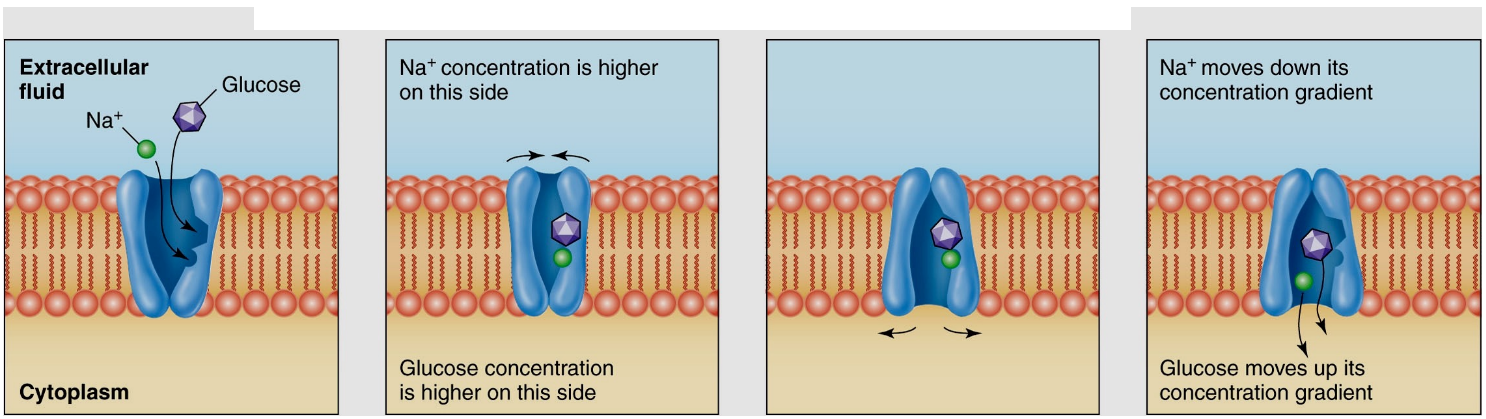


Fox Figure 6.20

Cotransport or **symport**: both molecules move in same direction
(e.g. Na^+ & glucose move into cell.)
Countertransport or **antiport**: molecules move in opposite directions
(e.g. one moves into cell, other moves out of cell.)

Putting mechanisms together:

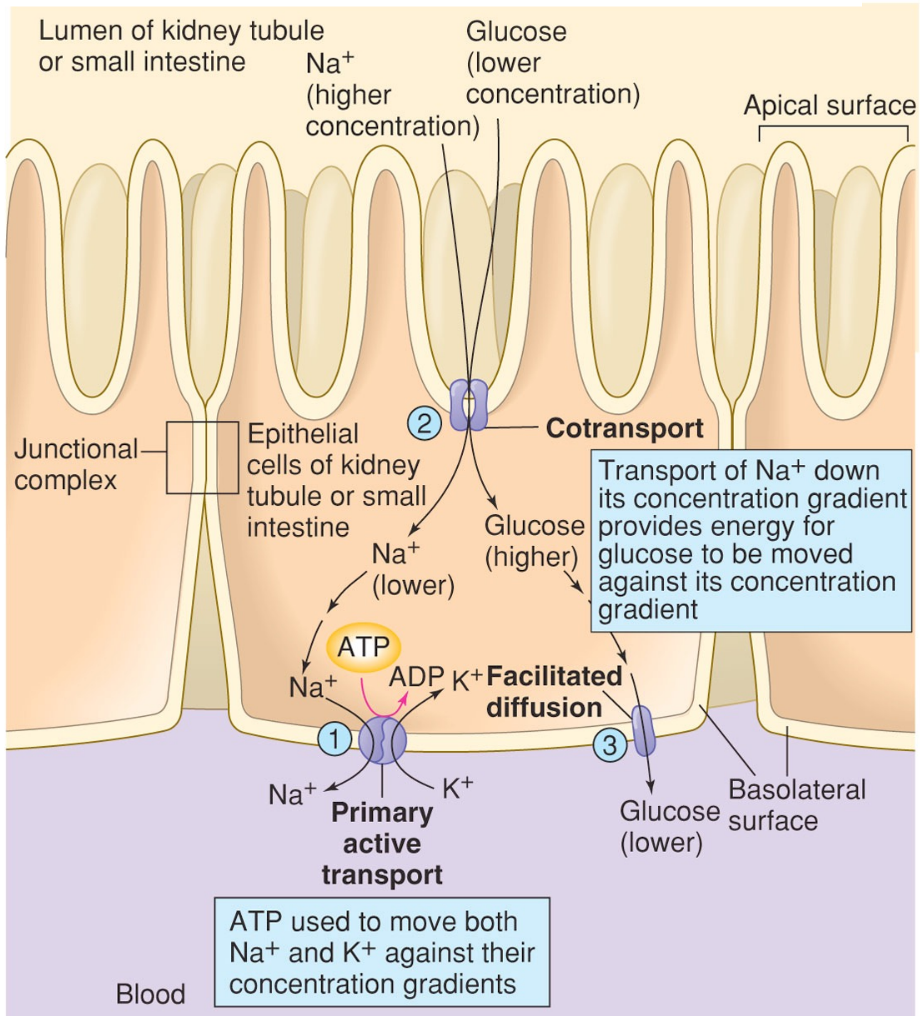
Na+, glucose

across epithelial cells

Na+, glucose

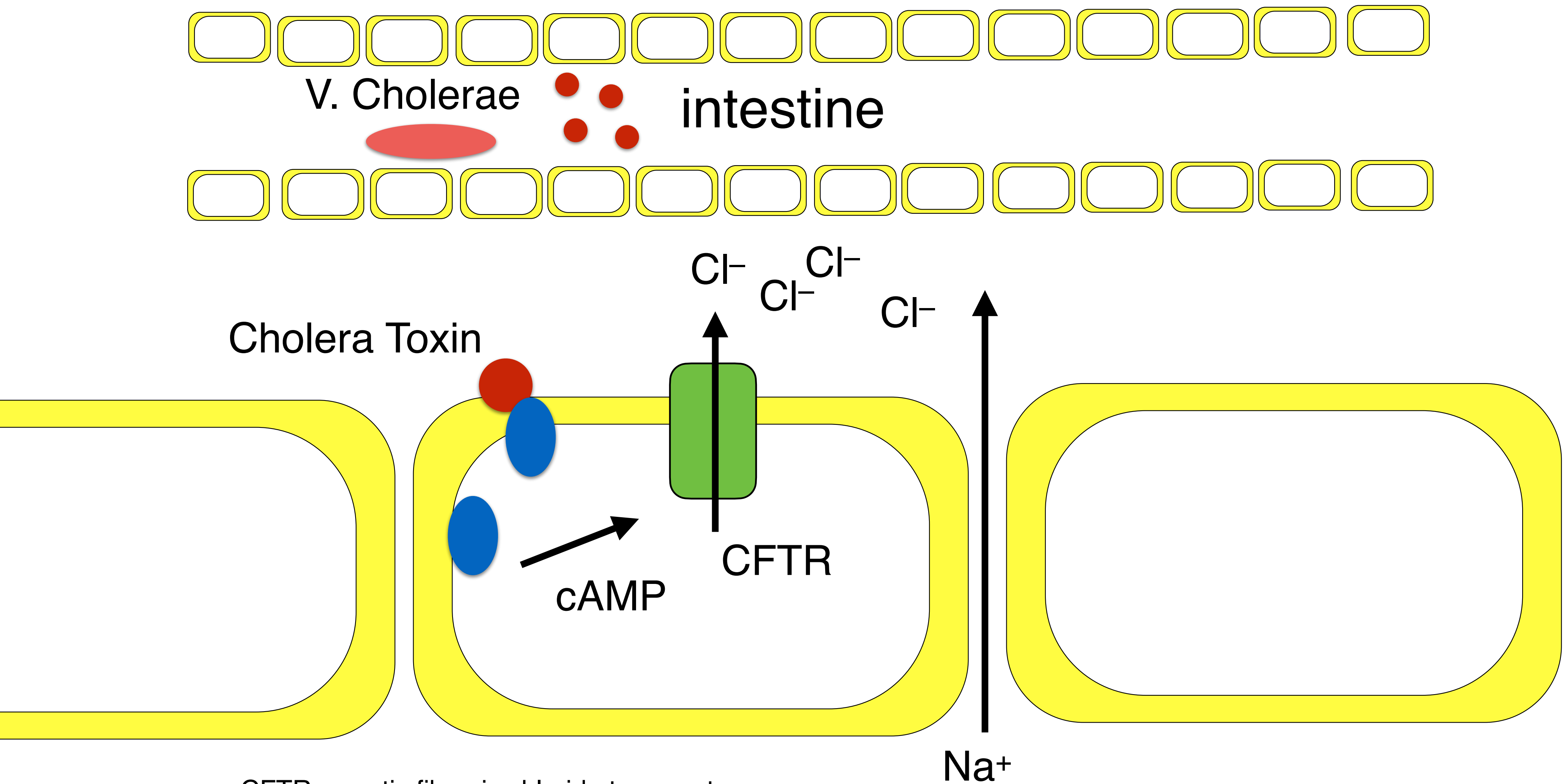
blood

Na+, glucose

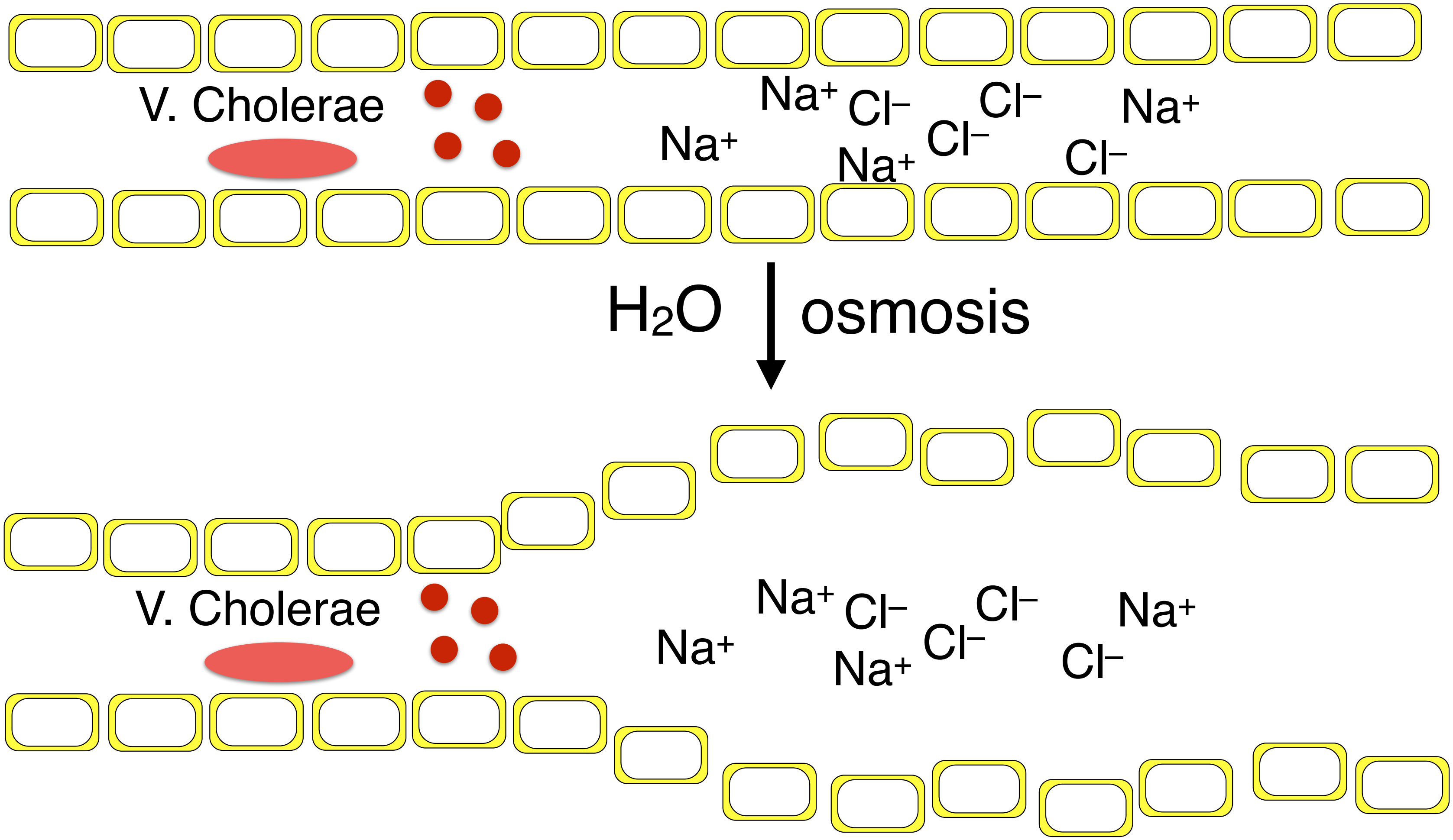


Fox Figure 6.21

Cholera : disease of membrane transport

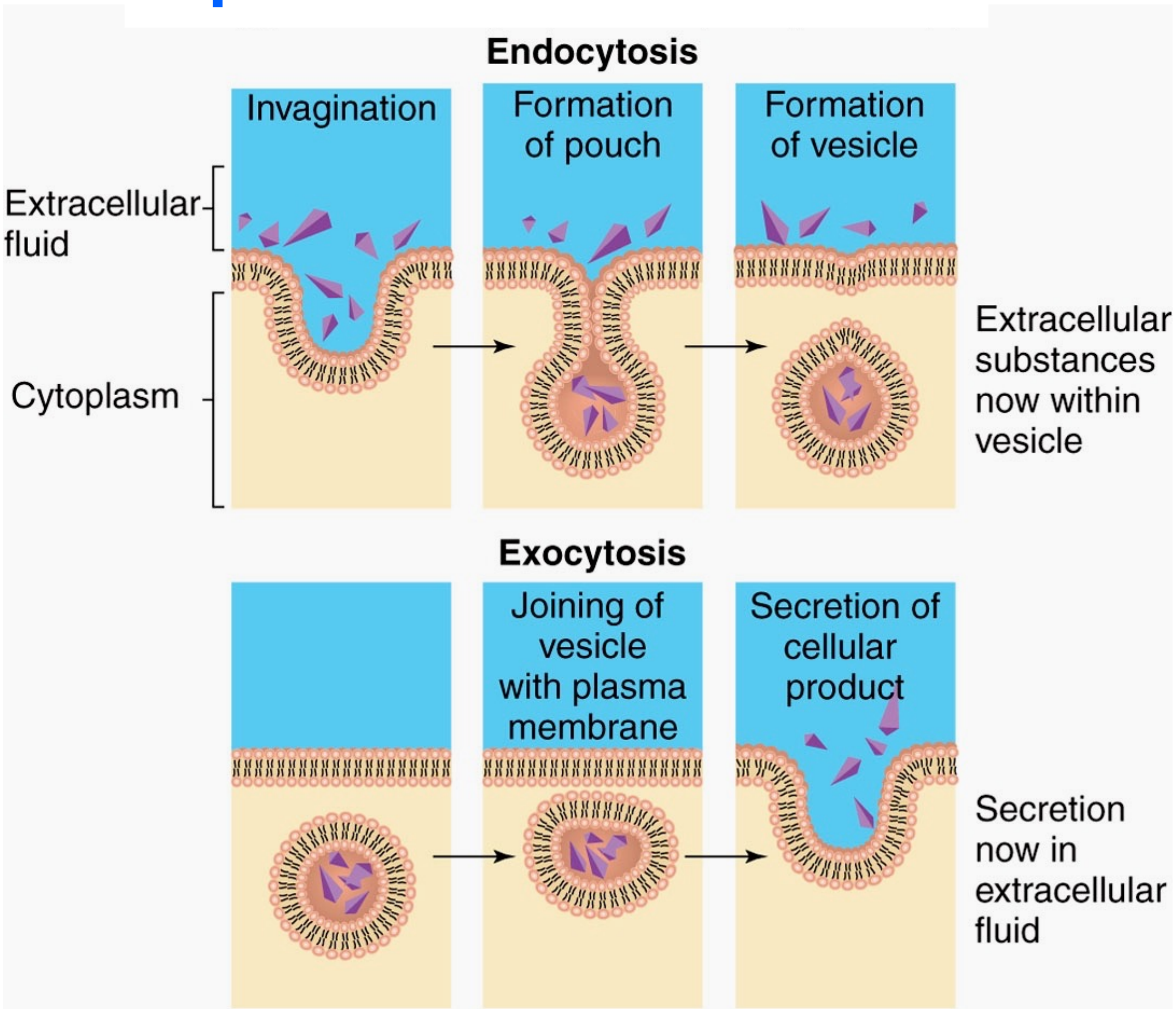


CFTR = cystic fibrosis chloride transporter



CFTR = cystic fibrosis chloride transporter

Bulk Transport



Fox Figure 6.23

Summary of Transport

Non-Carrier Mediated Transport

1. **Simple Diffusion** across Membrane (lipids, gases)

2. Diffusion of ions through **ion channel proteins**

3. **Osmosis**: diffusion of water through aquaporin channels across membrane

Note: because diffusion moves molecules down a concentration gradient, no extra energy is required to transport these molecules.

Carrier Protein Mediated Transport

1. **Facilitated Diffusion**: Transported molecule carried by transporter moves down its concentration gradient.

2. **Primary Active Transport**: Membrane carrier protein transports molecule against its concentration gradient

3. **Coupled Active Transport**: Couples energy of first molecule moving down concentration gradient to co-transport molecule 2 up its concentration gradient.

Note: Specific, saturable, competition. ***Active Transport*** *requires energy, using up ATP directly (primary) or indirectly (coupled) to transport against a concentration gradient.*

Bulk Transport

1. **Endocytosis**

2. **Exocytosis**

Note: Vesicles with phospholipid bilayers fuse with plasma membrane, or pinch off of plasma membrane, to move contents of vesicle in or out of the cell.