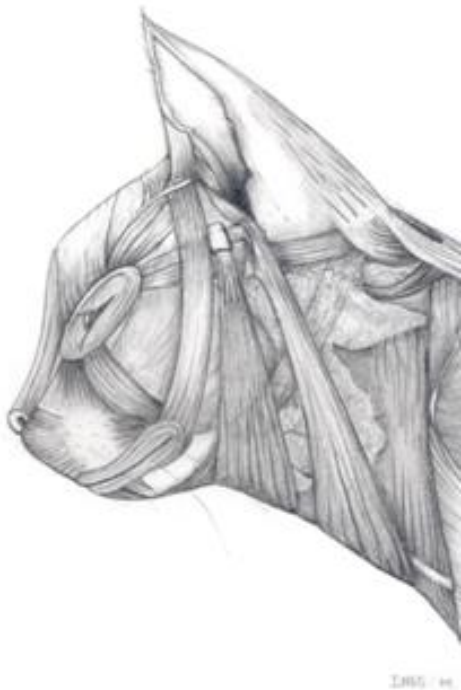
FIZIOLOGIJA ŽIVALI

Laboratorijske vaje

PREBAVA



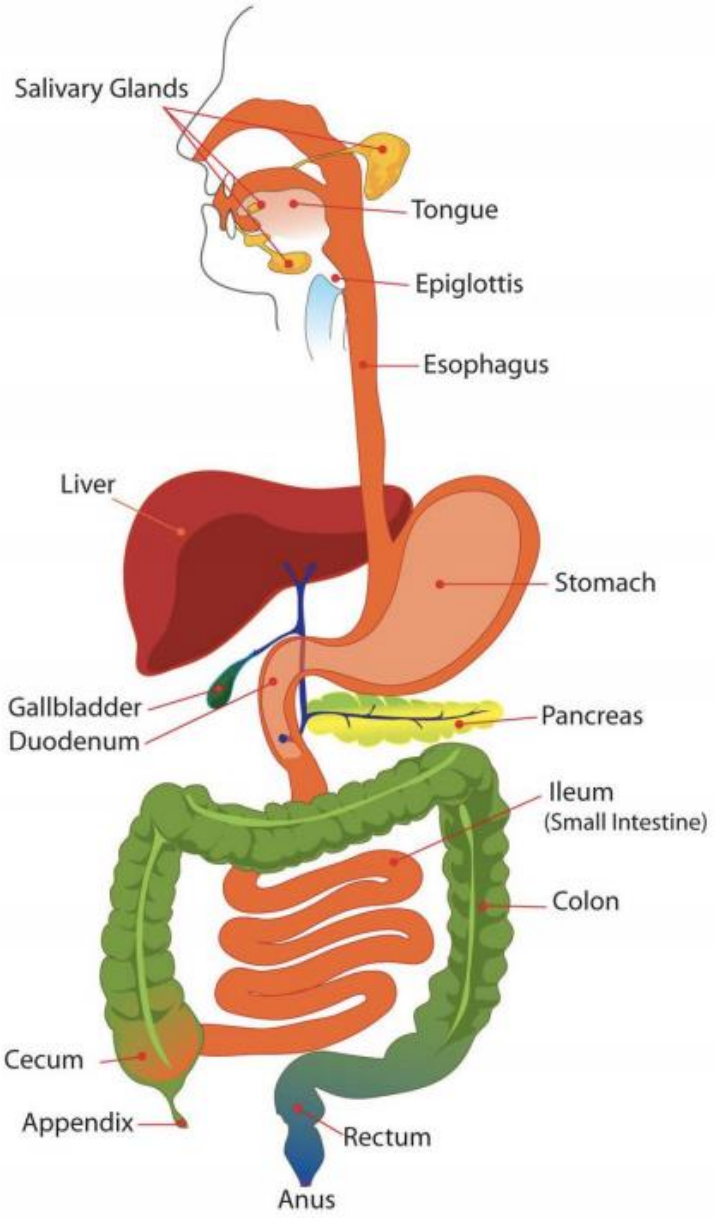
dr. Katja Adam

UP FAMNIT

PREBAVNI SISTEM

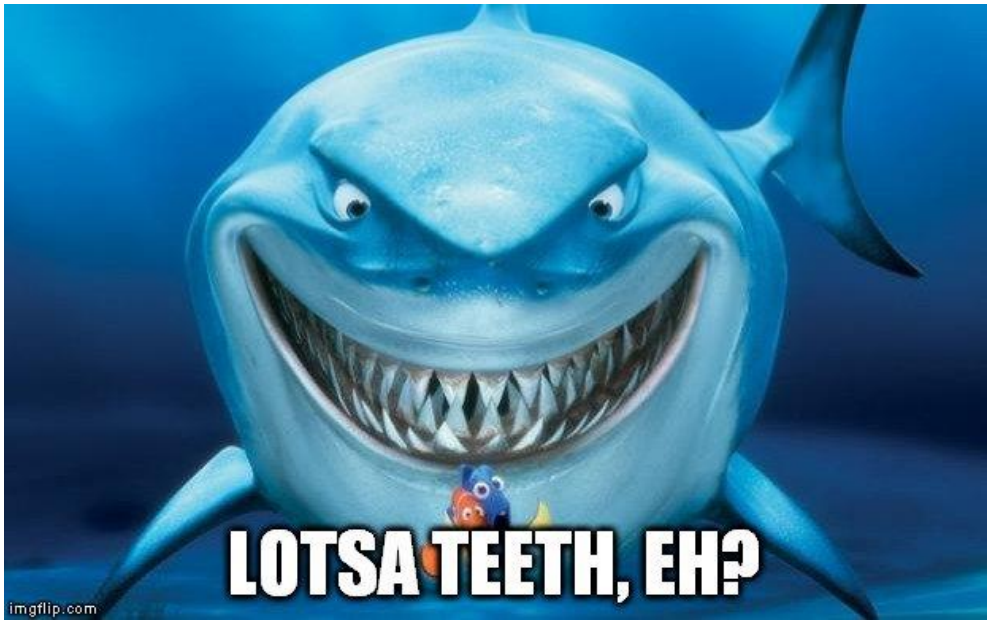
- gastrointestinalni trakt (usta, žrelo, požiralnik, želodec, tanko, debelo črevo, rektum, anus)
- + žleze, ki izločajo encime in tekočino

- PREBAVA – razgradnja makromolekul v manjše
- MEHANSKA, KEMIJSKA



MEHANSKA PREBAVA

- začne se v ustih (žvečenje) → želodec (peristaltika) → tanko črevo (mišice – gibanje naprej nazaj)
- olajša kemijsko prebavo → večja površina za encime

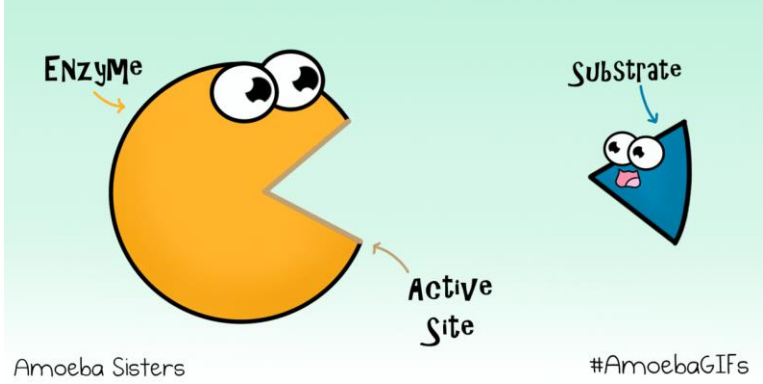


KEMIJSKA PREBAVA

- razgradnja hrane (makromolekul) z encimi
  - ŠKROB – z AMILAZO v disaharide in monosaharide
  - LIPIDI – z LIPAZO v glicerol in maščobne kisline
  - PROTEINI – s proteazami v peptide in aminokisline
    - PEPTIDI s PEPTIDAZO v aminokisline

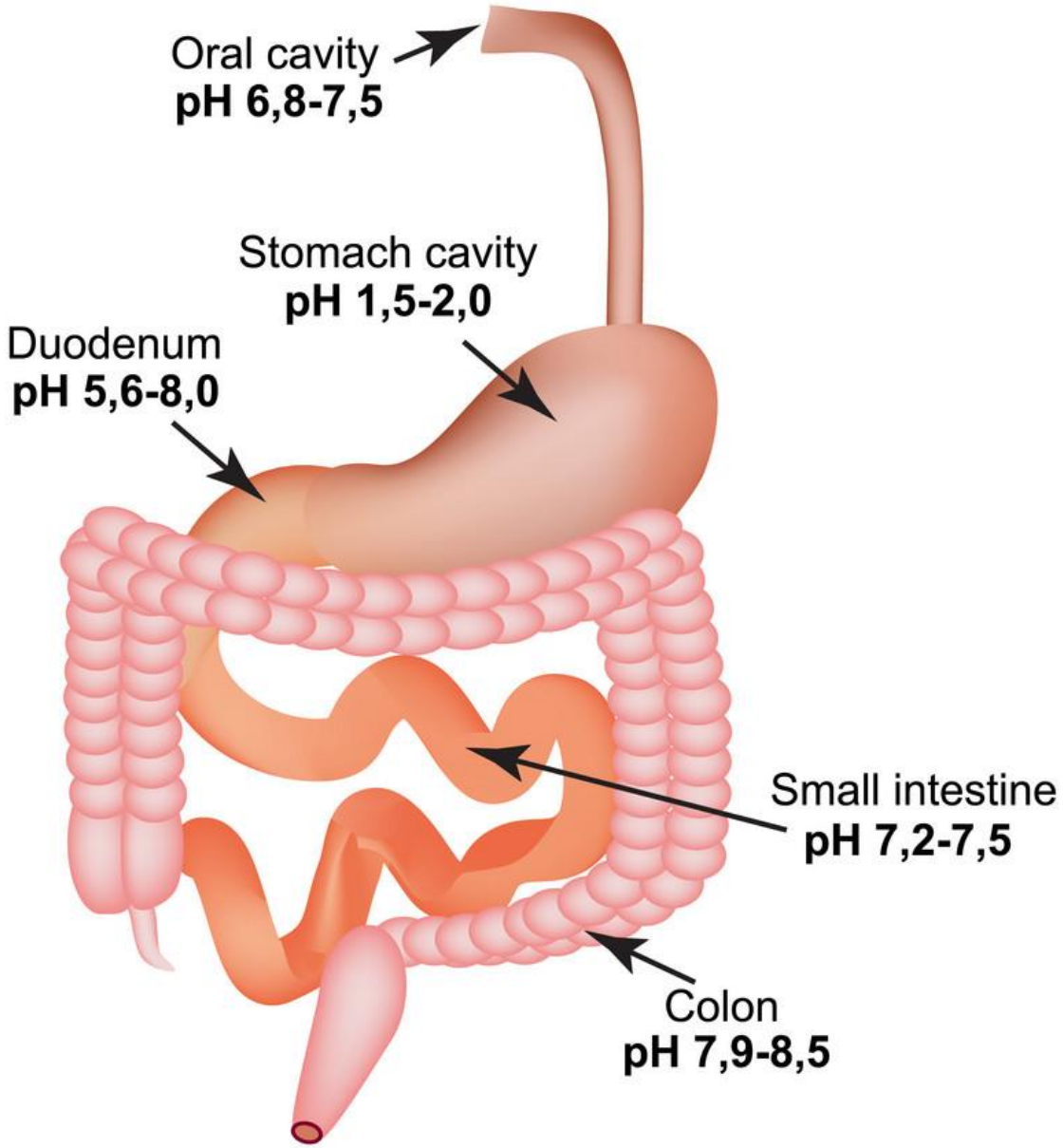
- dovolj majhne molekule – absorpcija v gastrointestinalnem traktu – za izgradnjo novih makromolekul ali ATP

ENCIMI



- običajno velike proteinske molekule, posebni biološki katalizatorji - pospešijo hitrost kemijskih reakcij
- so specifični, delujejo na specifične substrate
  - imajo aktivno mesto – tu se mora vezati substrat
- prebavni e. - so hidrolitični encimi HIDROLAZE – razgradijo substrat z dodatkom vode na molekularne vezi
- encimi delujejo bolje na substratu, ki je razgrajen na manjše koščke (večja površina)
- vsak ima svojo optimalno T in pH delovanja
  - T: v našem telesu delujejo optimalno pri 37°C, denaturirajo pri visokih T

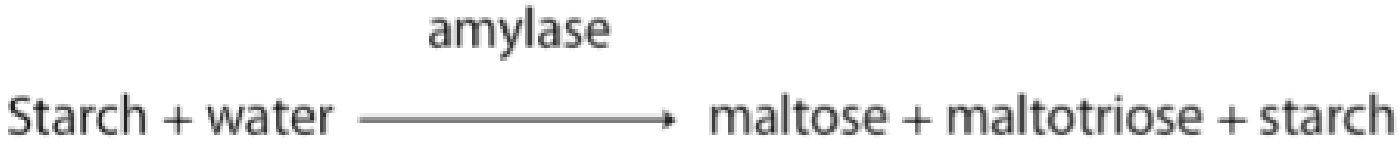
pH of the gastrointestinal tract



KEM. PREBAVA V USTIH

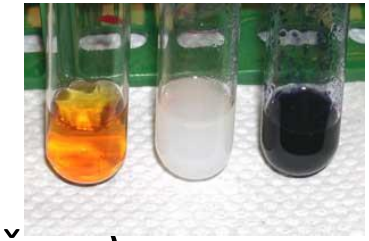
- LIPAZA začne prebavo trigliceridov

- **AMILAZA** začne s prebavo ogljikovih hidratov
  - izločajo jo žleze slinavke
  - ŠKROB – amilaza ga razgradi do maltoze (voda!) (2 glukozi) in maltotrioze (3 glukoze)



KEM. PREBAVA V USTIH

- škrob in celuloza – oba rastlinska polisaharida glukoze



- testi aktivnosti amilaze – 2 reagenta:
  - **IKI** (kalijev iodid) – barva škrob (obarva se modro-črno)
  - **Benediktov reagent** – barva glukozo ali maltozo (iz svetlo modre v zeleno – oranžno – rdečo), rahlo segrevanje

- ? ali amilaza razgradi celulozo
- ? ali bakterijska suspenzija razgradi celulozo
- ? ali peptidaza razgradi celulozo

KEM. PREBAVA V ŽELODCU

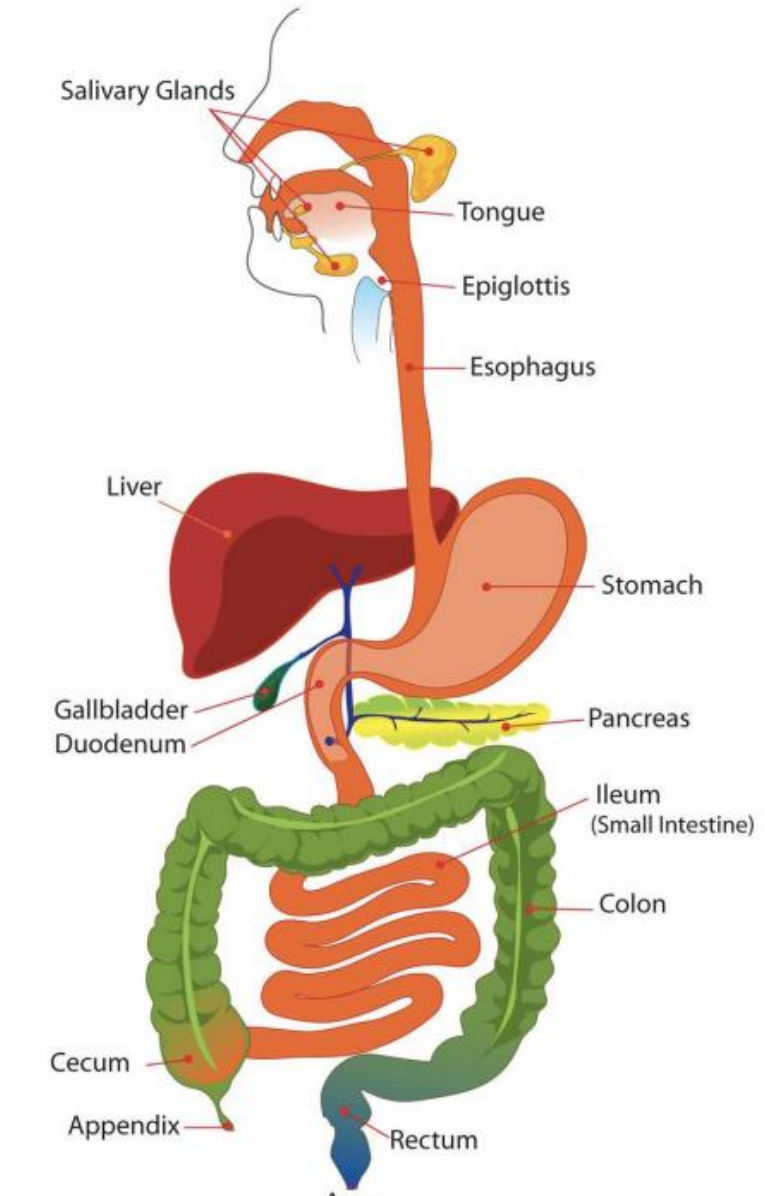
- nadaljuje se razgradnja trigliceridov z želodčno lipazo
- prične se razgradnja proteinov (peptidov)
  - peptidi – 2 ali več AK, 10-100 AK - polipeptid
- glavne celice (chief cells) izločajo PEPSINOGEN – ta se pod vplivom kislega pH (HCl) spremeni v aktivno obliko PEPSIN
- hidrolizira peptidne vezi

- BAPNA – substrat za oceno aktivnosti pepsina
  - ko je hidroliziran – rumena barva (ocena spektrofotometrično)
  - večja optična gostota – večja stopnja hidrolize

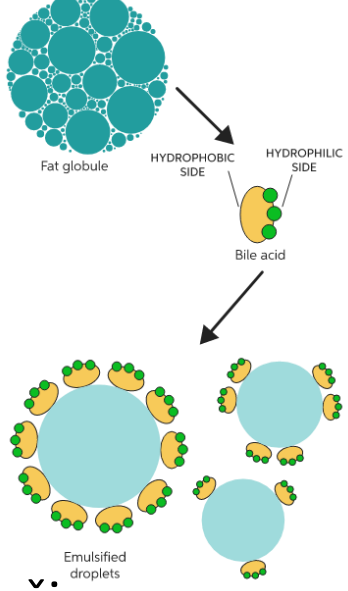
KEM. PREBAVA V TANKEM ČREVESU

- epitelne celice izločajo amilaze in peptidaze, ki razgrajujejo ogljikove hidrate in proteine

- PANKREAS – izloča
  - **pankreasno amilazo** za razgradnjo oglj. hidratov
  - **tripsin** za razgradnjo proteinov
  - **pankreasno lipazo** za razgradnjo maščob



KEM. PREBAVA V TANKEM ČREVESU



- **LIPIDI** - maščobe in olja, oboji slabo topni v vodi
- TRIGLICERIDI – tip lipidov
  - med prebavo se združujejo skupaj, samo majhna površina za delovanje lipaze
  - ŽOLČNE SOLI – izločene v tanko črevo za fizično emulzifikacijo lipidov – delujejo kot detergent, držijo narazen lipidne molekule – večja površina

- LIPAZA razgradi trigliceride v monogliceride + 2 maščobni kislini
  - tudi v ustih in želodcu – ni žolčnih soli, ampak vseeno delna razgradnja lipidov
  - razgradnja rastlinskega olja v eksperimentu

pH

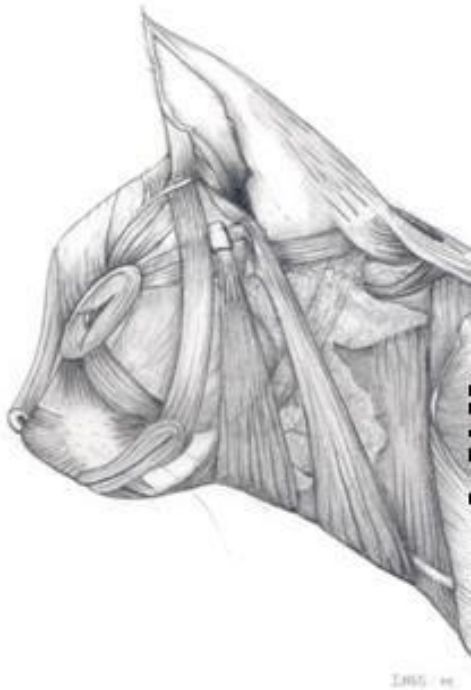
KONTROLA v EKSPERIMENTU

- pripravimo znan standard, s katerim se dela primerjave
- pozitivna kontrola – vse snovi so vključene, pričakovan **+** rezultat
- negativna kontrola - **-** rezultat pričakovan
  - za oceno, ali je v kakšnem reagentu prišlo do kontaminacije
  - - rezultat v – kontroli ovrednoti eksperiment

FIZIOLOGIJA ŽIVALI

Laboratorijske vaje

IZLOČANJE

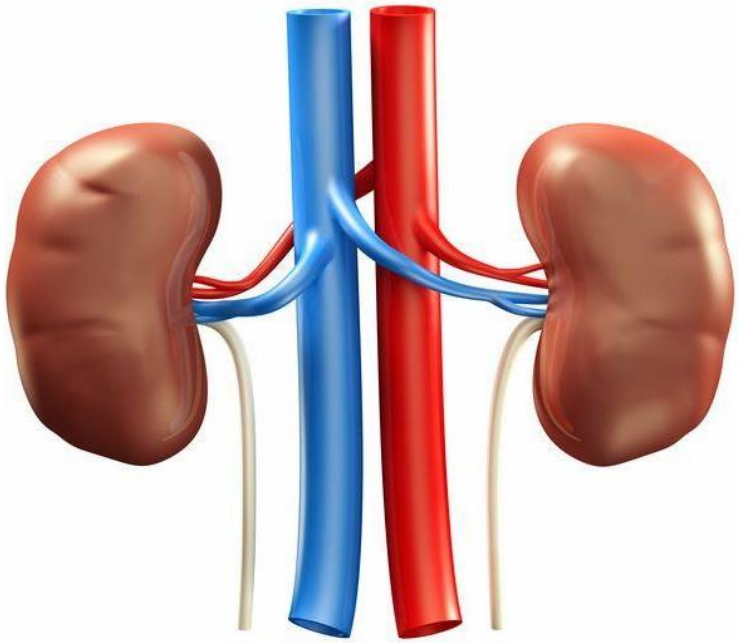


dr. Katja Adam

UP FAMNIT

LEDVICE

- izločalni in regulatorni organ
  - s filtracijo vode in topljencev iz krvi izločajo odvečno vodo in odpadne produkte
  - poleg tega regulirajo: ozmolarnost plazme, volumen plazme, kislo-bazično ravnovesje telesa*, ravnovesje elektrolitov v telesu

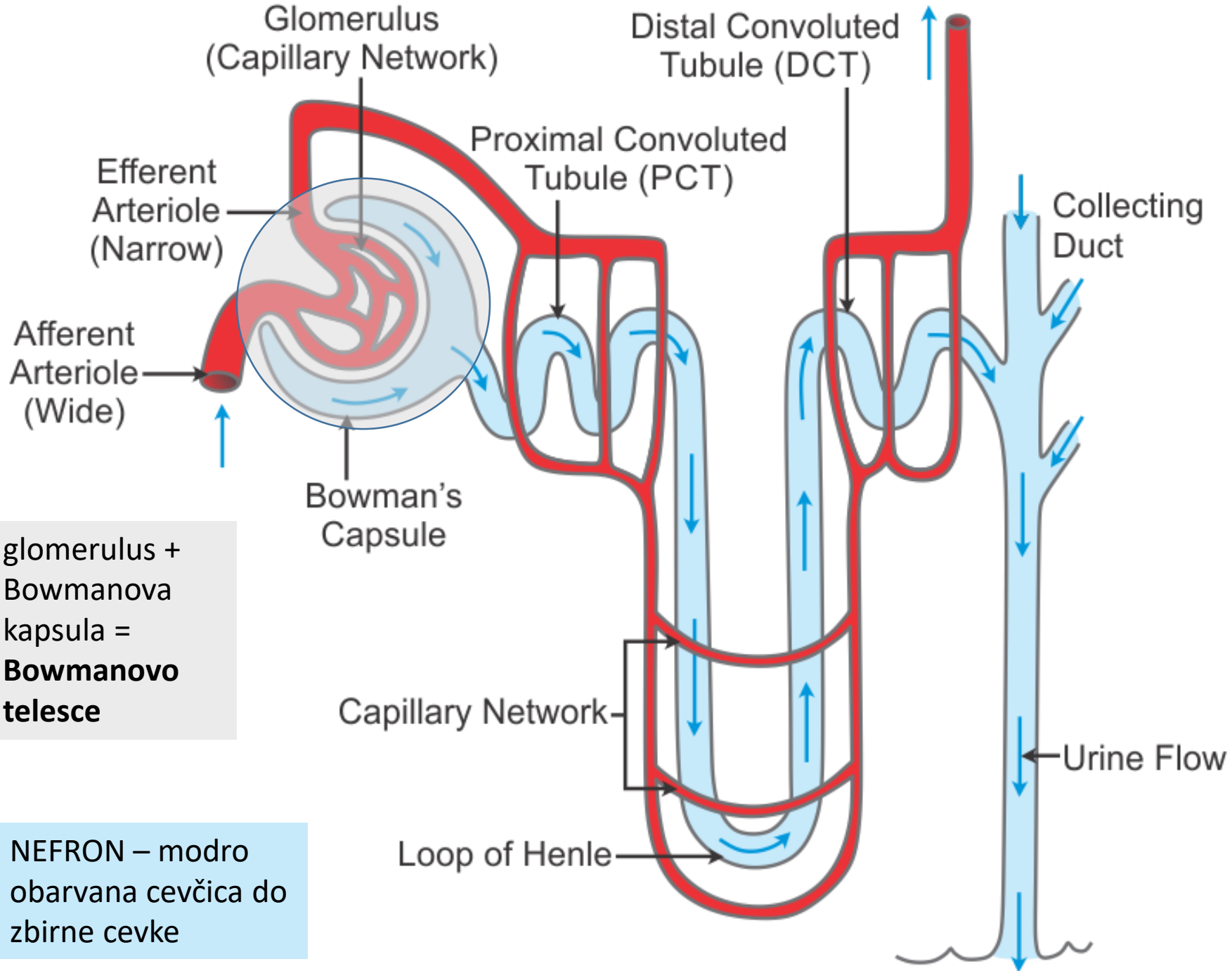


* kislo-bazično ravnovesje bomo delali na eni izmed prihodnjih vaj

LEDVICE - ZGRADBA

https://www.youtube.com/watch?v=9_h0ZXx1lFw → LEDVICE, NEFRONI, FILTRACIJA

- sestavljene so iz NEFRONOV – funkcionalne enote ledvic
  - 1 mio v eni zdravi ledvici ljudi
- SESTAVA ENEGA NEFRONA: začne se z Bowmanovo kapsulo, sledi cevčica (ločimo različne dele cevke: proksimalna zavita cevka, Henleyeva pentlja, distalna cevka)
- → zbirna cevka (ni del nefrona)
- ***glomerulus*** – prepleteno omrežje kapilar, ki vstopa v Bowmanovo kapsulo. Kapilara, ki vstopa v B. kapsulo, se imenuje AFERENTNA, tista, ki izstopa pa EFERENTNA
- iz glomerulusa se kri filtrira v lumen B. kapsule
  - filtracija – plazma brez celic in proteinov v B. kapsulo = filtrat
  - naloga *nefrona* – procesiranje filtrata, reabsorpcija koristnih snovi iz lumna in izločanje odpadnih snovi
- Bowmanovo telesce (angl. renal corpuscule): glomerulus + Bowmanova kapsula

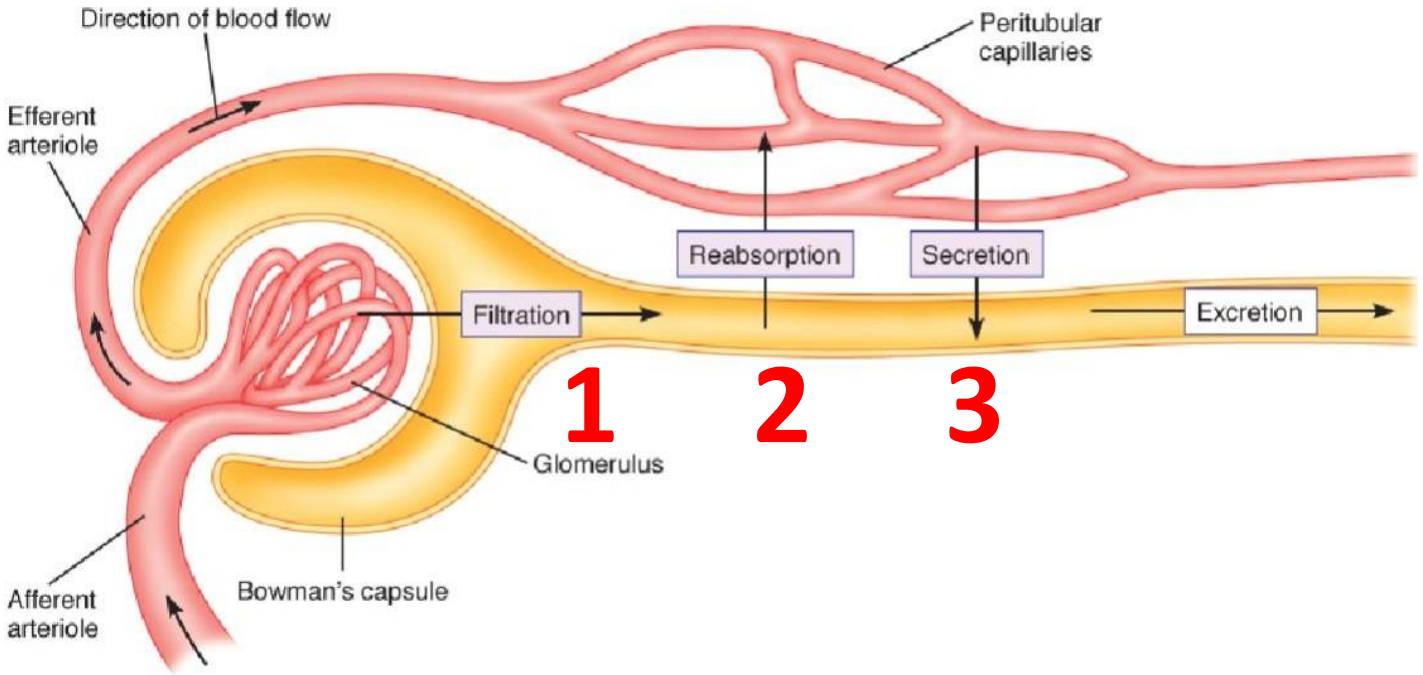


glomerulus + Bowmanova kapsula = **Bowmanovo telesce**

NEFRON – modro obarvana cevčica do zbirne cevke

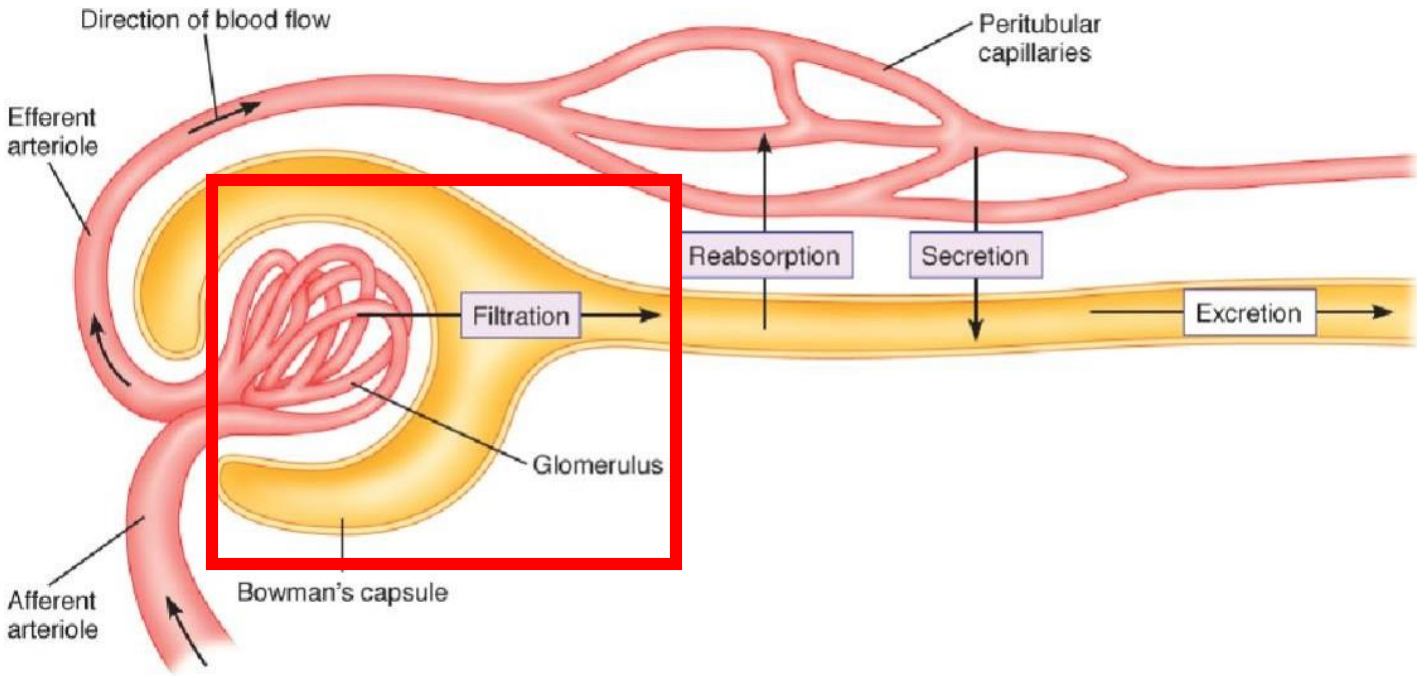
LEDVICE – NEFRON

- 3 pomembne naloge nefrona, ki spremenijo filtrat v urin:
  - 1. glomerularna filtracija
  - 2. reabsorpcija vseh koristnih snovi za telo iz nefrona v peritubularno kapilarno omrežje
  - 3. izločanje v cevke nefrona



Nefron: 1. Glomerularna filtracija

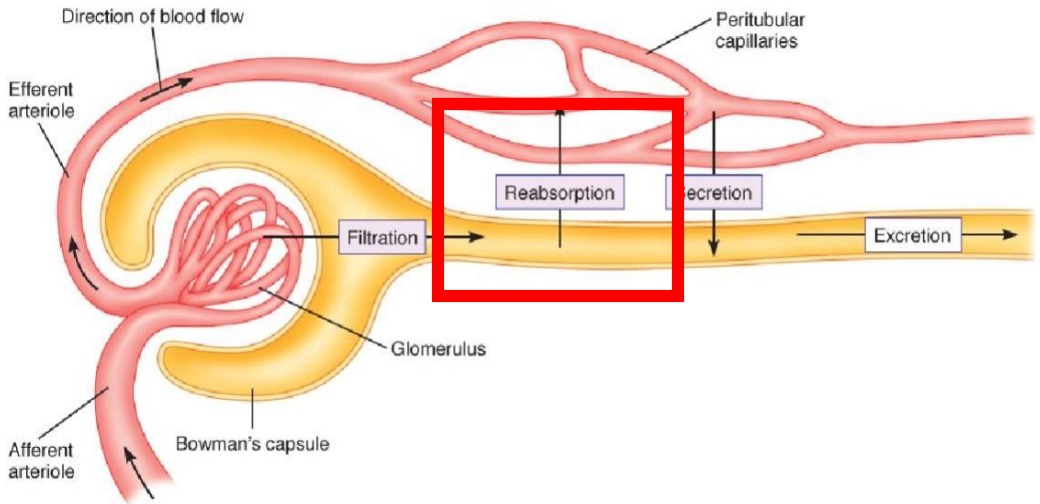
- pasiven proces – filtracija! ponovite!
- tekočina potuje iz lumna glomerulusa v Bowmanovo kapsulo



Nefron: 2. reabsorpcija

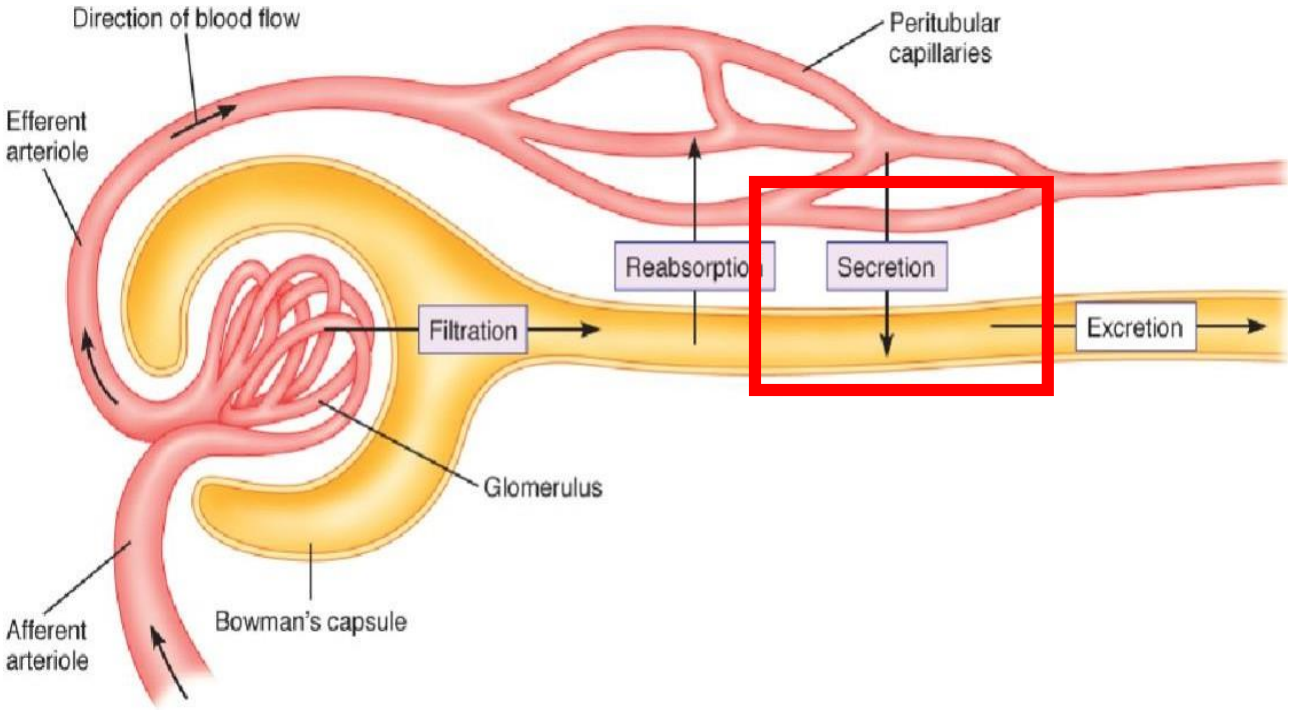
- iz cevk v nefronu poteka **reabsorpcija** H_2O in topljenca
  - nekatere topljence kri **aktivno** resorbira, drugi pa se **pasivno** premikajo v intersticijski prostor ob nefronu → od tod v kri - kapilare (**peritubularno omrežje** okoli tubulov zagotavlja vračanje snovi nazaj v krvni obtok; peritubularno omrežje izhaja iz eferentne arteriole, praznijo se v ledvične vene, ki izhajajo iz ledvic)
  - reabsorpcija je odv. od celotnega **koncentracijskega gradienta topljenca** v intersticijskem prostoru okoli cevk
  - max koncentracija topljenca je v intersticiju
  - BREZ RESORPCIJE bi izločali telesu koristne topljence in vodo

- **zapomnite si**, da se večina filtrata resorbira!



Nefron: 3. izločanje v cevke

- obratno od tubularne reabsorpcije
- iz krvi se v nefron dodatno izločijo nekoristne snovi, kot so amonijak in kreatinin

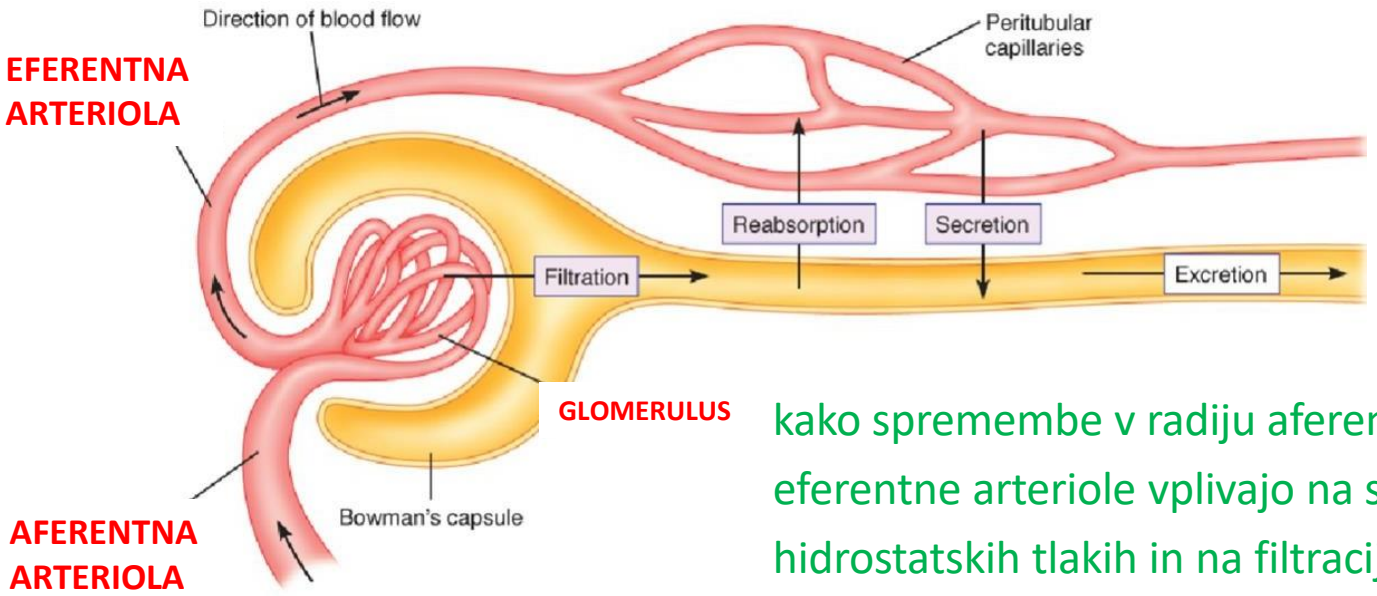


1. VPLIV RADIJA ARTERIOL NA FILTRACIJO V GLOMERULU

•2 arterioli sta povezani z vsakim B. telescem – **AFERENTA**
ki vstopa v Bowmanovo kapsulo (glomerularni preplet), in **EFERENTNA**, ki gre ven

•premer aferentne > premer eferentne

•razlike v tlakih – omogoča ultrafiltracijo krvi iz endotela kapilar glomerula *spomnite se na prve vaje in nalogo iz filtracije

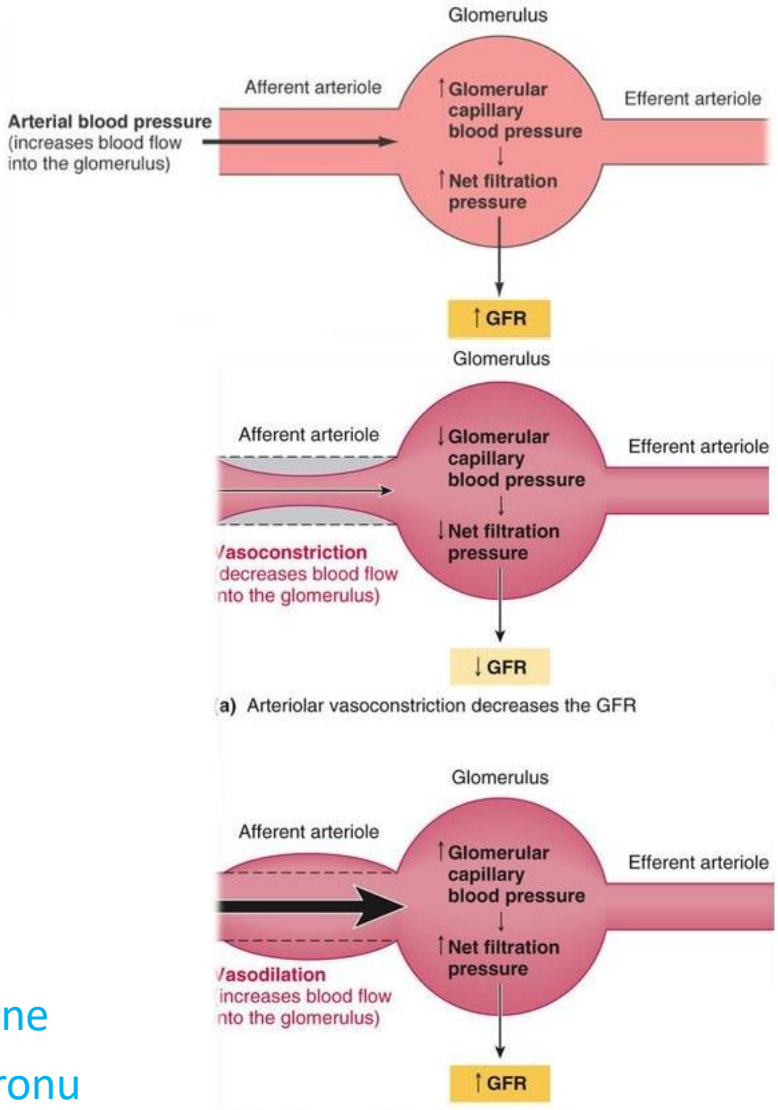


kako spremembe v radiju aferentne oziroma eferentne arteriole vplivajo na spremembo v hidrostatskih tlakih in na filtracijo?

1. VPLIV RADIJA ARTERIOL NA FILTRACIJO V GLOMERULIH

- v Bowmanovi kapsuli se iz glomerula filtrira vse, razen krvnih celic in proteinov v plazmi krvi

- STOPNJA FILTRACIJE V GLOMERULIH je pokazatelj delovanja ledvic
  - ljudje: 80-140 ml/min (180 L filtrata /24h)
  - 1x10^6 nefronov/ledvico
  - lahko se spremeni s spremembo hidrostatskega pritiska v arterioli oz. upora v arteriolah



- NALOGA 9_1: vpliv različnih radijev aferentne in eferentne arteriole na pritisk v glomerulu ter filtracijo v enem nefronu

2. VPLIV TLAKA na FILTRACIJO V GLOMERULUSU

- krvni tlak v glomerulu in tlak filtrata v ledvični cevki imata pomembno vlogo na stopnjo filtracije krvi
- med filtracijo vstopa kri v glomerulus iz aferentne arteriole → zaradi osmotskega in hidrostatskega pritiska gre filtrat v Bowmanovo kapsulo

- pribl. 20% krvi, ki vstopi v kapilare glomerulusa, se filtrira
- zelo visok tlak v glomerulusu skrbi za filtracijo

→ zato lahko stopnjo filtracije spremenimo s spremembo upora aferentne in eferentne arteriole (in s tem hidrostatskega tlaka)

3. ODGOVOR LEDVIC NA POVEČAN TLAK KRVI

- **tlak krvi**, ki vstopa v nefron, ima lahko velik vpliv na tlak v kapilarah glomerula in glomerularno filtracijo
- v realnosti v večini primerov tlak v glomerulu in stopnja filtracije ostajata bolj ali manj **konstantna**, saj ima nefron sposobnost spreminjanja premera aferentne in eferentne arteriole
    - z različnimi regulatornimi mehanizmi se vzdržuje relativno **konstantna stopnja filtracije** 125ml/min
- v ledvicah se spremembe v krvnem tlaku in premeru arteriol dogajajo simultano in ne ločeno

3. ODGOVOR LEDVIC NA POVEČAN TLAK KRVI

- Reguliranje stopnje glomerularne filtracije: radiji aferentne in eferentene arteriole, pritisk krvi

Afferent Radius (mm)	Efferent Radius (mm)	Beaker Press. (mm Hg)	Glomerular Press. (mm Hg)	Glom. Filt. Rate (ml/min)	Urine Volume (ml)
0.50	0.45	90	55.08	124.99	200.44
0.50	0.45	70	49.72	58.57	161.76
0.60	0.45	70	54.25	114.72	196.72
0.50	0.35	70	51.24	77.41	231.12
0.60	0.35	70	55.58	131.15	245.57

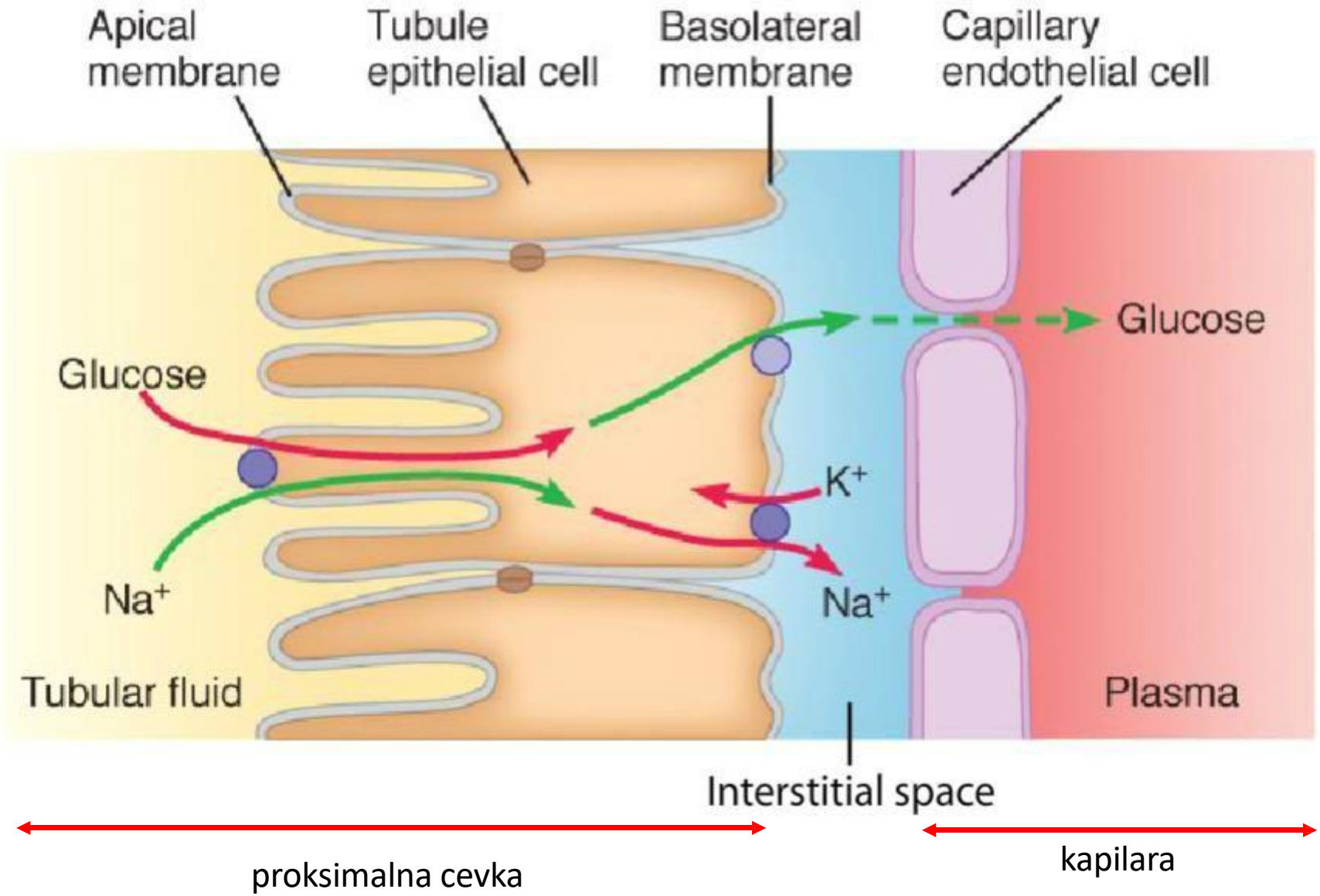
- Regulacija katere arteriole ima večji vpliv na stopnjo filtracije? Zakaj?
- Kako se zagotovi skoraj normalno stopnjo filtracije v telesu ob padcu pritiska krvi?

5. REABSORPCIJA GLUKOZE

- **glukoza** – ni velika, lahko prehaja iz plazme v Bowmanovo kapsulo in je del filtrata
- nazaj se resorbira praktično takoj po filtraciji
- v membrani **proksimalne cevke so** prenašalni proteini, ki skrbijo, da je glukoza reabsorbirana nazaj
  - to je pomembno, saj je vir energije!
  - če je glukoze preveč v filtratu – prisotna tudi v urinu, saj je število prenašalcev omejeno

5. REABSORPCIJA GLUKOZE

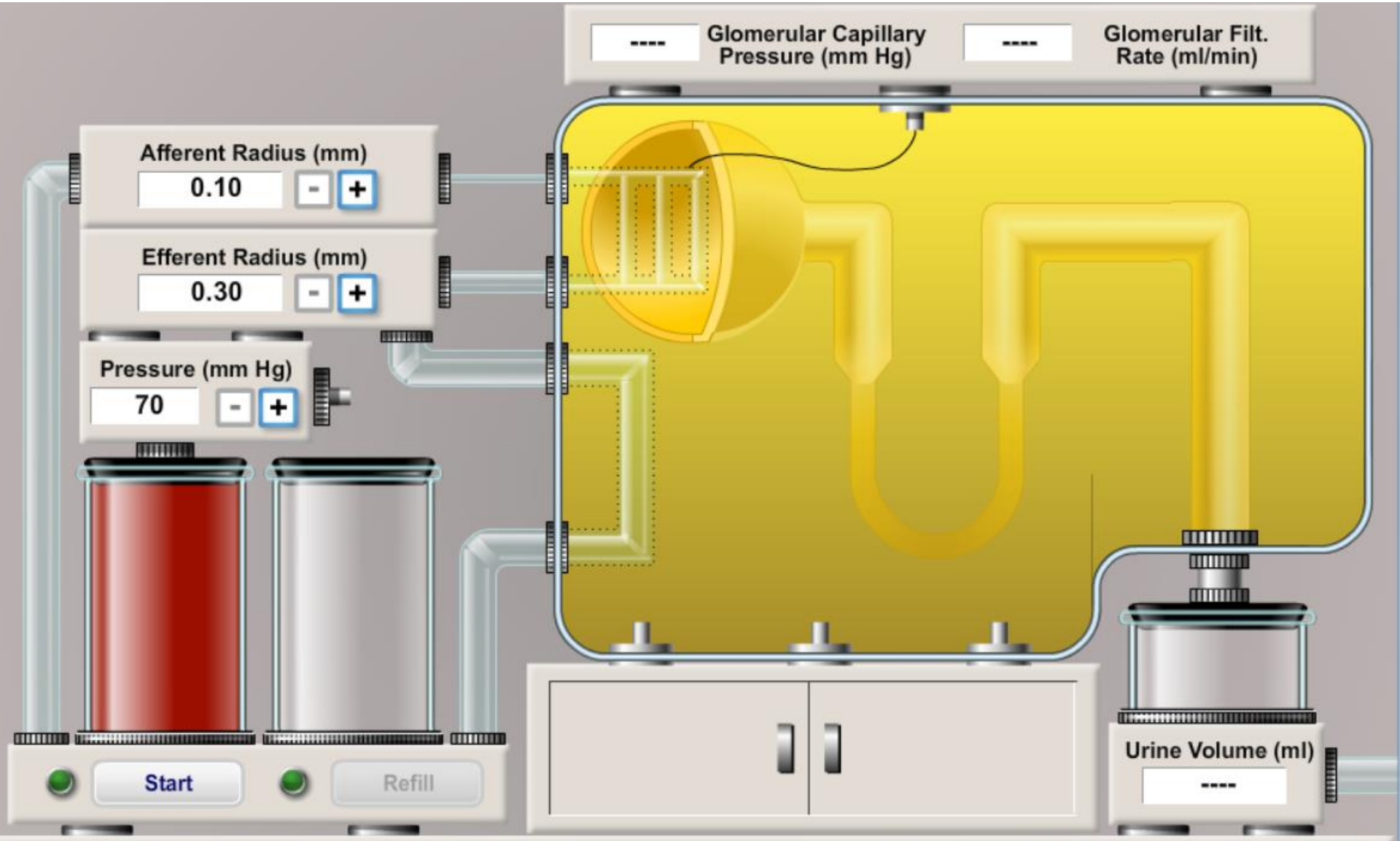
- * glej sliko na naslednji strani za pregled poti glukoze in flitrata v kri:
- glukoza se najprej prenese iz filtrata v **epitelne celice** proksimalnih cevk, nato gre iz celic v **intersticijski prostor** in na koncu skozi pore v **kapilare**
- v epitelne cevke glukoza vstopi na njihovi apikalni membrani s sekundarnim aktivnim transportom (istočasno se z glukozo kotransportira Na), iz celic pa izstopi z olajšano difuzijo na bazolateralni membrani celic
  - oba procesa vključujeta transmembranske proteine!
  - število proteinov normalno ne variira, temveč variira količina glukoze tekom dneva
  - VAJA – spreminjali boste št. prenašalcev in ne količine glukoze


Apical membrane
Tubule epithelial cell
Basolateral membrane
Capillary endothelial cell
Glucose
Glucose
K+
Na+
Na+
Tubular fluid
Plasma
Interstitial space
proksimalna cevka
kapilara

DANAŠNJE VAJE

- 8: Chemical and physical processes of digestion
  - Vaja 1
  - Vaja 3
  - Vaja 4

- 9: Renal system physiology
  - Vaja 1
  - Vaja 5



Afferent Radius (mm)	Efferent Radius (mm)	Beaker Press. (mm Hg)	Glomerular Press. (mm Hg)	Glom. Filt. Rate (ml/min)	Urine Volume (ml)

English (Unite
Slovenian key

To switch inp

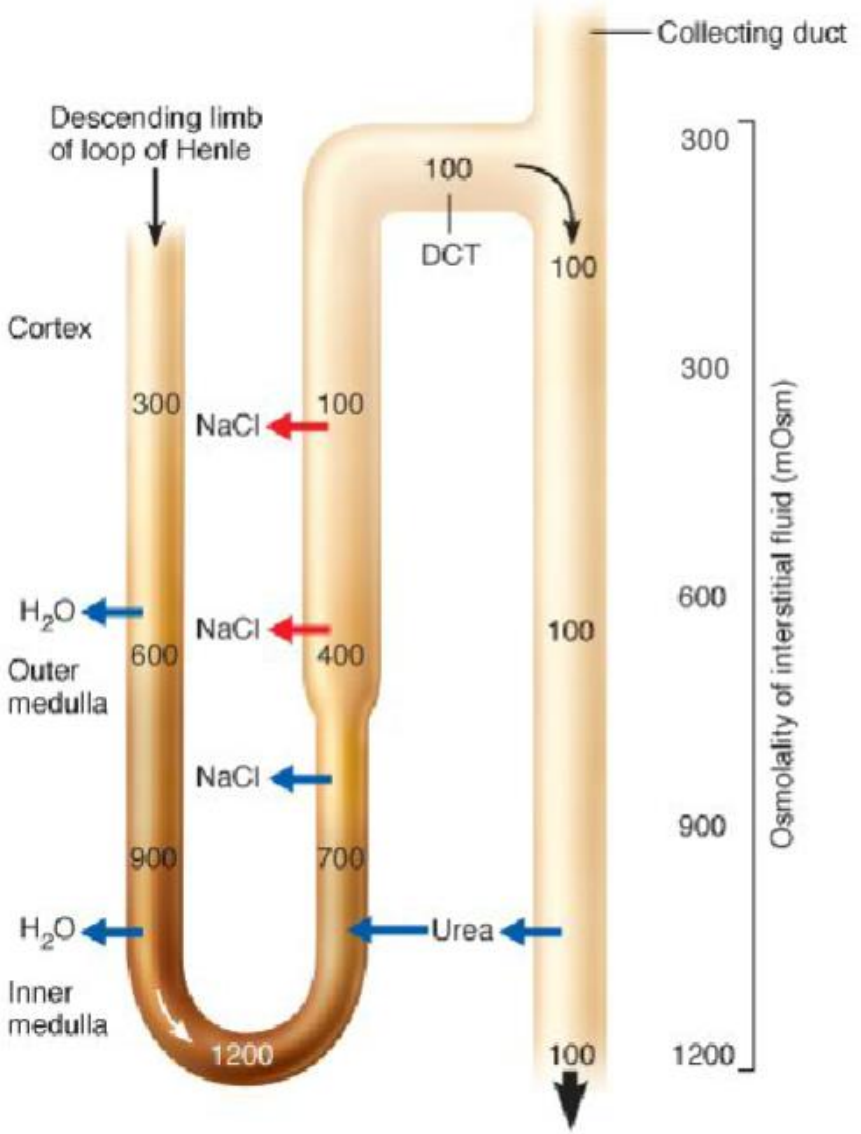
4. GRADIENT TOPLJENCEV IN NJEGOV VPLIV NA NASTANEK URINA

- REABSORPCIJA:
- ko se filtrat premika po cevkah, je premikanje topljencev in vode iz cevke odvisno od njihovega koncentracijskega gradienta – razlik v koncentraciji topljencev med lumnom cevk in intersticijsko tekočino, ki obdaja cevke
- intersticij – večinoma iz NaCl in uree
- prehod – do izenačitve koncentracij
- reabsorbirana voda in topljenci – vrnejo se v kri (peritubularno omrežje)
- **maksimalna koncentracija topljencev** se nanaša na količino topljencev v intersticiju
- smeri prehoda posameznih snovi vzdolž cevk nefronov – slika na nasl. slide

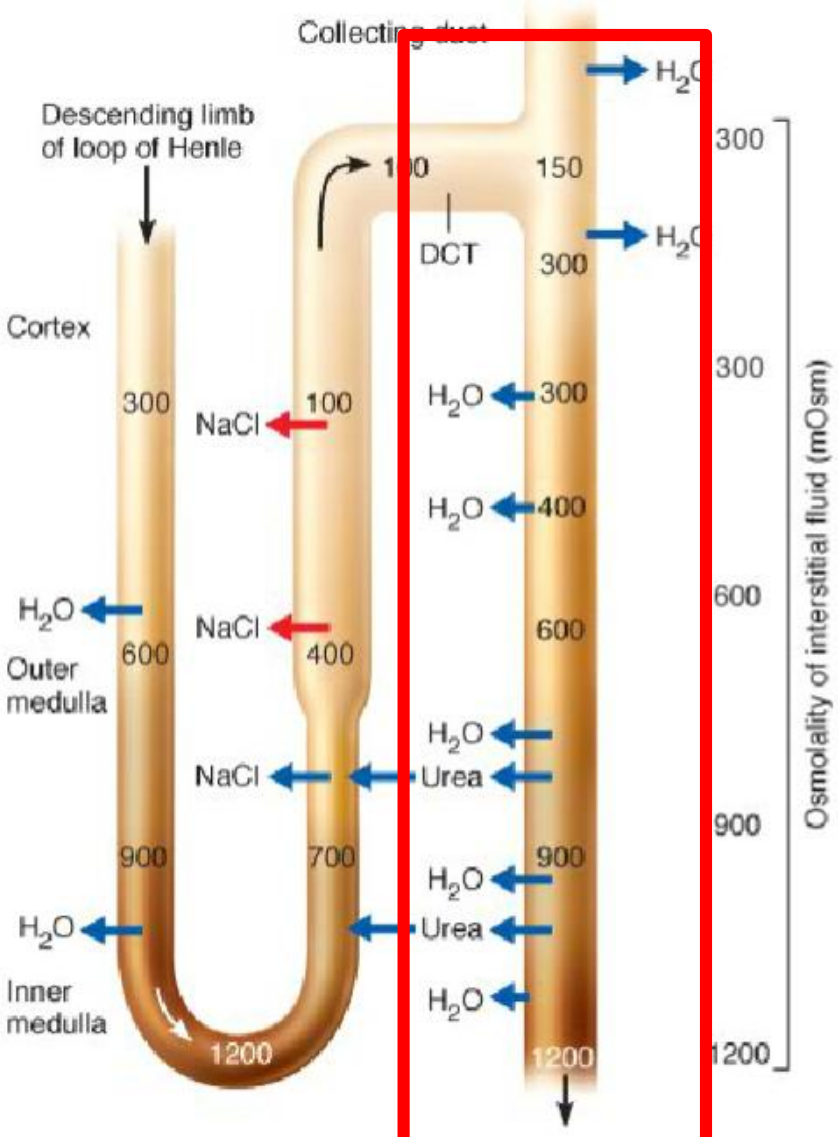
4. VPLIV HORMONA ADH NA KOLIČINO FILTRATA

- **ADH (antidiuretični) hormon** poveča permeabilnost za vodo v zbirnih cevkah → voda gre zato v območja z večjo koncentracijo topljenca (*spomnite se na osmozo!), iz zbirne cevke v intersticijsko območje → količina seča se na ta račun zmanjša
- **Diuretik** poveča diurezo (izločanje seča), anti-diuretik pa to zmanjša

- **osmolarnost** = koncentracija osmozno aktivnih delcev, merilo koncentracije topljenca



(a) **Absence of ADH**

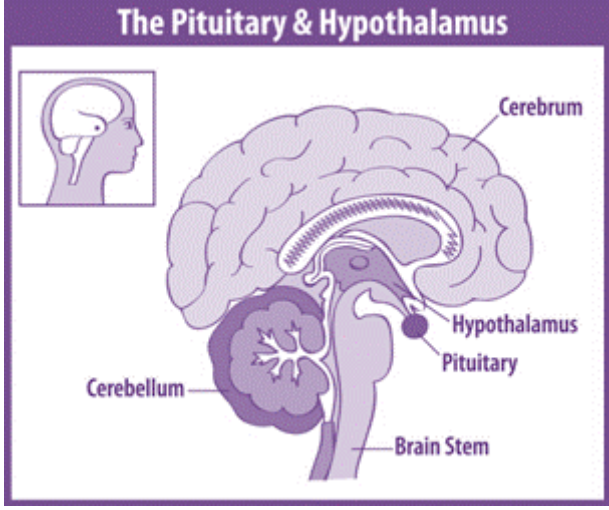


(b) **Maximal ADH**

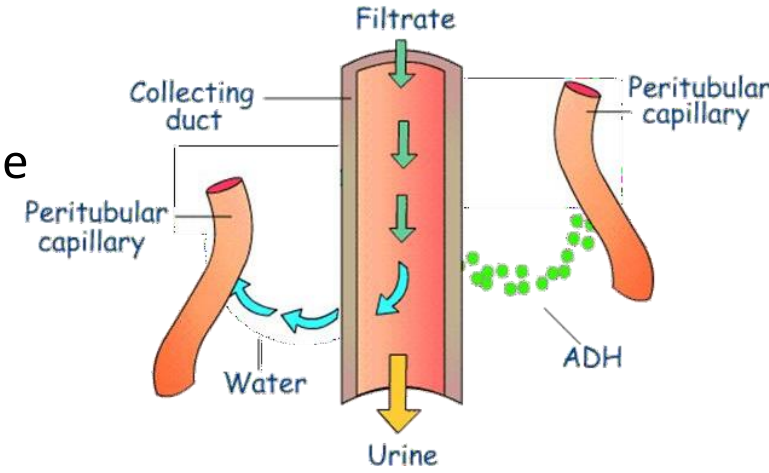
Henleyeva pentlja – zelo prepustna za H2O, slabo za toplience

ADH poveča premeabilnost zbirnih cevk za vodo

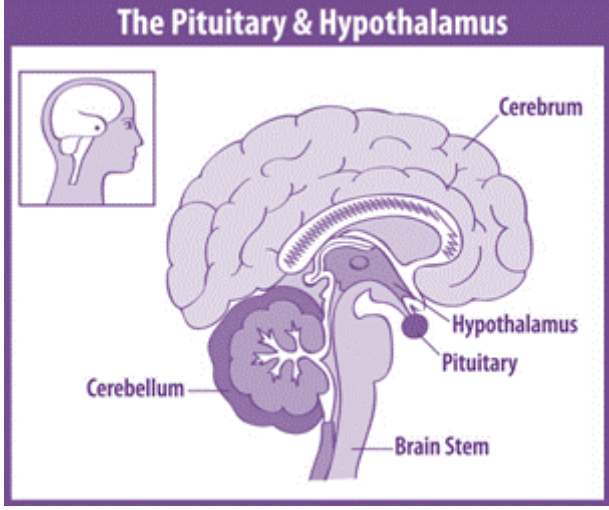
6. VPLIV HORMONOV NA OBLIKOVANJE URINA



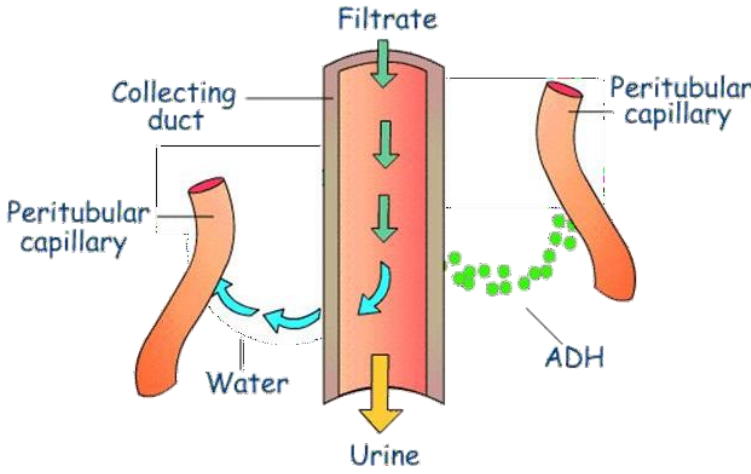
- **ADH** – proizvaja ga hipotalamus in shranjen je v hipofizi (pituitary gland)
- gl. naloga: povečanje permeabilnosti v **<u>zbirni cevki</u>** za vodo, tako da vstavlja akvaporine (kanalčke) v apikalno membrano → več vode je resorbirane v telo
- voda gre do območij z večjo koncentracijo topljenca: iz lumna cevke v okoliški intersticij



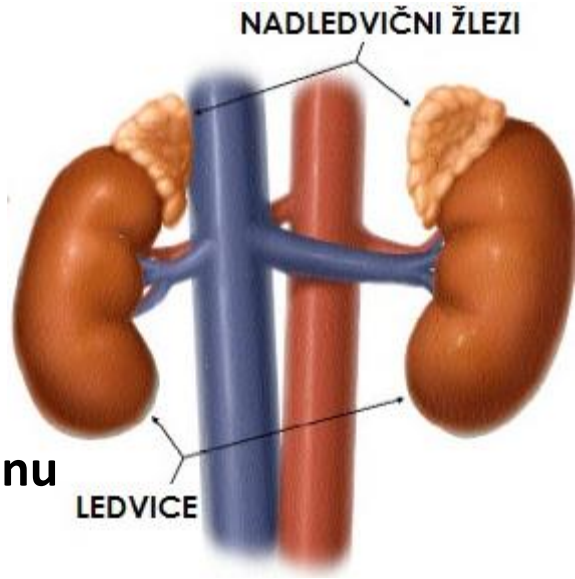
6. VPLIV HORMONOV NA OBLIKOVANJE URINA



- OSMOLARNOST TELESNIH TEKOČIN ter volumni in tlaki v obtočilnem sistemu vplivajo na izločanje ADH
- že samo 1% sprememba osmolarnosti povzroči izločanje ADH
  - sprememba v elektrolitih + dodatek antidiuretičnega hormona (ADH) → več vode je resorbirane v kri → koncentriran urin, krvni tlak naraste zaradi večje vsebnosti vode v krvi



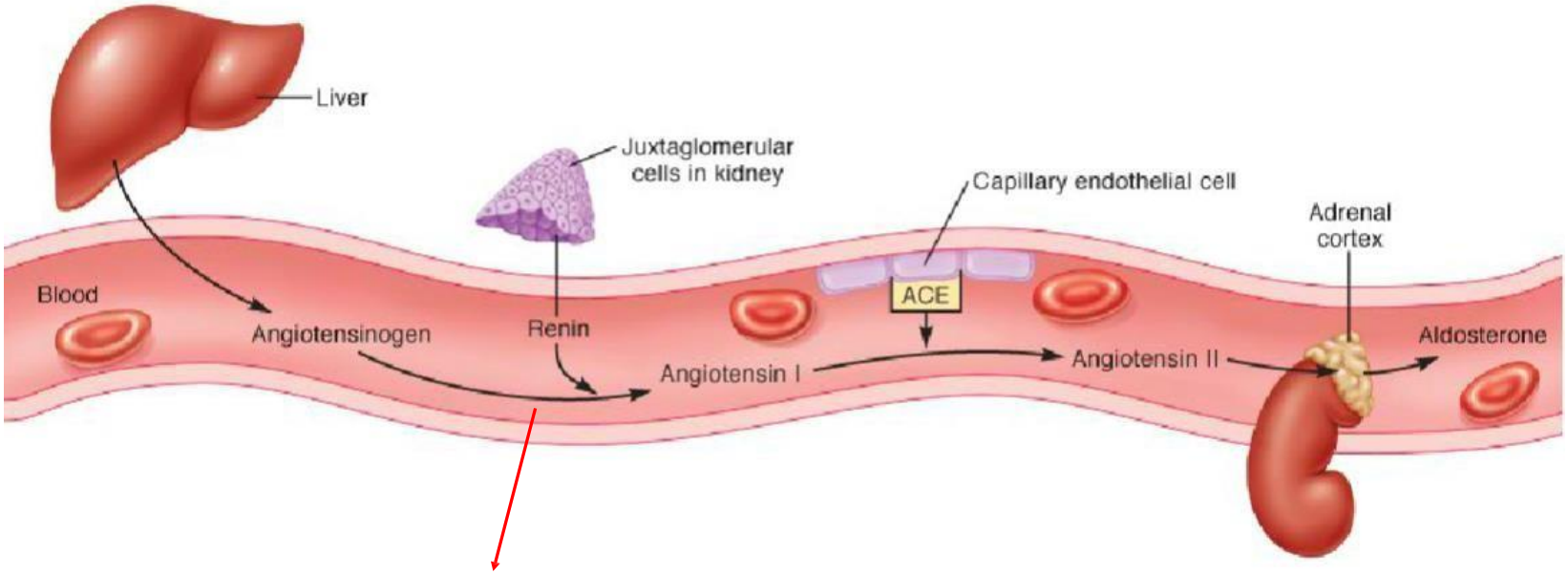
6. VPLIV HORMONOV NA OBLIKOVANJE URINA



- **ALDOSTERON** – proizvaja ga skorja nadledvičnih žlez
- vpliva na **distalne zavite cevke (in zbrine cevke) v nefronu** – spodbuja resorpcijo **Na^+** iz filtrata (iz cevke) v telo in izločanje **K^+** iz telesa v cevke – z NaCl se izloči tudi nekaj vode (osmoza!)
- Pod vplivom aldosterona se v distalnih cevkah:
  - reabsorbirajo - Na^+ in Cl^- ioni, ker so osmotsko aktivni, HCO_3- in voda
  - izločajo iz intersticija v filtrat - K^+, H^+ in amonijevi ioni, kar vzdržuje kislinsko-bazično ravnovesje krvi

PROIZVODNJA ALDOSTERONA

- proizvaja ga skorja nadledvične žleze v tako imenovanem RENIN-ANGIOTENZIN SISTEMU



KO SE ZNIŽA PRITISK KRVI – to zaznajo celice v aferentni arterioli in povzročijo izločanje **renina** → renin povzroča spremembo angiotenzinogena v angiotenzin I

endotelne celice povzročijo spremembo angiotenzina I v angiotenzin II → ta stimulira skorjo nadledvične žleze, da izloči **ALDOSTERON**

REGULACIJA IZLOČENE VODE/TOPLJENCEV

- ledvice regulirajo količino vode in topljencev, ki se izločajo, da vzdržujejo ravnovesje vode v telesu
- majhen vnos vode, izguba telesnih tekočin – ledvice delajo na shranjevanju vode, “naredijo” urin zelo **hiperosmotski** (ima visoko koncentracijo topljenca)
- velik vnos tekočin – urin je zelo **hipoosmotski**
- normalen urin – osmolarnost med 50-1200 miliosmolov/kg vode

Overview

Exercise Overview

Renal System Physiology

The **kidney** is *both* an excretory and a regulatory organ. By filtering the water and solutes in the blood, the kidneys are able to *excrete* excess water, waste products, and even foreign materials from the body. However, the kidneys also *regulate* (1) plasma osmolarity (the concentration of a solution expressed as osmoles of solute per liter of solvent), (2) plasma volume, (3) the body's acid-base balance, and (4) the body's electrolyte balance. All these activities are extremely important for maintaining homeostasis in the body.

The paired kidneys are located between the posterior abdominal wall and the abdominal peritoneum. The right kidney is slightly lower than the left kidney. Each human kidney contains approximately one million **nephrons**, the functional units of the kidney.

Each nephron is composed of a **renal corpuscle** and a **renal tubule**. The renal corpuscle consists of a "ball" of capillaries, called the *glomerulus*, which is enclosed by a fluid-filled capsule, called *Bowman's capsule,* or the glomerular capsule. An **afferent arteriole** supplies blood to the glomerulus. As blood flows through the glomerular capillaries, protein-free plasma filters into the Bowman's capsule, a process called **glomerular filtration**. An **efferent arteriole** then drains the glomerulus of the remaining blood (view Figure 9.1)

The filtrate flows from Bowman's capsule into the start of the renal tubule, called the **proximal convoluted tubule**, then into the **loop of Henle**, a U-shaped hairpin loop, and,

Exercise Overview

finally, into the **distal convoluted tubule** before emptying into a **collecting duct**. From the collecting duct, the filtrate flows into, and collects in, the minor calyces.

The nephron performs three important functions that process blood into filtrate and urine: (1) glomerular filtration, (2) tubular reabsorption, and (3) tubular secretion (view Figure 9.2). **Glomerular filtration** is a passive process in which fluid passes from the lumen of the glomerular capillary into the glomerular capsule of the renal tubule. **Tubular reabsorption** moves most of the filtrate back into the blood, leaving mainly saltwater and the wastes in the lumen of the tubule. Some of the desirable, or needed, solutes are actively reabsorbed, and others move passively from the lumen of the tubule into the interstitial spaces. **Tubular secretion** is essentially the reverse of tubular reabsorption and is a process by which the kidneys can rid the blood of additional unwanted substances, such as creatinine and ammonia.

The reabsorbed solutes and water that move into the interstitial space between the nephrons need to be returned to the blood, or the kidneys will rapidly swell like balloons. The **peritubular capillaries** surrounding the renal tubule reclaim the reabsorbed substances and return them to general circulation. Peritubular capillaries arise from the efferent arteriole exiting the glomerulus and empty into the renal veins leaving the kidney.

Introduction

Each of the million **nephrons** in each kidney contains two major parts: (1) a tubular component, the **renal tubule**, and (2) a vascular component, the **renal corpuscle** (view Figure 9.1). The **glomerulus** is a tangled capillary knot that filters fluid from the blood into the lumen of the renal tubule. The function of the renal tubule is to process the filtered fluid, also called the **filtrate**. The beginning of the renal tubule is an enlarged end called **Bowman's capsule** (or the glomerular capsule), which surrounds the glomerulus and serves to funnel the filtrate into the rest of the renal tubule. Collectively, the glomerulus and Bowman's capsule are called the renal corpuscle.

Two arterioles are associated with each glomerulus: an **afferent arteriole** feeds the **glomerular capillary** bed and an **efferent arteriole** drains it. These arterioles are responsible for blood flow through the glomerulus (view Figure 9.2). The diameter of the efferent arteriole is smaller than the diameter of the afferent arteriole, restricting blood flow out of the glomerulus. Consequently, the pressure in the glomerular capillaries forces fluid through the endothelium of the capillaries into the lumen of the surrounding Bowman's capsule. In essence, everything in the blood except for the blood cells (red and white) and plasma proteins is filtered through the glomerular wall. From the Bowman's capsule, the filtrate moves into the rest of the renal tubule for processing. The job of the tubule is to reabsorb all the beneficial substances from its lumen and allow the wastes to travel down the tubule for elimination from the body.

During glomerular filtration, blood enters the glomerulus from the afferent arteriole and

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protein-free plasma flows from the blood across the walls of the glomerular capillaries and into the Bowman's capsule. The **glomerular filtration rate** is an index of kidney function. In humans, the filtration rate ranges from 80 to 140 ml/min, so that, in 24 hours, as much as 180 liters of filtrate is produced by the glomeruli. The filtrate formed is devoid of cellular debris, is essentially protein free, and contains a concentration of salts and organic molecules similar to that in blood.

The glomerular filtration rate can be altered by changing arteriole resistance or arteriole hydrostatic pressure. In this activity, you will explore the effect of arteriole radius on glomerular capillary pressure and filtration in a single nephron. You can apply the concepts you learn by studying a single nephron to understand the function of the kidney as a whole.

Equipment Used

- Source beaker for blood (first beaker on left side of screen)—simulates blood flow and pressure (mm Hg) from general circulation to the nephron
- Drain beaker for blood (second beaker on left side of screen)—simulates the renal vein
- Flow tube with adjustable radius—simulates the afferent arteriole and connects the blood supply to the glomerular capillaries
- Second flow tube with adjustable radius—simulates the efferent arteriole and drains the glomerular capillaries into the peritubular capillaries, which ultimately drain into the renal

Introduction

vein (drain beaker).

- Simulated nephron (The filtrate forms in Bowman's capsule, flows through the renal tubule—the tubular components, and empties into a collecting duct, which, in turn, drains into the urinary bladder.)
  - Nephron tank
  - Glomerulus—"ball" of capillaries that forms part of the filtration membrane
  - Glomerular (Bowman's) capsule—forms part of the filtration membrane and a capsular space where the filtrate initially forms
  - Proximal convoluted tubule
  - Loop of Henle
  - Distal convoluted tubule
  - Collecting duct
- Drain beaker for filtrate (beaker on right side of screen)—simulates the urinary bladder

Introduction

Cellular metabolism produces a complex mixture of waste products that must be eliminated from the body. This excretory function is performed by a combination of organs, most importantly, the paired kidneys. Each kidney consists of approximately one million nephrons, which carry out three crucial processes: (1) glomerular filtration, (2) tubular reabsorption, and (3) tubular secretion.

Both the blood pressure in the **glomerular capillaries** and the **filtrate** pressure in the **renal tubule** can have a significant impact on the **glomerular filtration rate**. During glomerular filtration, blood enters the **glomerulus** from the **afferent arteriole**. **Starling forces** (hydrostatic and osmotic pressure gradients) drive protein-free fluid between the blood in the glomerular capillaries and the filtrate in **Bowman's capsule**. The glomerular filtration rate is an index of kidney function. In humans, the filtration rate ranges from 80 to 140 ml/min, so that, in 24 hours, as much as 180 liters of filtrate is produced by the glomerular capillaries. The filtrate formed is devoid of blood cells, is essentially protein free, and contains a concentration of salts and organic molecules similar to that in blood.

Approximately 20% of the blood that enters the glomerular capillaries is normally filtered into Bowman's capsule, where it is then referred to as filtrate. The unusually high hydrostatic blood pressure in the glomerular capillaries promotes this filtration. Thus, the glomerular filtration rate can be altered by changing the afferent arteriole resistance (and, therefore, the hydrostatic pressure). In this activity you will explore the effect of blood pressure on the glomerular

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filtration rate in a single nephron. You can apply the concepts you learn by studying a single nephron to understand the function of the kidney as a whole.

Equipment Used

- Left source beaker (first beaker on left side of screen)—simulates blood flow and pressure (mm Hg) from general circulation to the nephron
- Drain beaker for blood (second beaker on left side of screen)—simulates the renal vein
- Flow tube with adjustable radius—simulates the afferent arteriole and connects the blood supply to the glomerular capillaries
- Second flow tube with adjustable radius—simulates the efferent arteriole and drains the glomerular capillaries into the peritubular capillaries, which ultimately drain into the renal vein (drain beaker).
- Simulated nephron (The filtrate forms in Bowman's capsule, flows through the renal tubule—the tubular components, and empties into a collecting duct, which, in turn, drains into the urinary bladder.)
  - Nephron tank
  - Glomerulus—"ball" of capillaries that forms part of the filtration membrane
  - Glomerular (Bowman's) capsule—forms part of the filtration membrane and a capsular space where the filtrate initially forms
  - Proximal convoluted tubule

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  - Loop of Henle
  - Distal convoluted tubule
  - Collecting duct
- One-way valve between end of collecting tube (duct) and urinary bladder—used to restrict the flow of filtrate into the urinary bladder, increasing the volume and pressure in the renal tubule
- Drain beaker for filtrate (beaker on right side of screen)—simulates the urinary bladder

Introduction

In humans approximately 180 liters of filtrate flows into the **renal tubules** every day. As demonstrated in Activity 2, the **blood pressure** supplying the **nephron** can have a substantial impact on the **glomerular capillary pressure** and **glomerular filtration**. However, under most circumstances, glomerular capillary pressure and glomerular filtration remain relatively constant despite changes in blood pressure because the nephron has the capacity to alter its **afferent** and **efferent arteriole** radii.

During glomerular filtration, blood enters the **glomerulus** from the afferent arteriole. **Starling forces** (primarily hydrostatic pressure gradients) drive protein-free fluid out of the glomerular capillaries and into **Bowman's capsule**. Importantly for our body's homeostasis, a relatively constant glomerular filtration rate of 125 ml/min is maintained despite a wide range of blood pressures that occur throughout the day for an average human.

Activities 1 and 2 explored the independent effects of arteriole radii and blood pressure on glomerular capillary pressure and glomerular filtration. In the human body, these effects occur simultaneously. Therefore, in this activity, you will alter both variables to explore their combined effects on glomerular filtration and observe how changes in one variable can compensate for changes in the other to maintain an adequate glomerular filtration rate.

Equipment Used

Introduction

- Source beaker for blood (first beaker on left side of screen)—simulates blood flow and pressure (mm Hg) from general circulation to the nephron
- Drain beaker for blood (second beaker on left side of screen)—simulates the renal vein
- Flow tube with adjustable radius—simulates the afferent arteriole and connects the blood supply to the glomerular capillaries
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  - Nephron tank
  - Glomerulus—"ball" of capillaries that forms part of the filtration membrane
  - Glomerular (Bowman's) capsule—forms part of the filtration membrane and a capsular space where the filtrate initially forms
  - Proximal convoluted tubule
  - Loop of Henle
  - Distal convoluted tubule
  - Collecting duct
  - Drain beaker for filtrate (beaker on right side of screen)—simulates the urinary bladder

Introduction

As filtrate moves through the tubules of a nephron, solutes and water move *from* the **tubule lumen** into the **interstitial spaces** of the nephron. This movement of solutes and water relies on the total solute concentration gradient in the interstitial spaces surrounding the tubule lumen. The interstitial fluid is comprised mostly of NaCl and urea. When the nephron is permeable to solutes or water, equilibrium will be reached between the interstitial fluid and the tubular fluid contents.

Antidiuretic hormone (**ADH**) increases the water permeability of the **collecting duct**, allowing water to flow to areas of higher solute concentration, from the tubule lumen into the surrounding interstitial spaces (view Figure 9.3). **Reabsorption** describes this movement of filtered solutes and water from the lumen of the renal tubules back into the plasma. The reabsorbed solutes and water that move into the interstitial space need to be returned to the blood, or the kidneys will rapidly swell like balloons. The **peritubular capillaries** surrounding the renal tubule reclaim the reabsorbed substances and return them to general circulation. Peritubular capillaries arise from the efferent arteriole exiting the glomerulus and empty into the renal veins leaving the kidney.

Without reabsorption, we would excrete the solutes and water that our bodies need to maintain homeostasis. In this activity you will examine the process of passive reabsorption that occurs while filtrate travels through a nephron and urine is formed. While completing the experiment, assume that, when ADH is present, the conditions favor the formation of the most concentrated

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urine possible.

Equipment Used

- Simulated nephron surrounded by interstitial space between the nephron and peritubular capillaries (Reabsorbed solutes, such as glucose, will move from the lumen of the tubule, into the interstitial space, and then into the peritubular capillaries that branch out from the efferent arteriole.)
- Drain beaker for filtrate—simulates the urinary bladder
- Antidiuretic hormone (ADH)

Introduction

The concentration and volume of urine excreted by our kidneys will change depending on what our body needs for homeostasis. For example, if a person consumes a large quantity of water, the excess water will be eliminated as a large volume of dilute urine. On the other hand, when dehydration occurs, there is a clear benefit in being able to produce a small volume of concentrated urine to retain water. Activity 4 demonstrated how the total solute concentration gradient in the interstitial spaces surrounding the tubule lumen makes it possible to excrete concentrated urine.

Aldosterone is a hormone produced by the adrenal cortex under the control of the body's *renin-angiotensin system*. A decrease in blood pressure is detected by cells in the afferent arteriole, triggering the release of renin. Renin acts as a proteolytic enzyme, causing angiotensinogen to be converted into angiotensin I. Endothelial cells throughout the body possess a *converting enzyme* that converts angiotensin I into angiotensin II. Angiotensin II signals the adrenal cortex to secrete aldosterone (view Figure 9.5). Aldosterone acts on the distal convoluted tubule cells in the nephron to promote the reabsorption of sodium from filtrate *into* the body and the secretion of potassium *from* the body. This electrolyte shift, coupled with the addition of **antidiuretic hormone** (**ADH**), also causes more water to be reabsorbed into the blood, resulting in increased blood pressure.

ADH is manufactured by the hypothalamus and stored in the posterior pituitary gland. ADH levels are influenced by the osmolality of body fluids and the volume and pressure of the

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cardiovascular system. A 1% change in body osmolality will cause this hormone to be secreted. The primary action of this hormone is to increase the permeability of the collecting duct to water so that more water is reabsorbed into the body by inserting aquaporins, or water channels, in the apical membrane. Without this water reabsorption, the body would quickly dehydrate.

Thus, our kidneys tightly regulate the amount of water and solutes excreted to maintain water balance in the body. If water intake is down, or if there has been a fluid loss from the body, the kidneys work to conserve water by making the urine very hyperosmotic (having a relatively high solute concentration) to the blood. If there has been a large intake of fluid, the urine is more hypo-osmotic. In the normal individual, urine osmolarity varies from 50 to 1200 milliosmoles/kg water.

Equipment Used

- Simulated nephron surrounded by interstitial space between the nephron and peritubular capillaries (Reabsorbed solutes, such as glucose, will move from the lumen of the tubule, into the interstitial space, and then into the peritubular capillaries that branch out from the efferent arteriole.)
- Drain beaker for filtrate—simulates the urinary bladder
- Aldosterone

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- Antidiuretic hormone (ADH)

Introduction

Reabsorption is the movement of filtered solutes and water from the lumen of the renal tubules back into the plasma. Without reabsorption, we would excrete the solutes and water that our bodies require for homeostasis.

Glucose is not very large and is therefore easily filtered out of the plasma into Bowman's capsule as part of the filtrate. To ensure that glucose is reabsorbed into the body so that it can fuel cellular metabolism, glucose **carrier proteins** are present in the proximal tubule cells of the nephron (view Figure 9.4). There are a finite number of these glucose carriers in each renal tubule cell. Therefore, if too much glucose is present in the filtrate, it will not all be reabsorbed and glucose will be inappropriately excreted into the urine.

Glucose is first absorbed by **secondary active transport** at the **apical membrane** of proximal tubule cells and then it leaves the tubule cell via **facilitated diffusion** along the **basolateral membrane** (view Figure 9.4). Both types of carrier proteins that transport these molecules across the tubule membranes are transmembrane proteins. Because carrier proteins are needed to move glucose from the lumen of the nephron into the interstitial spaces, there is a limit to the amount of glucose that can be reabsorbed. When all glucose carriers are bound with the glucose they are transporting, excess glucose in the filtrate is eliminated in urine.

In this activity you will examine the effect of varying the number of glucose transport proteins in the *proximal convoluted tubule*. It is important to note that, normally, the number of glucose

Introduction

carriers is constant in a human kidney and that it is the plasma glucose that varies during the day. Plasma glucose will be held constant in this activity, and the number of glucose carriers will be varied.

Equipment Used

- Simulated nephron surrounded by interstitial space between the nephron and peritubular capillaries (Reabsorbed solutes, such as glucose, will move from the lumen of the tubule, into the interstitial space, and then into the peritubular capillaries that branch out from the efferent arteriole.)
- Drain beaker for filtrate—simulates the urinary bladder
- Glucose carrier protein control box—used to adjust the number of glucose carriers that will be inserted into the proximal tubule

Overview

Exercise Overview

Renal System Physiology

The **kidney** is *both* an excretory and a regulatory organ. By filtering the water and solutes in the blood, the kidneys are able to *excrete* excess water, waste products, and even foreign materials from the body. However, the kidneys also *regulate* (1) plasma osmolarity (the concentration of a solution expressed as osmoles of solute per liter of solvent), (2) plasma volume, (3) the body's acid-base balance, and (4) the body's electrolyte balance. All these activities are extremely important for maintaining homeostasis in the body.

The paired kidneys are located between the posterior abdominal wall and the abdominal peritoneum. The right kidney is slightly lower than the left kidney. Each human kidney contains approximately one million **nephrons**, the functional units of the kidney.

Each nephron is composed of a **renal corpuscle** and a **renal tubule**. The renal corpuscle consists of a "ball" of capillaries, called the *glomerulus*, which is enclosed by a fluid-filled capsule, called *Bowman's capsule,* or the glomerular capsule. An **afferent arteriole** supplies blood to the glomerulus. As blood flows through the glomerular capillaries, protein-free plasma filters into the Bowman's capsule, a process called **glomerular filtration**. An **efferent arteriole** then drains the glomerulus of the remaining blood (view Figure 9.1)

The filtrate flows from Bowman's capsule into the start of the renal tubule, called the **proximal convoluted tubule**, then into the **loop of Henle**, a U-shaped hairpin loop, and,

Exercise Overview

finally, into the **distal convoluted tubule** before emptying into a **collecting duct**. From the collecting duct, the filtrate flows into, and collects in, the minor calyces.

The nephron performs three important functions that process blood into filtrate and urine: (1) glomerular filtration, (2) tubular reabsorption, and (3) tubular secretion (view Figure 9.2). **Glomerular filtration** is a passive process in which fluid passes from the lumen of the glomerular capillary into the glomerular capsule of the renal tubule. **Tubular reabsorption** moves most of the filtrate back into the blood, leaving mainly saltwater and the wastes in the lumen of the tubule. Some of the desirable, or needed, solutes are actively reabsorbed, and others move passively from the lumen of the tubule into the interstitial spaces. **Tubular secretion** is essentially the reverse of tubular reabsorption and is a process by which the kidneys can rid the blood of additional unwanted substances, such as creatinine and ammonia.

The reabsorbed solutes and water that move into the interstitial space between the nephrons need to be returned to the blood, or the kidneys will rapidly swell like balloons. The **peritubular capillaries** surrounding the renal tubule reclaim the reabsorbed substances and return them to general circulation. Peritubular capillaries arise from the efferent arteriole exiting the glomerulus and empty into the renal veins leaving the kidney.

Introduction

Each of the million **nephrons** in each kidney contains two major parts: (1) a tubular component, the **renal tubule**, and (2) a vascular component, the **renal corpuscle** (view Figure 9.1). The **glomerulus** is a tangled capillary knot that filters fluid from the blood into the lumen of the renal tubule. The function of the renal tubule is to process the filtered fluid, also called the **filtrate**. The beginning of the renal tubule is an enlarged end called **Bowman's capsule** (or the glomerular capsule), which surrounds the glomerulus and serves to funnel the filtrate into the rest of the renal tubule. Collectively, the glomerulus and Bowman's capsule are called the renal corpuscle.

Two arterioles are associated with each glomerulus: an **afferent arteriole** feeds the **glomerular capillary** bed and an **efferent arteriole** drains it. These arterioles are responsible for blood flow through the glomerulus (view Figure 9.2). The diameter of the efferent arteriole is smaller than the diameter of the afferent arteriole, restricting blood flow out of the glomerulus. Consequently, the pressure in the glomerular capillaries forces fluid through the endothelium of the capillaries into the lumen of the surrounding Bowman's capsule. In essence, everything in the blood except for the blood cells (red and white) and plasma proteins is filtered through the glomerular wall. From the Bowman's capsule, the filtrate moves into the rest of the renal tubule for processing. The job of the tubule is to reabsorb all the beneficial substances from its lumen and allow the wastes to travel down the tubule for elimination from the body.

During glomerular filtration, blood enters the glomerulus from the afferent arteriole and

Introduction

protein-free plasma flows from the blood across the walls of the glomerular capillaries and into the Bowman's capsule. The **glomerular filtration rate** is an index of kidney function. In humans, the filtration rate ranges from 80 to 140 ml/min, so that, in 24 hours, as much as 180 liters of filtrate is produced by the glomeruli. The filtrate formed is devoid of cellular debris, is essentially protein free, and contains a concentration of salts and organic molecules similar to that in blood.

The glomerular filtration rate can be altered by changing arteriole resistance or arteriole hydrostatic pressure. In this activity, you will explore the effect of arteriole radius on glomerular capillary pressure and filtration in a single nephron. You can apply the concepts you learn by studying a single nephron to understand the function of the kidney as a whole.

Equipment Used

- Source beaker for blood (first beaker on left side of screen)—simulates blood flow and pressure (mm Hg) from general circulation to the nephron
- Drain beaker for blood (second beaker on left side of screen)—simulates the renal vein
- Flow tube with adjustable radius—simulates the afferent arteriole and connects the blood supply to the glomerular capillaries
- Second flow tube with adjustable radius—simulates the efferent arteriole and drains the glomerular capillaries into the peritubular capillaries, which ultimately drain into the renal

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vein (drain beaker).

- Simulated nephron (The filtrate forms in Bowman's capsule, flows through the renal tubule—the tubular components, and empties into a collecting duct, which, in turn, drains into the urinary bladder.)
  - Nephron tank
  - Glomerulus—"ball" of capillaries that forms part of the filtration membrane
  - Glomerular (Bowman's) capsule—forms part of the filtration membrane and a capsular space where the filtrate initially forms
  - Proximal convoluted tubule
  - Loop of Henle
  - Distal convoluted tubule
  - Collecting duct
- Drain beaker for filtrate (beaker on right side of screen)—simulates the urinary bladder

Introduction

Cellular metabolism produces a complex mixture of waste products that must be eliminated from the body. This excretory function is performed by a combination of organs, most importantly, the paired kidneys. Each kidney consists of approximately one million nephrons, which carry out three crucial processes: (1) glomerular filtration, (2) tubular reabsorption, and (3) tubular secretion.

Both the blood pressure in the **glomerular capillaries** and the **filtrate** pressure in the **renal tubule** can have a significant impact on the **glomerular filtration rate**. During glomerular filtration, blood enters the **glomerulus** from the **afferent arteriole**. **Starling forces** (hydrostatic and osmotic pressure gradients) drive protein-free fluid between the blood in the glomerular capillaries and the filtrate in **Bowman's capsule**. The glomerular filtration rate is an index of kidney function. In humans, the filtration rate ranges from 80 to 140 ml/min, so that, in 24 hours, as much as 180 liters of filtrate is produced by the glomerular capillaries. The filtrate formed is devoid of blood cells, is essentially protein free, and contains a concentration of salts and organic molecules similar to that in blood.

Approximately 20% of the blood that enters the glomerular capillaries is normally filtered into Bowman's capsule, where it is then referred to as filtrate. The unusually high hydrostatic blood pressure in the glomerular capillaries promotes this filtration. Thus, the glomerular filtration rate can be altered by changing the afferent arteriole resistance (and, therefore, the hydrostatic pressure). In this activity you will explore the effect of blood pressure on the glomerular

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filtration rate in a single nephron. You can apply the concepts you learn by studying a single nephron to understand the function of the kidney as a whole.

Equipment Used

- Left source beaker (first beaker on left side of screen)—simulates blood flow and pressure (mm Hg) from general circulation to the nephron
- Drain beaker for blood (second beaker on left side of screen)—simulates the renal vein
- Flow tube with adjustable radius—simulates the afferent arteriole and connects the blood supply to the glomerular capillaries
- Second flow tube with adjustable radius—simulates the efferent arteriole and drains the glomerular capillaries into the peritubular capillaries, which ultimately drain into the renal vein (drain beaker).
- Simulated nephron (The filtrate forms in Bowman's capsule, flows through the renal tubule—the tubular components, and empties into a collecting duct, which, in turn, drains into the urinary bladder.)
  - Nephron tank
  - Glomerulus—"ball" of capillaries that forms part of the filtration membrane
  - Glomerular (Bowman's) capsule—forms part of the filtration membrane and a capsular space where the filtrate initially forms
  - Proximal convoluted tubule

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  - Loop of Henle
  - Distal convoluted tubule
  - Collecting duct
- One-way valve between end of collecting tube (duct) and urinary bladder—used to restrict the flow of filtrate into the urinary bladder, increasing the volume and pressure in the renal tubule
- Drain beaker for filtrate (beaker on right side of screen)—simulates the urinary bladder

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In humans approximately 180 liters of filtrate flows into the **renal tubules** every day. As demonstrated in Activity 2, the **blood pressure** supplying the **nephron** can have a substantial impact on the **glomerular capillary pressure** and **glomerular filtration**. However, under most circumstances, glomerular capillary pressure and glomerular filtration remain relatively constant despite changes in blood pressure because the nephron has the capacity to alter its **afferent** and **efferent arteriole** radii.

During glomerular filtration, blood enters the **glomerulus** from the afferent arteriole. **Starling forces** (primarily hydrostatic pressure gradients) drive protein-free fluid out of the glomerular capillaries and into **Bowman's capsule**. Importantly for our body's homeostasis, a relatively constant glomerular filtration rate of 125 ml/min is maintained despite a wide range of blood pressures that occur throughout the day for an average human.

Activities 1 and 2 explored the independent effects of arteriole radii and blood pressure on glomerular capillary pressure and glomerular filtration. In the human body, these effects occur simultaneously. Therefore, in this activity, you will alter both variables to explore their combined effects on glomerular filtration and observe how changes in one variable can compensate for changes in the other to maintain an adequate glomerular filtration rate.

Equipment Used

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- Source beaker for blood (first beaker on left side of screen)—simulates blood flow and pressure (mm Hg) from general circulation to the nephron
- Drain beaker for blood (second beaker on left side of screen)—simulates the renal vein
- Flow tube with adjustable radius—simulates the afferent arteriole and connects the blood supply to the glomerular capillaries
- Second flow tube with adjustable radius—simulates the efferent arteriole and drains the glomerular capillaries into the peritubular capillaries, which ultimately drain into the renal vein (drain beaker).
- Simulated nephron (The filtrate forms in Bowman's capsule, flows through the renal tubule—the tubular components, and empties into a collecting duct, which, in turn, drains into the urinary bladder.)
  - Nephron tank
  - Glomerulus—"ball" of capillaries that forms part of the filtration membrane
  - Glomerular (Bowman's) capsule—forms part of the filtration membrane and a capsular space where the filtrate initially forms
  - Proximal convoluted tubule
  - Loop of Henle
  - Distal convoluted tubule
  - Collecting duct
  - Drain beaker for filtrate (beaker on right side of screen)—simulates the urinary bladder

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As filtrate moves through the tubules of a nephron, solutes and water move *from* the **tubule lumen** into the **interstitial spaces** of the nephron. This movement of solutes and water relies on the total solute concentration gradient in the interstitial spaces surrounding the tubule lumen. The interstitial fluid is comprised mostly of NaCl and urea. When the nephron is permeable to solutes or water, equilibrium will be reached between the interstitial fluid and the tubular fluid contents.

Antidiuretic hormone (**ADH**) increases the water permeability of the **collecting duct**, allowing water to flow to areas of higher solute concentration, from the tubule lumen into the surrounding interstitial spaces (view Figure 9.3). **Reabsorption** describes this movement of filtered solutes and water from the lumen of the renal tubules back into the plasma. The reabsorbed solutes and water that move into the interstitial space need to be returned to the blood, or the kidneys will rapidly swell like balloons. The **peritubular capillaries** surrounding the renal tubule reclaim the reabsorbed substances and return them to general circulation. Peritubular capillaries arise from the efferent arteriole exiting the glomerulus and empty into the renal veins leaving the kidney.

Without reabsorption, we would excrete the solutes and water that our bodies need to maintain homeostasis. In this activity you will examine the process of passive reabsorption that occurs while filtrate travels through a nephron and urine is formed. While completing the experiment, assume that, when ADH is present, the conditions favor the formation of the most concentrated

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urine possible.

Equipment Used

- Simulated nephron surrounded by interstitial space between the nephron and peritubular capillaries (Reabsorbed solutes, such as glucose, will move from the lumen of the tubule, into the interstitial space, and then into the peritubular capillaries that branch out from the efferent arteriole.)
- Drain beaker for filtrate—simulates the urinary bladder
- Antidiuretic hormone (ADH)

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The concentration and volume of urine excreted by our kidneys will change depending on what our body needs for homeostasis. For example, if a person consumes a large quantity of water, the excess water will be eliminated as a large volume of dilute urine. On the other hand, when dehydration occurs, there is a clear benefit in being able to produce a small volume of concentrated urine to retain water. Activity 4 demonstrated how the total solute concentration gradient in the interstitial spaces surrounding the tubule lumen makes it possible to excrete concentrated urine.

Aldosterone is a hormone produced by the adrenal cortex under the control of the body's *renin-angiotensin system*. A decrease in blood pressure is detected by cells in the afferent arteriole, triggering the release of renin. Renin acts as a proteolytic enzyme, causing angiotensinogen to be converted into angiotensin I. Endothelial cells throughout the body possess a *converting enzyme* that converts angiotensin I into angiotensin II. Angiotensin II signals the adrenal cortex to secrete aldosterone (view Figure 9.5). Aldosterone acts on the distal convoluted tubule cells in the nephron to promote the reabsorption of sodium from filtrate *into* the body and the secretion of potassium *from* the body. This electrolyte shift, coupled with the addition of **antidiuretic hormone** (**ADH**), also causes more water to be reabsorbed into the blood, resulting in increased blood pressure.

ADH is manufactured by the hypothalamus and stored in the posterior pituitary gland. ADH levels are influenced by the osmolality of body fluids and the volume and pressure of the

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cardiovascular system. A 1% change in body osmolality will cause this hormone to be secreted. The primary action of this hormone is to increase the permeability of the collecting duct to water so that more water is reabsorbed into the body by inserting aquaporins, or water channels, in the apical membrane. Without this water reabsorption, the body would quickly dehydrate.

Thus, our kidneys tightly regulate the amount of water and solutes excreted to maintain water balance in the body. If water intake is down, or if there has been a fluid loss from the body, the kidneys work to conserve water by making the urine very hyperosmotic (having a relatively high solute concentration) to the blood. If there has been a large intake of fluid, the urine is more hypo-osmotic. In the normal individual, urine osmolarity varies from 50 to 1200 milliosmoles/kg water.

Equipment Used

- Simulated nephron surrounded by interstitial space between the nephron and peritubular capillaries (Reabsorbed solutes, such as glucose, will move from the lumen of the tubule, into the interstitial space, and then into the peritubular capillaries that branch out from the efferent arteriole.)
- Drain beaker for filtrate—simulates the urinary bladder
- Aldosterone

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- Antidiuretic hormone (ADH)

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Reabsorption is the movement of filtered solutes and water from the lumen of the renal tubules back into the plasma. Without reabsorption, we would excrete the solutes and water that our bodies require for homeostasis.

Glucose is not very large and is therefore easily filtered out of the plasma into Bowman's capsule as part of the filtrate. To ensure that glucose is reabsorbed into the body so that it can fuel cellular metabolism, glucose **carrier proteins** are present in the proximal tubule cells of the nephron (view Figure 9.4). There are a finite number of these glucose carriers in each renal tubule cell. Therefore, if too much glucose is present in the filtrate, it will not all be reabsorbed and glucose will be inappropriately excreted into the urine.

Glucose is first absorbed by **secondary active transport** at the **apical membrane** of proximal tubule cells and then it leaves the tubule cell via **facilitated diffusion** along the **basolateral membrane** (view Figure 9.4). Both types of carrier proteins that transport these molecules across the tubule membranes are transmembrane proteins. Because carrier proteins are needed to move glucose from the lumen of the nephron into the interstitial spaces, there is a limit to the amount of glucose that can be reabsorbed. When all glucose carriers are bound with the glucose they are transporting, excess glucose in the filtrate is eliminated in urine.

In this activity you will examine the effect of varying the number of glucose transport proteins in the *proximal convoluted tubule*. It is important to note that, normally, the number of glucose

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carriers is constant in a human kidney and that it is the plasma glucose that varies during the day. Plasma glucose will be held constant in this activity, and the number of glucose carriers will be varied.

Equipment Used

- Simulated nephron surrounded by interstitial space between the nephron and peritubular capillaries (Reabsorbed solutes, such as glucose, will move from the lumen of the tubule, into the interstitial space, and then into the peritubular capillaries that branch out from the efferent arteriole.)
- Drain beaker for filtrate—simulates the urinary bladder
- Glucose carrier protein control box—used to adjust the number of glucose carriers that will be inserted into the proximal tubule