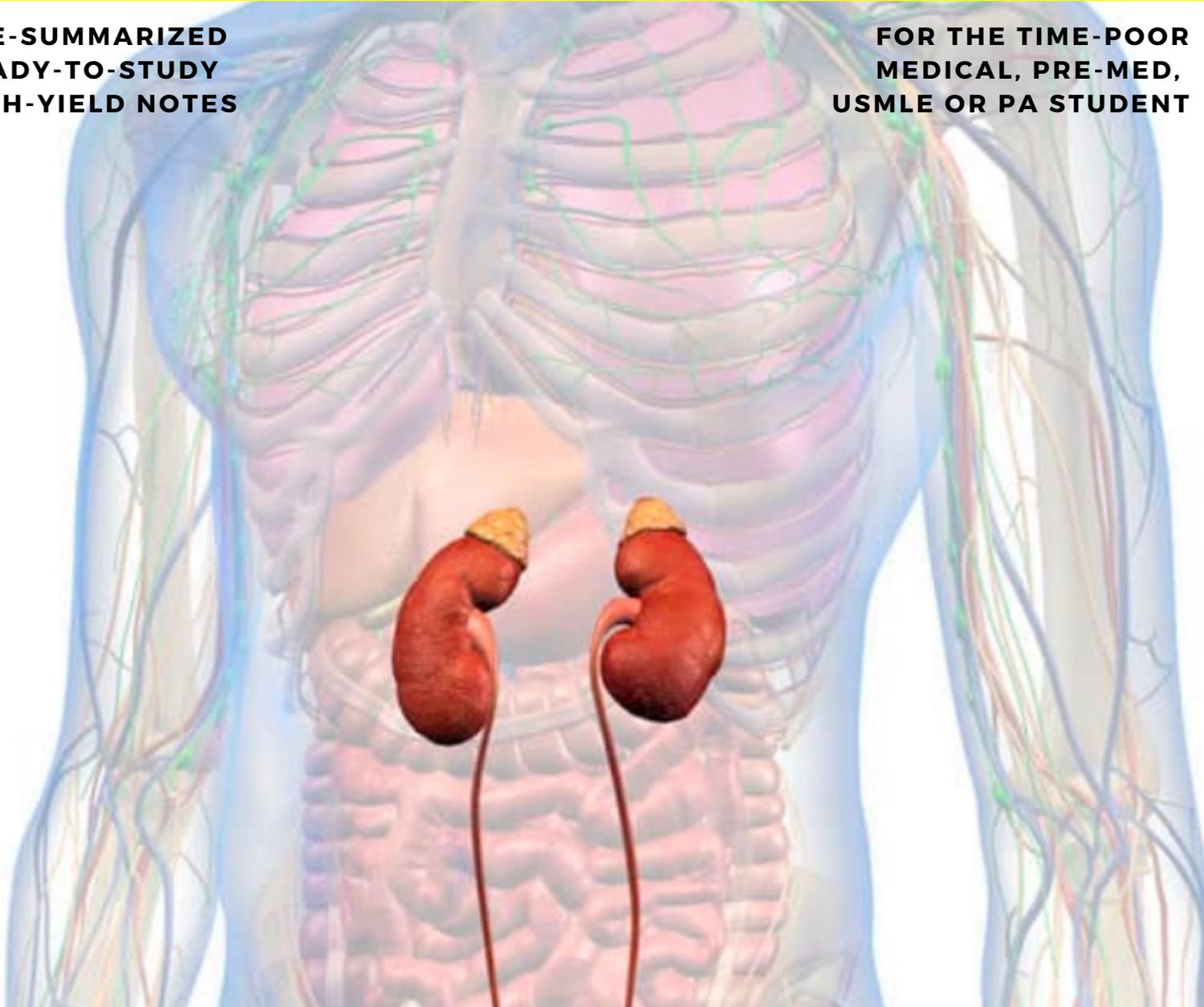


ANATOMY, PHYSIOLOGY & PATHOLOGY NOTES OF THE **URINARY/RENAL** SYSTEM

FOURTH EDITION

PRE-SUMMARIZED
READY-TO-STUDY
HIGH-YIELD NOTES

FOR THE TIME-POOR
MEDICAL, PRE-MED,
USMLE OR PA STUDENT



133 PAGES



A Message From Our Team

Studying medicine or any health-related degree can be stressful; believe us, we know from experience! The human body is an incredibly complex organism, and finding a way to streamline your learning is crucial to succeeding in your exams and future profession. Our goal from the outset has been to create the greatest educational resource for the next generation of medical students, and to make them as affordable as possible.

In this fourth edition of our notes we have made a number of text corrections, formatting updates, and figure updates which we feel will enhance your study experience. We have also endeavoured to use only open-source images and/or provide attribution where possible.

If you are new to us, here are a few things to help get the most out of your notes:

- 1. Once saved, the notes are yours for life!** However, we strongly advise that you download and save the files immediately upon purchasing for permanent offline access.
- 2. Sharing notes is prohibited.** All files are share-protected and our system will automatically revoke access to and lock files if it detects a customer attempting to share or distribute our notes.
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What's included: Ready-to-study anatomy, physiology and pathology notes of the **Genitourinary System** presented in succinct, intuitive and richly illustrated downloadable PDF documents. Once downloaded, you may choose to either print and bind them, or make annotations digitally on your iPad or tablet PC.

Anatomy & Physiology Notes:

- FUNCTIONAL ANATOMY OF THE URINARY SYSTEM
- RENAL PHYSIOLOGY
 - STEP 1 – GLOMERULAR FILTRATION
 - STEP 2 – TUBULAR REABSORPTION
 - STEP 3 – TUBULAR SECRETION
- MICTURITION REFLEX (URINATION)
- ROLE OF THE KIDNEYS IN FLUID & ELECTROLYTE BALANCE
- FLUID BALANCE
- ELECTROLYTE BALANCE

Pathology Notes:

- GENERAL OVERVIEW OF RENAL PATHOLOGY
- CONGENITAL KIDNEY ABNORMALITIES
 - CYSTIC DISEASES OF THE KIDNEY (Eg: **POLYCYSTIC KIDNEY DISEASE**)
- URINARY INCONTINENCE
- ACUTE RENAL FAILURES
- PRE-RENAL FAILURES
 - **RENAL ARTERY STENOSIS**
 - **RENAL CORTICAL NECROSIS**
- INTRA-RENAL FAILURES
 - **GLOMERULONEPHRITIS**
- NEPHROTIC SYNDROMES
 - **MCD – MINIMAL CHANGE DISEASE (“FOOT PROCESS DISEASE” / “NIL DISEASE”)**
 - **MGN – MEMBRANOUS GLOMERULONEPHRITIS**
 - **FSGS – FOCAL SEGMENTAL GLOMERULOSCLEROSIS**
 - **NEPHROSCLEROSIS**
 - **DIABETIC NEPHROPATHY**
 - **SLE – LUPUS NEPHRITIS**
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 - **IGA NEPHROPATHY (“BERGER’S DISEASE”)**
 - **HEMOLYTIC-UREMIC SYNDROME (HUS)**
 - **RPGN – RAPIDLY PROGRESSIVE GLOMERULONEPHRITIS**
- TUBULO-INTERSTITIAL DISEASES
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- RENAL SYSTEM CANCERS
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 - **WILM’S TUMOUR / “NEPHROBLASTOMA”**
 - **TRANSITIONAL CELL CARCINOMAS**
- URINARY & KIDNEY INFECTIONS
 - **PYELONEPHRITIS:**
 - **URINARY TRACT INFECTIONS / (“CYSTITIS”)**
 - **RENAL AND PERINEPHRIC ABSCESS**

- ELECTROLYTE IMBALANCES
- FLUID IMBALANCES
- DIURETICS
- DRUGS ALTERING THE pH URINE
- POPULATION HEALTH & RENAL DISEASE
- MISCELLANEOUS POINTS
- UROGENIC PAIN
- CATHETERIZATION
- URINE ANALYSIS
- MCQS - URINARY TRACT DISEASE

FUNCTIONAL ANATOMY OF THE URINARY SYSTEM

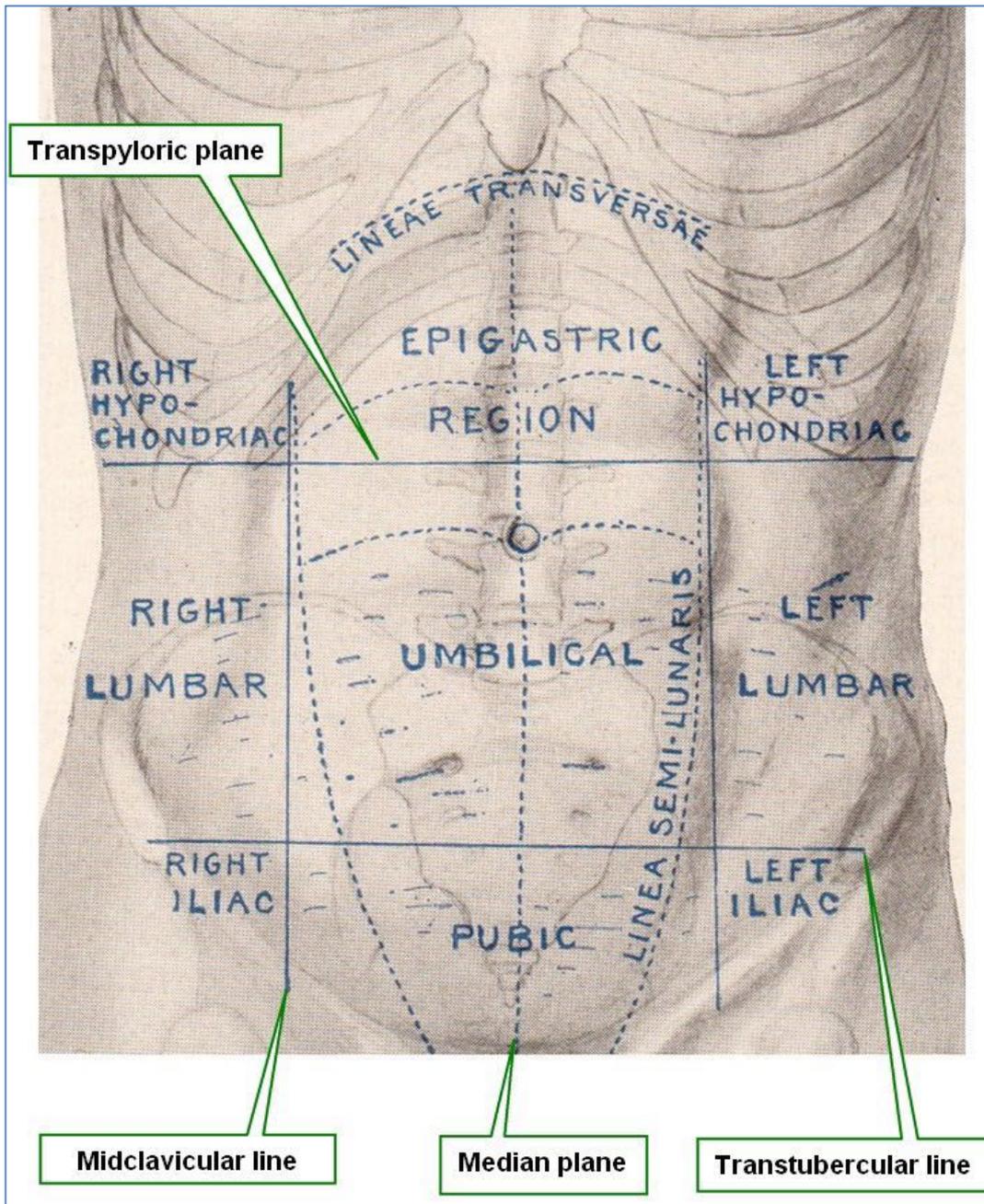
FUNCTIONAL ANATOMY OF THE URINARY SYSTEM

Urinary System - General Functions:

- Filter blood (Through "Ultrafiltration" – A filtration process using a porous membrane to remove particles, bacteria & viruses)
- Disposal of Metabolic Wastes & Drugs
- Regulate Water Balance
- Regulate Electrolyte Balance
- Regulate Body Fluid Osmolality & Electrolyte Concentrations
- Store & Eliminate Urine
- Maintain Blood Volume
- Regulate Acid/Base Balance (in Conjunction with Respiratory System)
- Regulate Arterial Blood Pressure
- Reproduction (Males)
- Endocrine Function – Excretion of Hormones
- Gluconeogenesis (Eg: From Amino Acids)

Surface Projections:

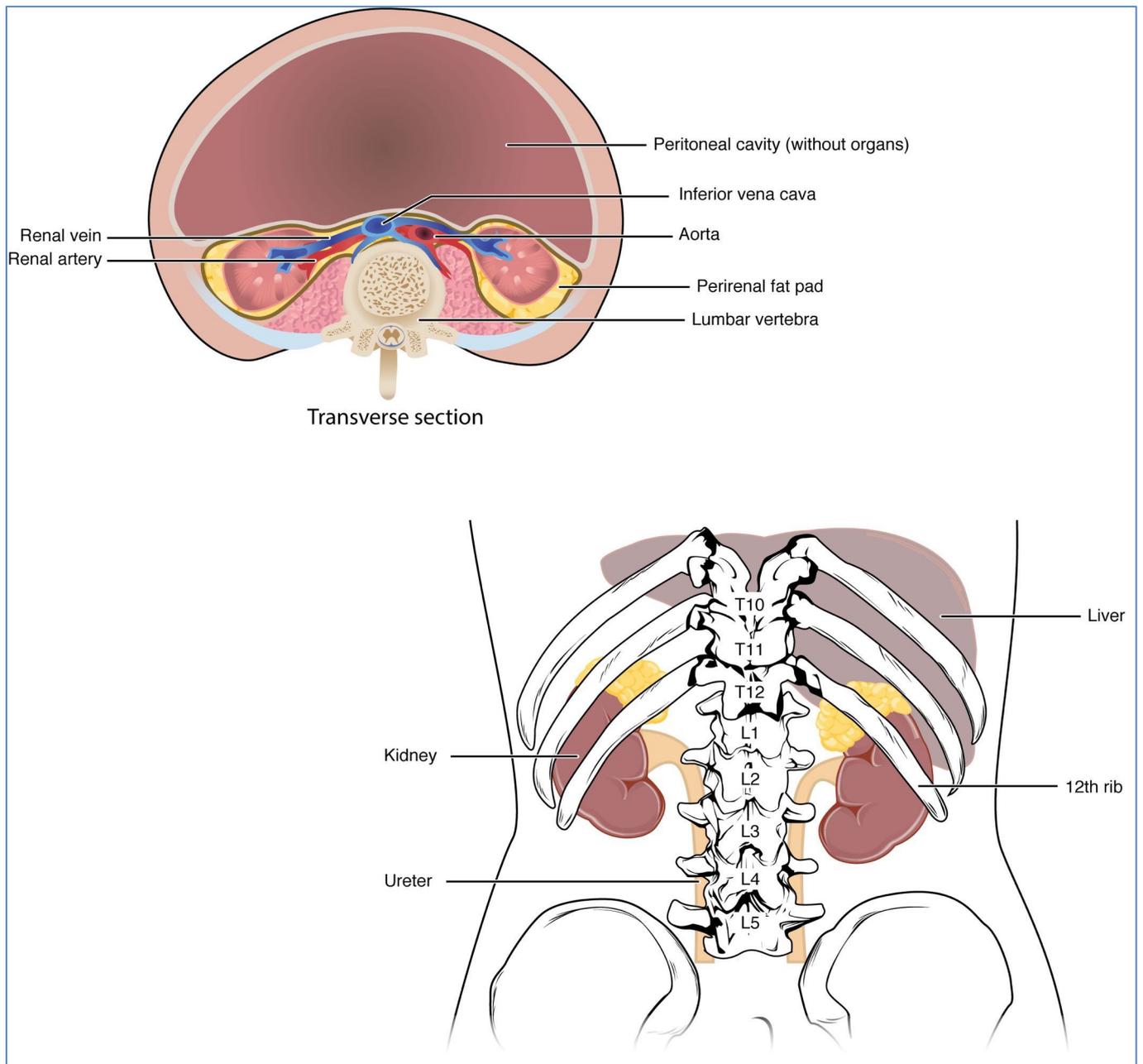
- **Transpyloric Plane (Transverse line @ T12):**
 - o Hilum of L-Kidney
 - o Superior Pole of R-Kidney
- **Median Line (Midline):**
 - o Hilum of Kidneys ≈ 5cm from Midline
 - o Slightly Splayed Outwards (further from midline at inferior pole)
 - o Ureters ≈ 5cm from Midline
- **Height:**
 - o Kidneys lie just deep to Ribs 11 & 12.
 - o Kidneys move up/down 2-3cm during deep breathing.
 - o Inferior Pole of R-Kidney = a finger's breadth superior to Iliac Crest
- **Right Vs. Left:**
 - o Left = Higher than Right
 - o Right = Lower (The Palpable One)
 - o (by ≈2.5 cm)
 - o Due to liver (invades R-Abdomen)
 - o Left Renal Artery – Shorter than Right (as Aorta lies to left of midline)
 - o Left Renal Vein – Longer than Right (as IVC lies to right of midline)
- **Dimensions:**
 - o 12 cm Long
 - o 3-4 cm Thick
 - o 5-6 cm Wide



Unattributable

Position of Kidneys Within Abdomen:

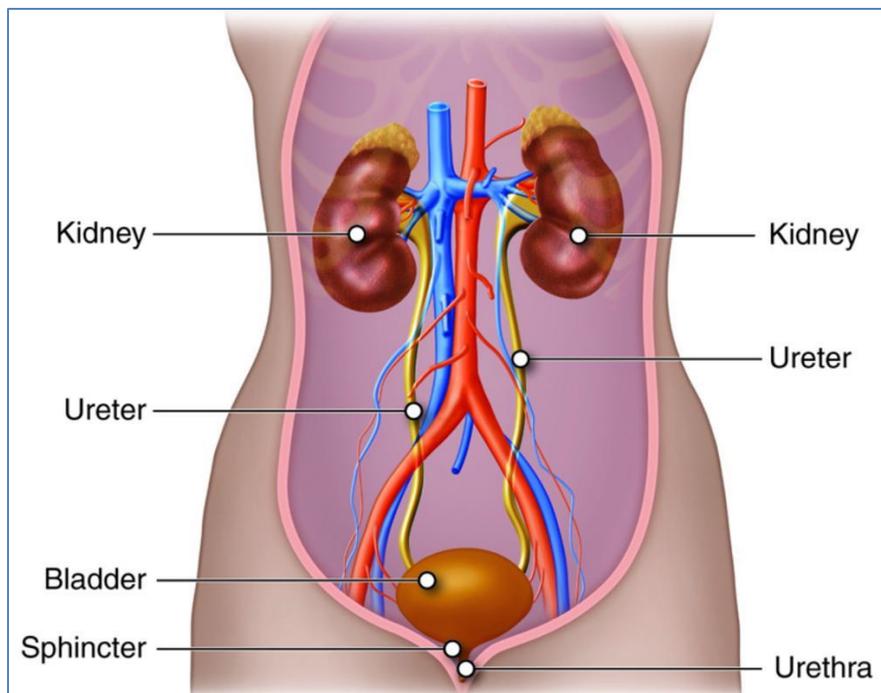
- Retroperitoneal
- Spleen on Lateral Border of L-Kidney
- Adrenal Glands on Superior Poles of Both Kidneys
- Pancreas on Anterior Margin of L-Kidney
- Duodenum on Anterior Margin of R-Kidney
- Liver on Superior Aspects of Both Kidneys
- Ascending Colon Anterior To R-Kidney
- Descending Colon Anterior To L-Kidney



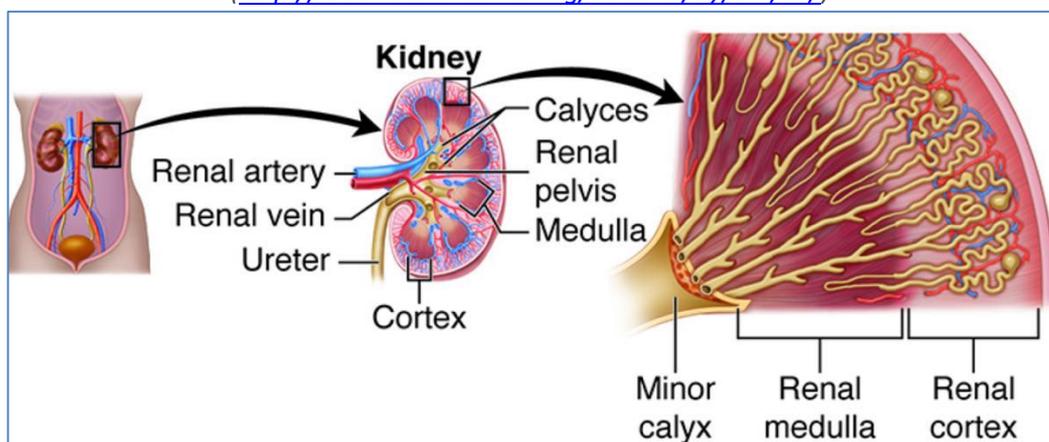
<https://open.oregonstate.edu/aandp/chapter/25-1-internal-and-external-anatomy-of-the-kidney/>

Functional Components:

- **Kidneys:**
 - Filter Blood
 - Produce Urine
 - Blood pH/Volume/Pressure Homeostasis
- **Renal Veins:**
 - Anterior
 - Drain Blood From Kidneys
- **Renal Arteries:**
 - Supply Blood to Kidneys
 - Between Vein & Hilum
- **Renal Hilums (“Opening”):**
 - Beginning of Ureters
 - Posterior
- **Ureters:**
 - Transport Urine → Bladder
- **Bladder:**
 - Stores Urine
- **Urethra:**
 - Excretion of Urine



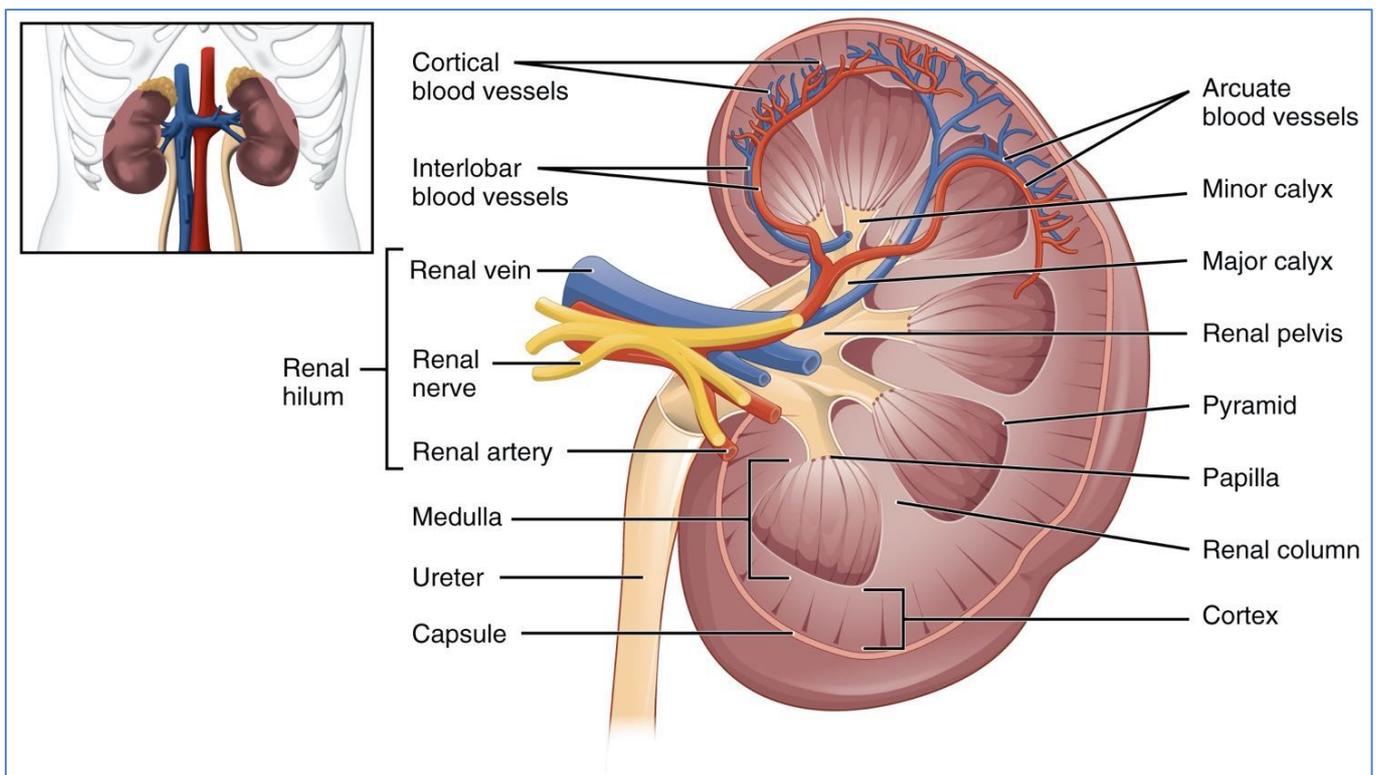
Urinary system organs. This work by Cenveo is licensed under a Creative Commons Attribution 3.0 United States (<http://creativecommons.org/licenses/by/3.0/us/>).



Internal structure of kidney. This work by Cenveo is licensed under a Creative Commons Attribution 3.0 United States (<http://creativecommons.org/licenses/by/3.0/us/>).

Macroscopic Anatomy of Kidneys:

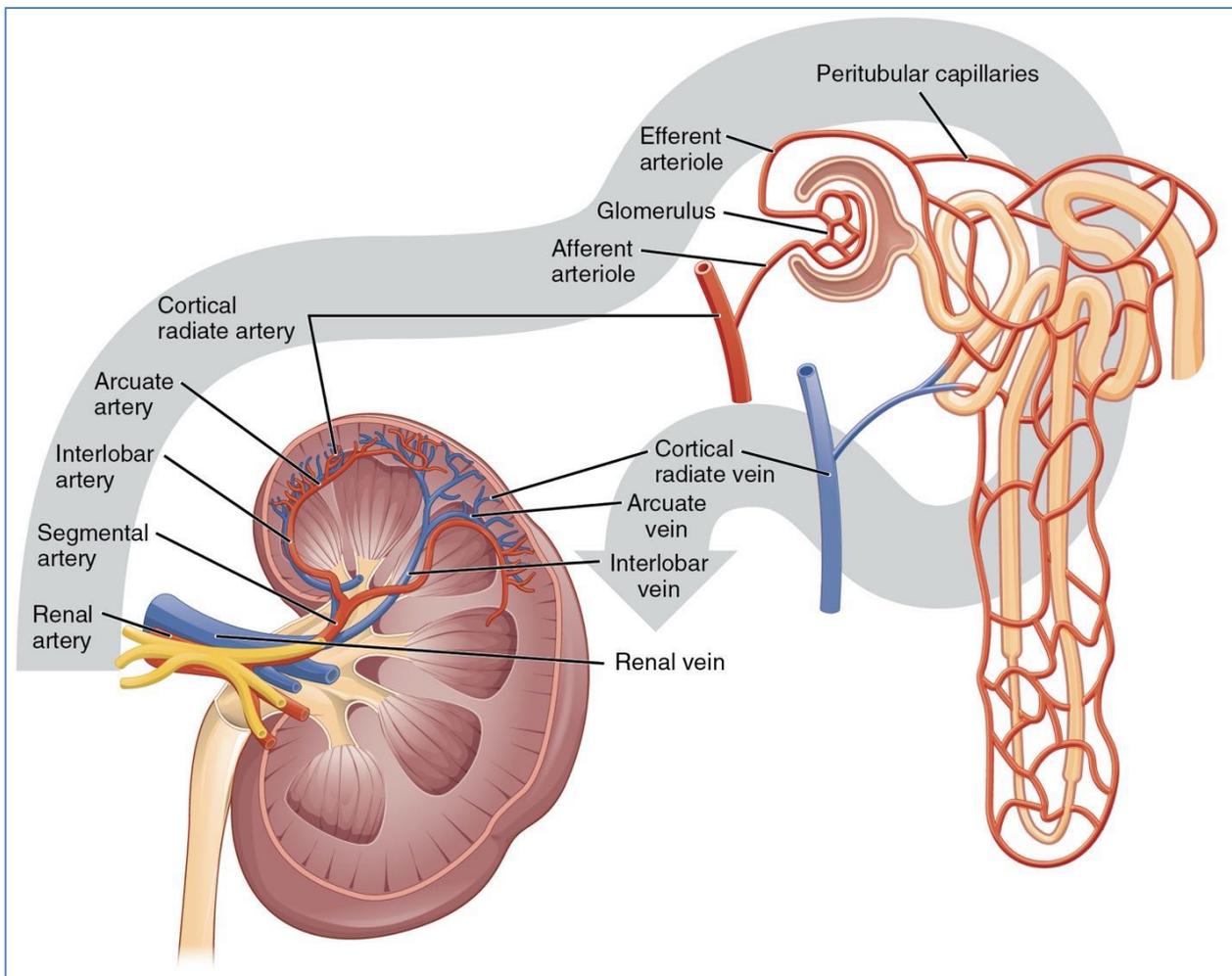
- **Encased In Fascia & Fat:**
 - o (Fat – Important in Stabilisation & protection)
- **Renal Capsule:**
 - o Tough, Fibrous layer surrounding the Kidney.
- **(Outer) Cortex:**
 - o Contains the Filtering Apparatus:
 - Blood Vessels
 - Renal Corpuscles
 - Renal Tubules (excluding the Loop of Henle – in Medulla)
- **(Inner) Medulla:**
 - o Contains the Major Blood Vessels
 - o Made up of Renal Pyramids & Columns
 - o Contains Collecting Ducts – Deliver Urine to Minor Calyces.
- **Renal Pyramids:**
 - o Cone-shaped tissues
 - o Formed by straight parallel segments of Nephrons.
- **Renal Lobes:**
 - o Portion consisting of a Renal Pyramid & the Renal Cortex Above.
- **Renal Columns:**
 - o Spaces between Renal Pyramids
 - o Contains Interlobar Blood Vessels
- **Renal Papilla:**
 - o Where the Collecting Ducts of the Medullary Pyramids empty Urine into the renal pelvis.
- **Minor Calyx (Calyces):**
 - o Transport Urine from Collecting Ducts → Major Calyces
- **Major Calyx (Calyces):**
 - o Transport Urine → Renal Pelvis
- **Renal Pelvis / Hilum:**
 - o Convergence of all Calyces & Connecting Ducts
 - o Becomes the Ureter as it Exits the Kidney.

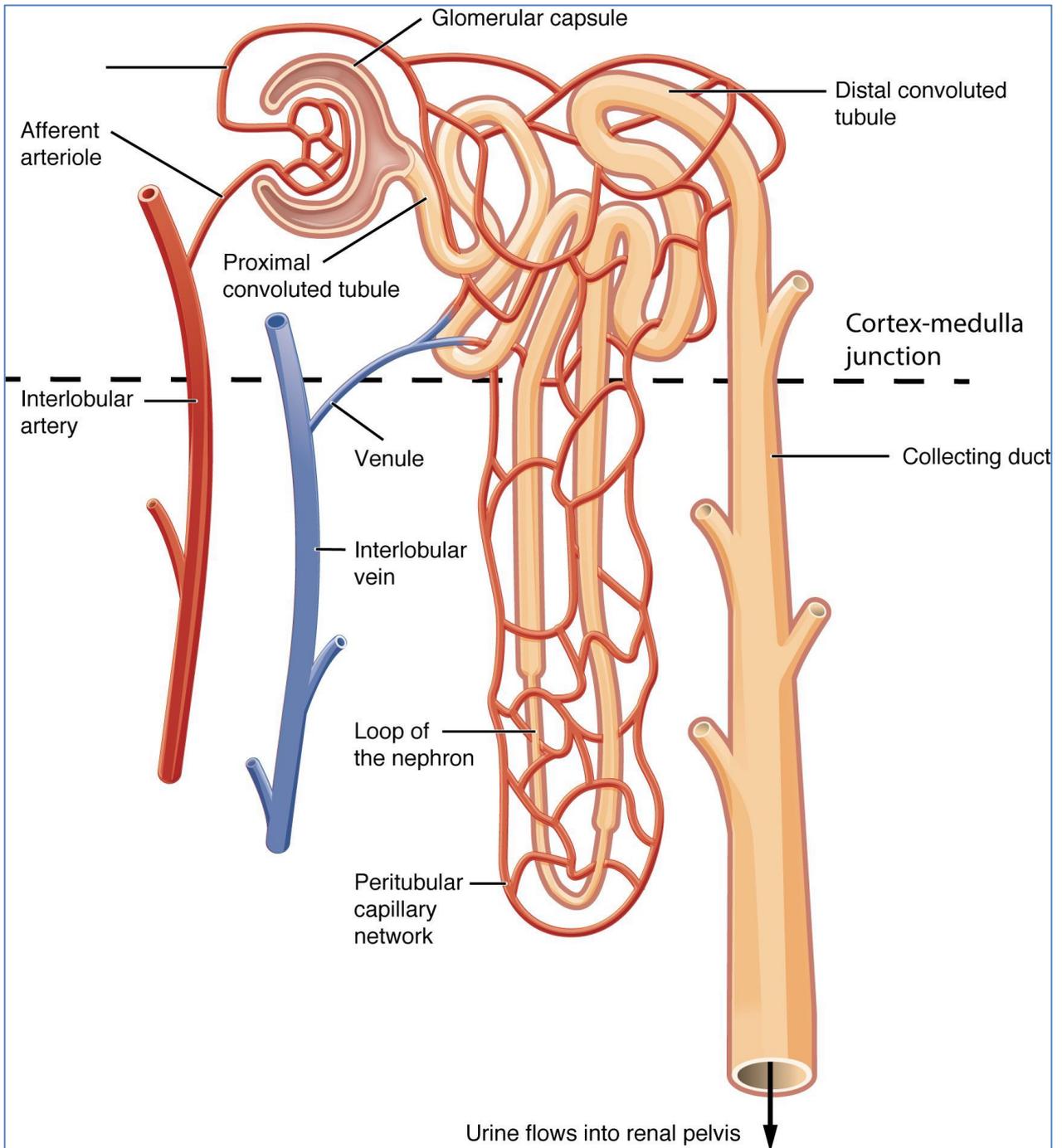


Microscopic Anatomy of Kidneys:

- Microvascular Supply:

- **Interlobar Arteries & Veins:**
 - Run up from the Medulla *Through* the Renal Columns
 - Each form an arc with Interlobular Arteries/Veins.
 - 'horseshoe bends'
- **Interlobular → Arcuate Arteries/Veins:**
 - Projections of the Interlobar Arteries/Veins into the Cortex.
 - 'little dead-end streets'
- **Afferent Arterioles:**
 - Carry blood from Interlobar Arteries → Corpuscle of the Nephron
 - 'driveways off little dead-end streets'
- **Renal Corpuscle:**
 - **The Glomerular Capillaries + Glomerular Capsule**
 - *Glomerular Capsule* = Little deeply-concaved membrane in which a convoluted mass of *Glomerular Capillaries* are bundled.
 - **Note:** Glomerular Capillaries are *Highly Fenestrated* → 'Leaky' → Aids in filtration.
 - Place of filtration
- **Efferent Arterioles:**
 - Carry blood away from the Corpuscles → Peritubular Capillaries
- **Peritubular Capillaries:**
 - Supply the rest of the Nephron (Renal Tubules & Ascending/Descending Limbs)
- **Venules:**
 - Drain filtered blood back to Inferior Vena Cava.
 - Peritubular Capillaries → Interlobular Venules → Arcuate Veins → Interlobar Veins → Segmental Veins → Renal Vein → IVC.

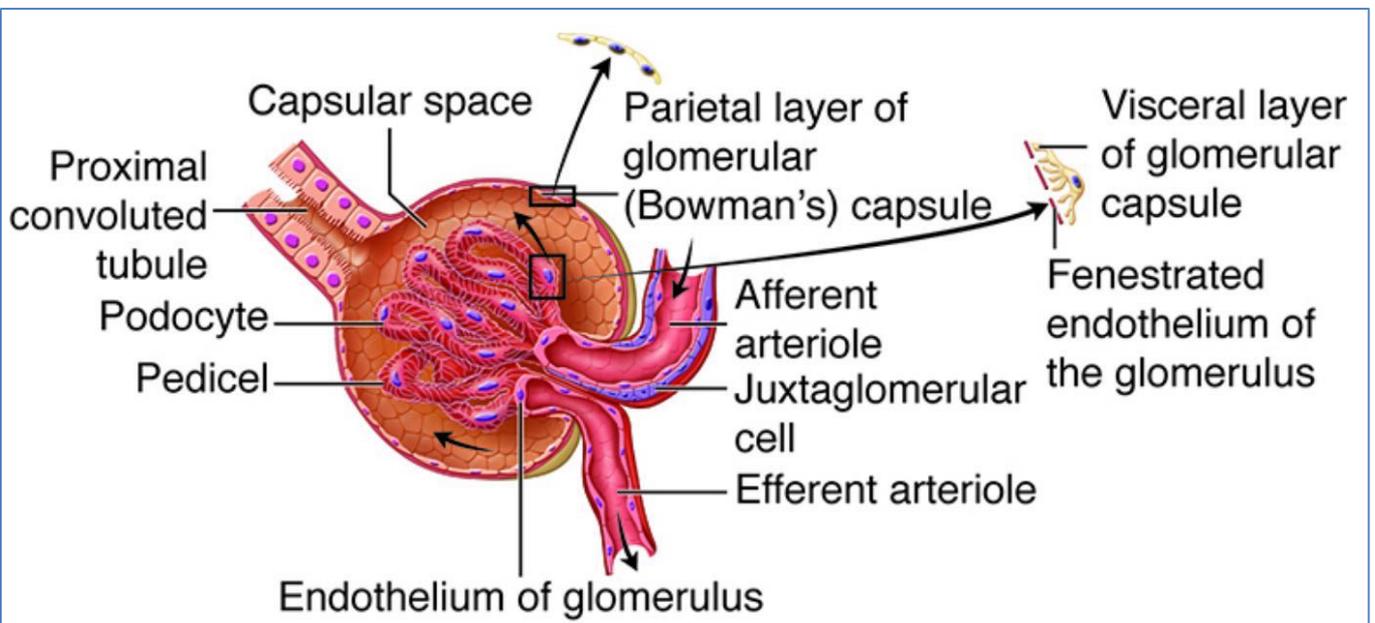




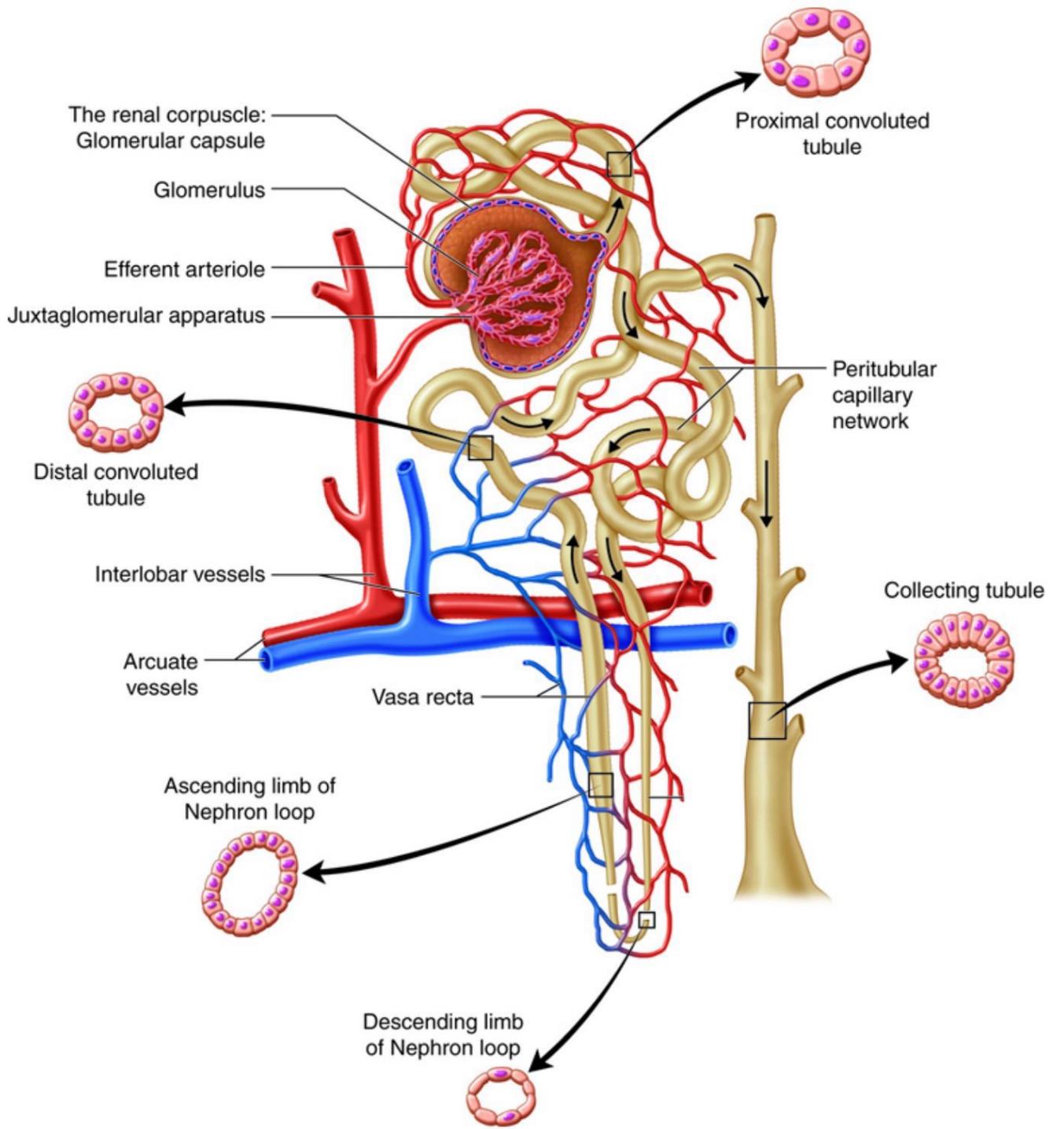
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- **The Nephron:**

- **Renal Corpuscle:**
 - **The Glomerular Capillaries + Glomerular Capsule**
 - *Glomerular Capsule* = Little deeply-concaved membrane in which a convoluted mass of *Glomerular Capillaries* are bundled.
 - Place of filtration
- **Renal Tubule:**
 - **Proximal Convoluted Tubule:**
 - Reabsorption of Water, ions & Organic Nutrients.
 - **Histology: Simple Cuboidal Epithelia with Microvilli** for bulk Reabsorption.
 - **Loop of Henle:**
 - **Descending Limb (Thick & Thin):**
 - Further Water Reabsorption
 - **Histology: Simple Squamous Epithelia** → H₂O Reabsorption only.
 - **Ascending Limb (Thin & Thick):**
 - Na⁺ Reabsorption
 - Cl⁻ Reabsorption
 - **Histology: Simple Cuboidal Epithelia** → Resorption of Ions.
 - **Distal Convoluted Tubule:**
 - Secretion of Ions, Acids, Drugs & toxins
 - Variable Reabsorption of Water, Na⁺ & Ca⁺ ions (under endocrine control)
 - **Histology: Simple Cuboidal Epithelia (No Microvilli)** → Resorption of Ions.
- **Collecting System:**
 - **Collecting Duct:**
 - Variable Reabsorption of Water
 - Reabsorption OR Secretion of Na⁺, K⁺, H⁺ & HCO₃⁻.
 - **Histology: Simple Cuboidal – Columnar Epithelia** for reabsorption of H₂O, Urea & other Ions.
 - **Papillary Duct:**
 - Carries urine to Minor Calyces.



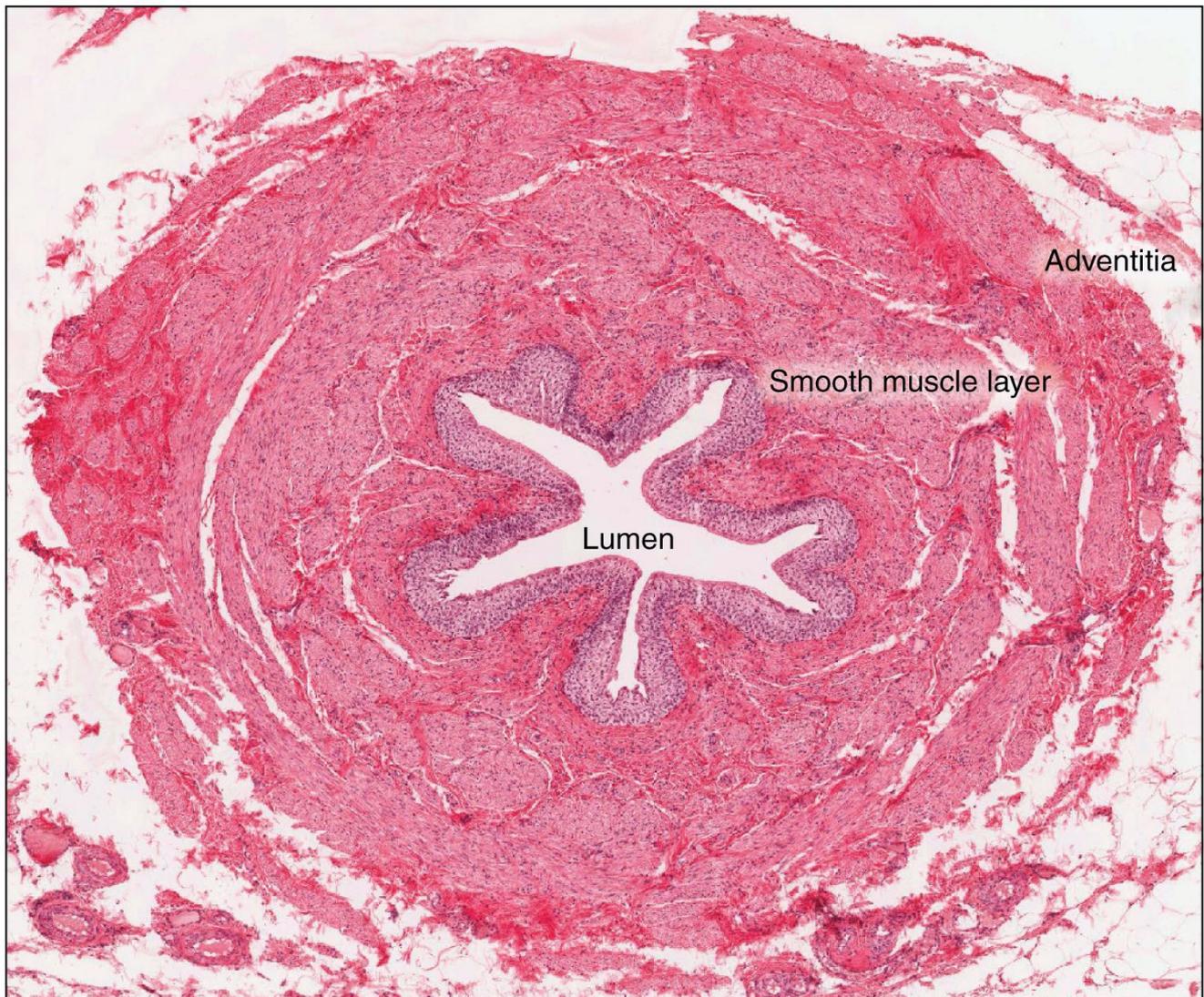
The glomerulus. This work by Cenveo is licensed under a Creative Commons Attribution 3.0 United States (<http://creativecommons.org/licenses/by/3.0/us/>).



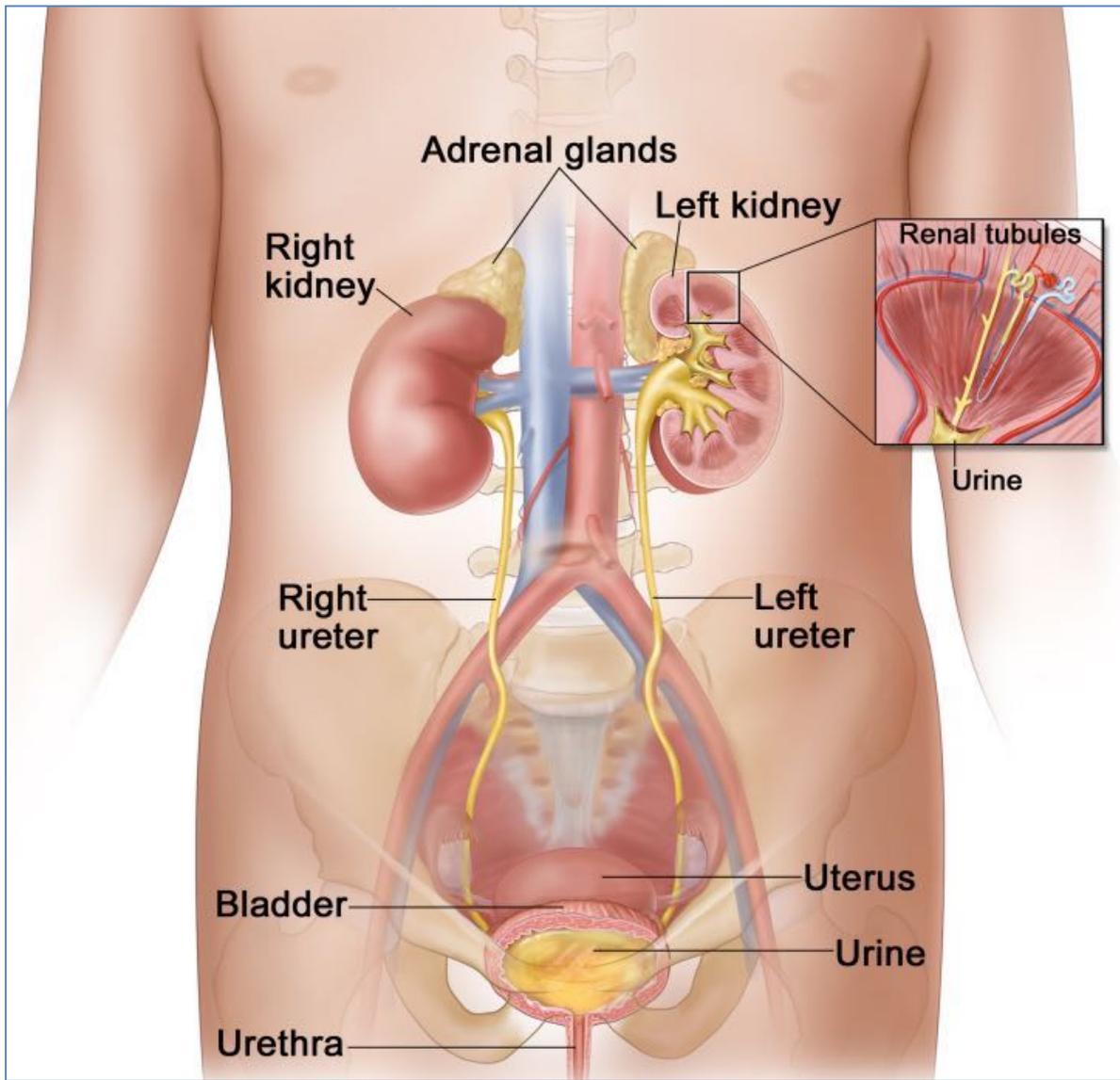
Loop of Henle. This work by Cenvo is licensed under a Creative Commons Attribution 3.0 United States (<http://creativecommons.org/licenses/by/3.0/us/>).

- **The Ureters**

- Carry Urine from Renal Pelvis → Bladder
- 30-35cm Long
- **Muscular Tubes:**
 - Peristaltic Contractions – help urine flow
- **Histology:**
 - Mucosa = Transitional Epithelium
 - Smooth Muscle Outer Layer
- **Abdominal Part** – Runs just anterior to Psoas Major
- **Pelvic Part** – From below Bifurcation of Common Iliac Artery
- **3 Sites of Constriction:** - (where calculi can be caught)
 - 1- Junction with Renal Pelvis (Hilum)
 - 2- Entry to Bony Pelvis (Over the Pelvic Brim)
 - 3- Entry to Bladder
- **Blood Supply:**
 - Upper Ureter – Branch of Renal Artery
 - Middle Ureter – Branches of Gonadal (Ovarian/Testicular), Aorta & Common Iliac Arteries.
 - Lower Ureter – Branches of Internal Iliac



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<https://www.ncbi.nlm.nih.gov/books/NBK65953/>

- **The Bladder:**

○ **General Info:**

- Muscular-Walled Sac (**Detrusor Muscle**)
- Inferior to Peritoneum
- Ureter Openings – Just Below Pubic Tubercles.

○ **Notable Areas:**

- **Trigone:**
 - Smooth Triangular Area on lower-posterior bladder wall
 - Triangle defined by openings of Ureters (top) & Urethra (bottom)
- **Apex** at bottom
- **Neck** – Entry to Urethra
 - Guarded by **Internal Urethral Sphincter**
- **Body**
- **Fundus** – Above Ureteral Openings.

○ **Histology:**

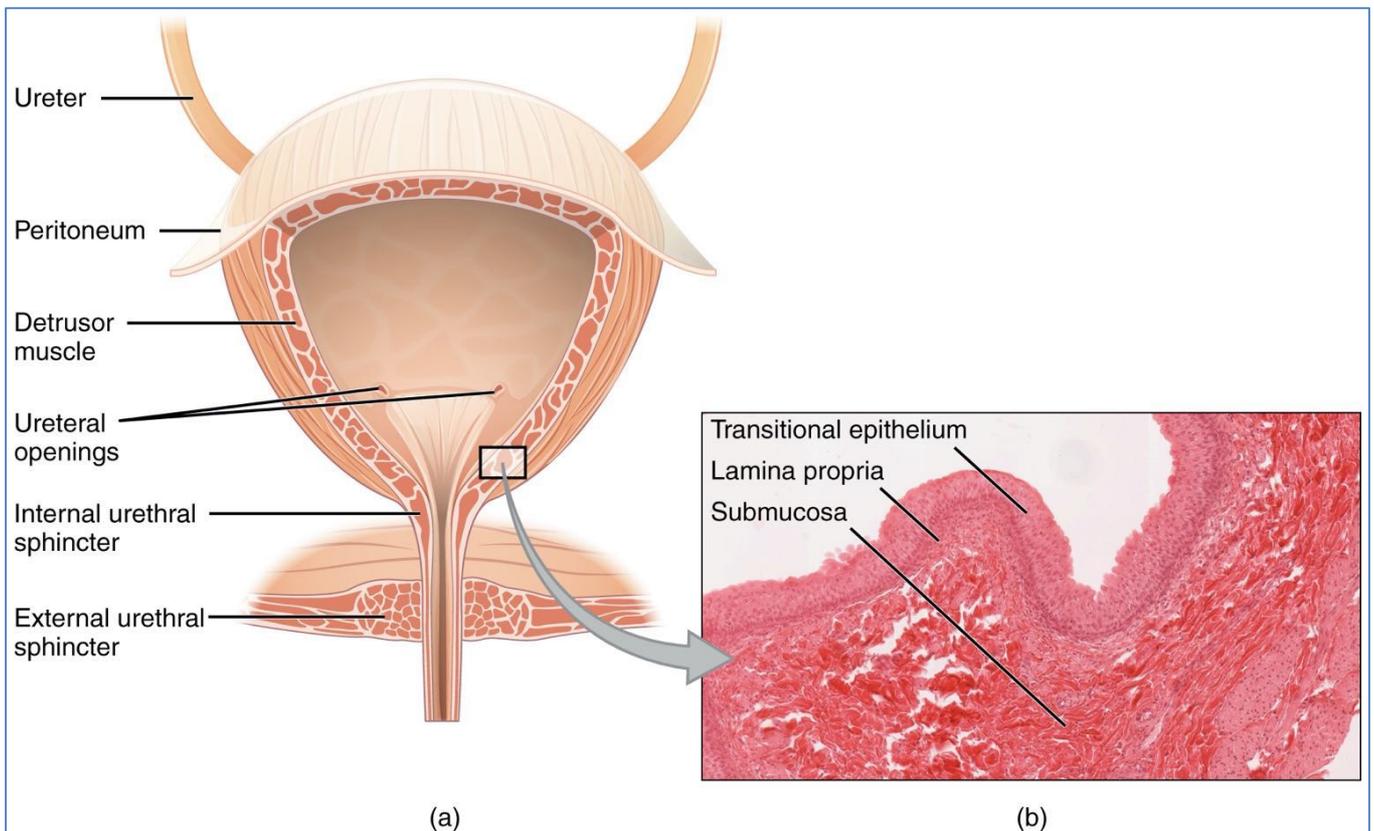
- Mucosa = Transitional Epithelium
- Muscular Layer = Detrusor Muscle
- Visceral Peritoneum

○ **Male:**

- **Rectovesical Pouch** – Space between Bladder & Rectum
- **Blood Supply** – Internal Iliac Artery

○ **Female:**

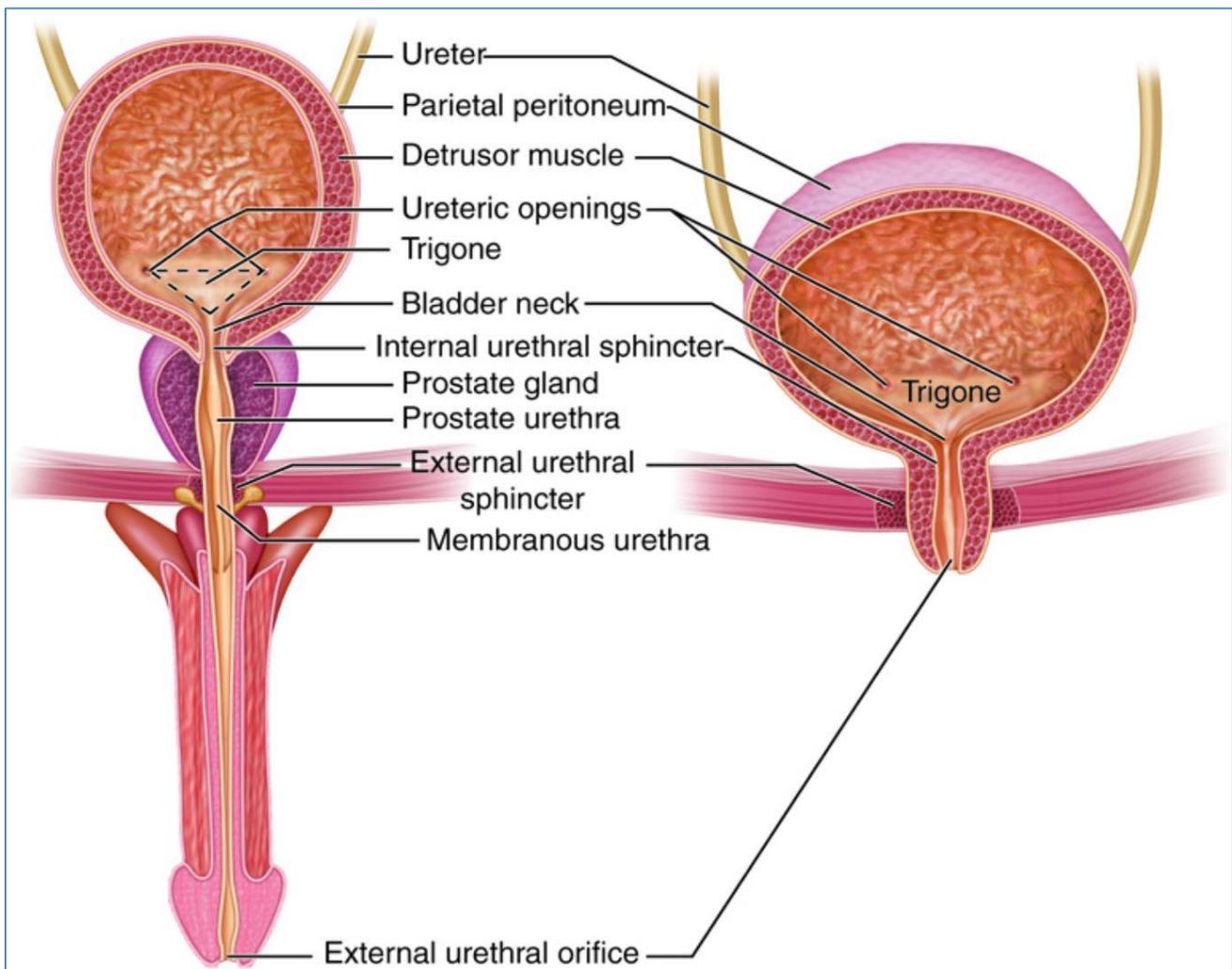
- **VesicoUterine Pouch** – Space between Bladder & Uterus
- **Blood Supply** – Internal Iliac & Vaginal Arteries.



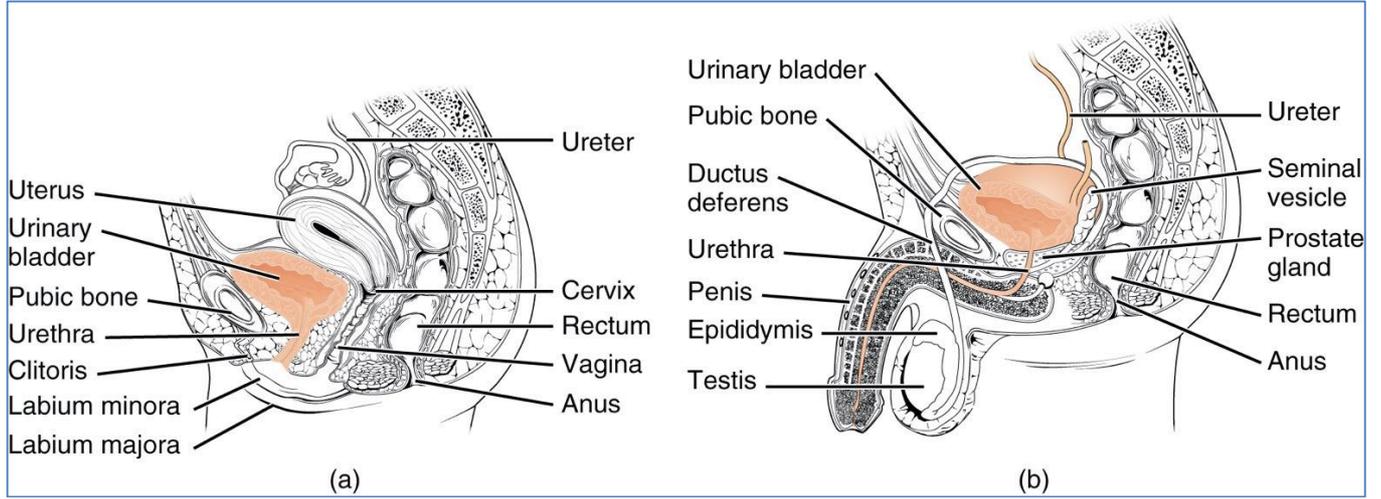
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- **Urethra:**

- Thin-Walled Muscular Tube.
- Drains Urine from Bladder → Outside
- **Sphincters:**
 - **Internal Urethral Sphincter**
 - @ Bladder-Urethra Junction
 - Prevents leakage between urinations.
 - **External Urethral Sphincter**
 - @ Urethra-Pelvic Diaphragm Junction
 - Voluntary
- **Male:**
 - 20cm Long
 - Integrated with Reproductive System
 - **3 Parts + Histology:**
 - Prostatic Urethra - Transitional Epithelium
 - Membranous Urethra - Pseudostratified Columnar Epithelium
 - Spongy (Penile) Urethra - Pseudostratified Columnar Epithelium
- **Female:**
 - 2-3cm Long
 - **Histology:**
 - Mostly Pseudostratified Columnar Epithelium
 - Stratified Squamous (external orifice)
 - Separate from Repro. System



Urethra. This work by Cenvo is licensed under a Creative Commons Attribution 3.0 United States (<http://creativecommons.org/licenses/by/3.0/us/>).



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RENAL PHYSIOLOGY

RENAL PHYSIOLOGY:

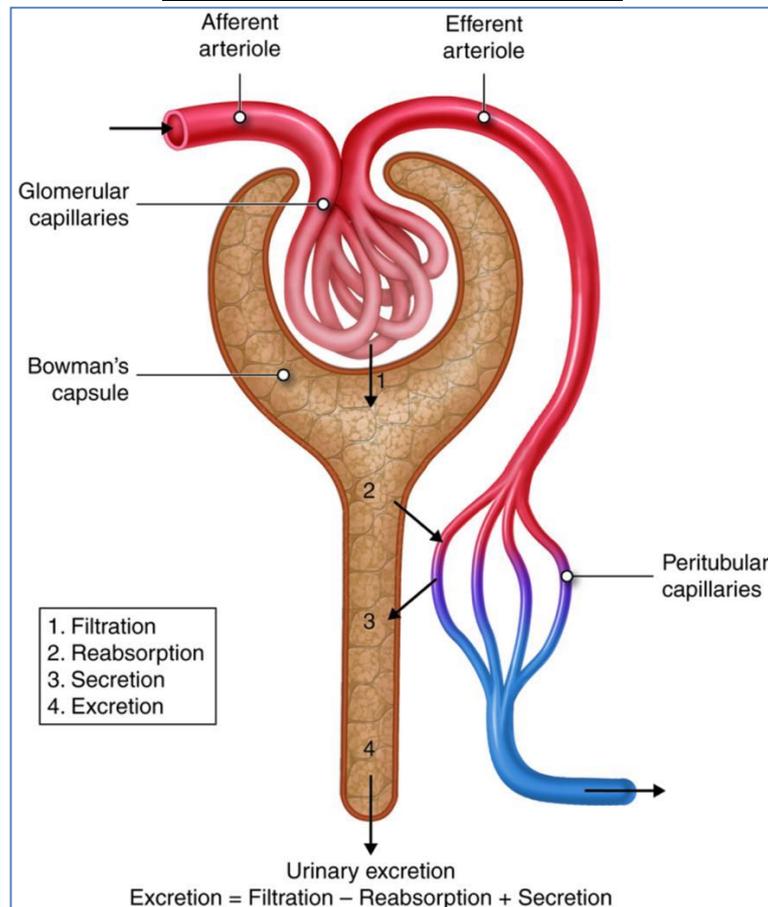
7 Physiological Functions of the Kidney:

- Fluid Conservation
- Electrolyte Balance (Particularly Na^+ , K^+ , PO_4^- & HCO_3^-)
- Waste Disposal (Urea, Creatinine, Urobilin/Bilirubin)
- Acid-Base Homeostasis (H^+ Resorption/Excretion...OR HCO_3^- Resorption/Excretion)
- Blood Pressure Regulation (Fluid Volume + Hormonal [Renin/Angiotensin])
- Haematopoiesis (Erythropoietin EPO)
- Vitamin D Activation

Relevant Hormones:

- **Renin:**
 - o Released by Juxta-Glomerular Apparatus in response to Renal Hypoperfusion
 - o Causes → Conversion of Angiotensin-I to Angiotensin-II,
 - → & Vasodilates Afferent Arteriole to ↑ Kidney Perfusion
- **Angiotensin-II:**
 - o Released by Lungs in response to Renin
 - o Causes → Systemic Vasoconstriction → ↑ BP
 - → & Constriction of the Efferent Arteriole to ↑ GFR
 - → & Adrenal Release of Aldosterone
- **Aldosterone:**
 - o Released by Adrenal Glands in response to AT-II, HyperKalaemia, & HypoNatraemia.
 - o Causes → ↑ Na^+ Reabsorption (& K^+ Excretion) (& H_2O Reabsorption)
- **Anti-Diuretic Hormone (ADH):**
 - o Released by Posterior Pituitary Gland in response to ↑ Plasma-Osmolality (Dehydration)
 - o Causes → ↑ Water Resorption from the Collecting Ducts → ↑ Plasma Volume & ↓ Urine

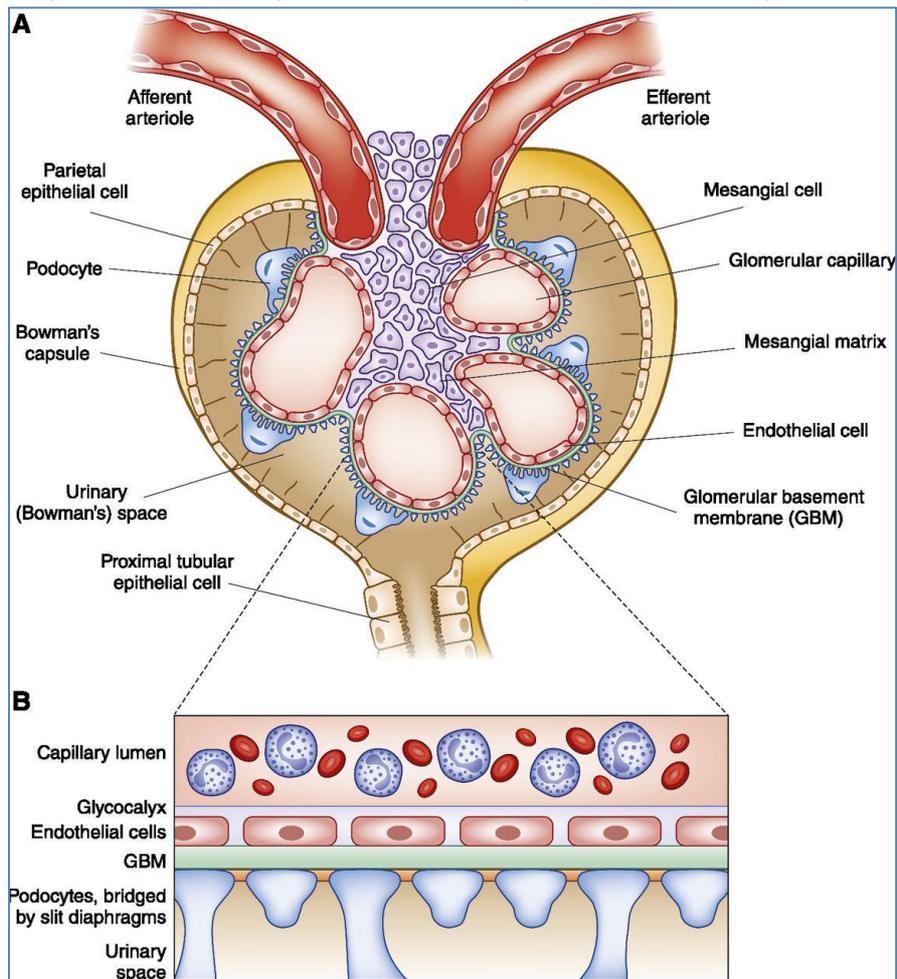
URINE PRODUCTION AND EXCRETION



Reabsorption and secretion. This work by Cenvéo is licensed under a Creative Commons Attribution 3.0 United States (<http://creativecommons.org/licenses/by/3.0/us/>).

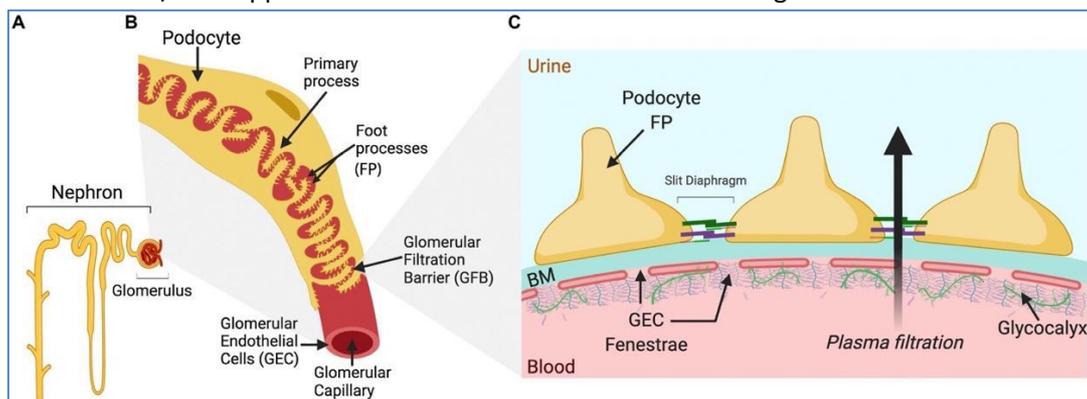
STEP 1 – GLOMERULAR FILTRATION:

- **Filtration of Large Volumes of Blood:**
 - o Filtration is *Passive & Non-Selective* (Fluids & Solutes are forced through via Hydrostatic Pressure)
- **Filtration Through 3 Layers of Capillary (Glomerular) Membrane:**
 - o Endothelium (Endothelial cells)
 - o Basement Membrane (GBM)
 - o “Podocytes” of Visceral Layer of Glomerular Capsule (Note: “Podocyte” = “Cells with Feet”)

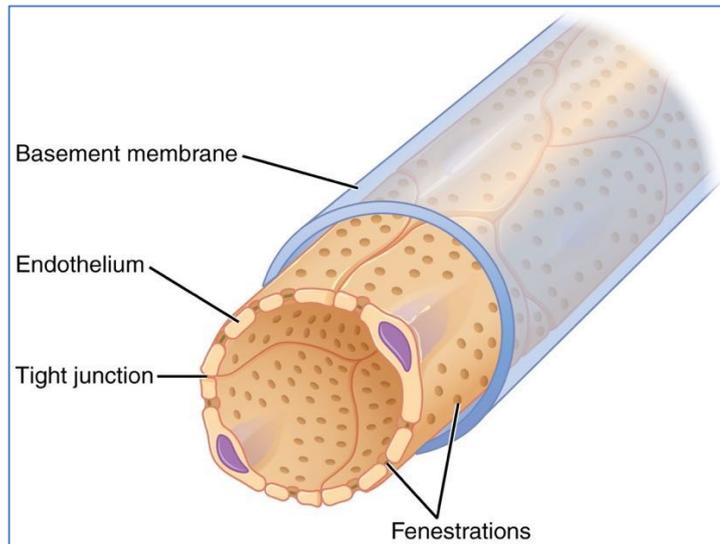


The Players: Cells Involved in Glomerular Disease; A. Richard Kitching, Holly L. Hutton;
<https://cjasn.asnjournals.org/content/11/9/1664>

- **Filtrate:**
 - o I.e: The Glomerular *FILTRATE* = Similar to Plasma (But *Without* the Proteins)
- **Permeability of Glomerular Membrane:**
 - o Filterability of Solutes – Based on Size.
 - o Small Chemicals are often bound to Plasma Proteins (Ca^+ , FA's, Drugs) – Hence not freely filtered.
 - o **Note:** Visceral Membrane of Glomerular Capsule is *IMPEREABLE TO PROTEINS* – I.e: If Proteins/Cells appear in urine → Means Membrane is Damaged

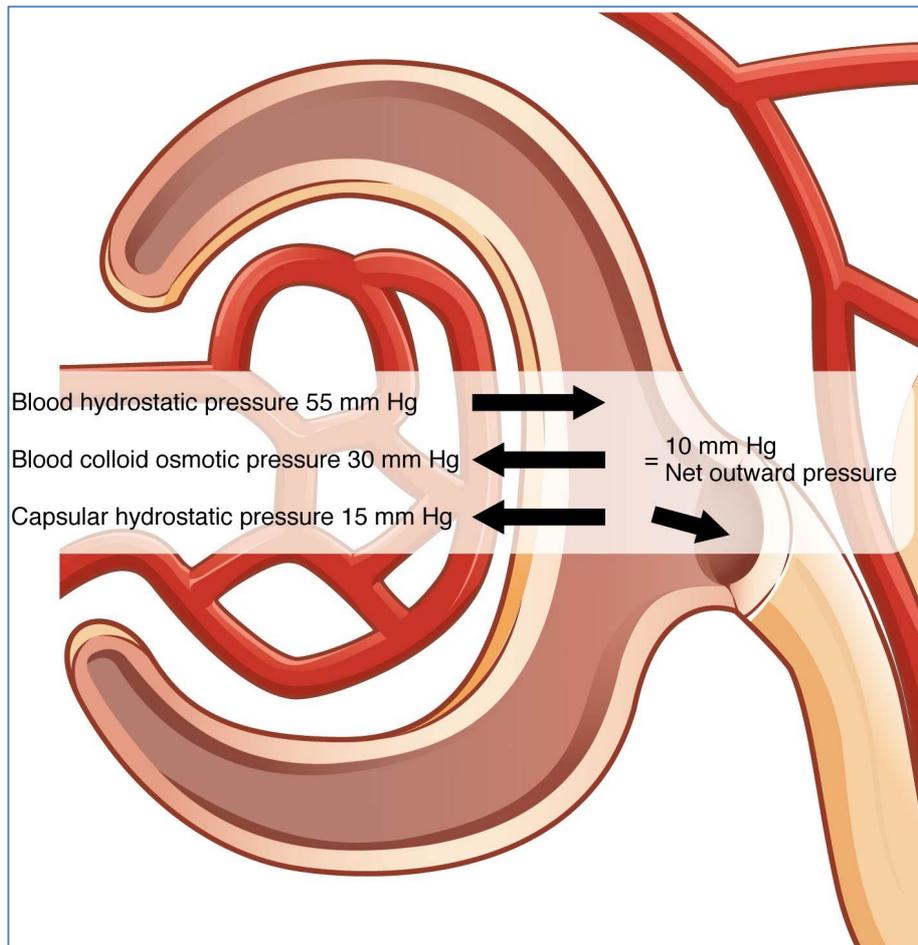


Front. Physiol., 02 June 2021 | <https://doi.org/10.3389/fphys.2021.689083>



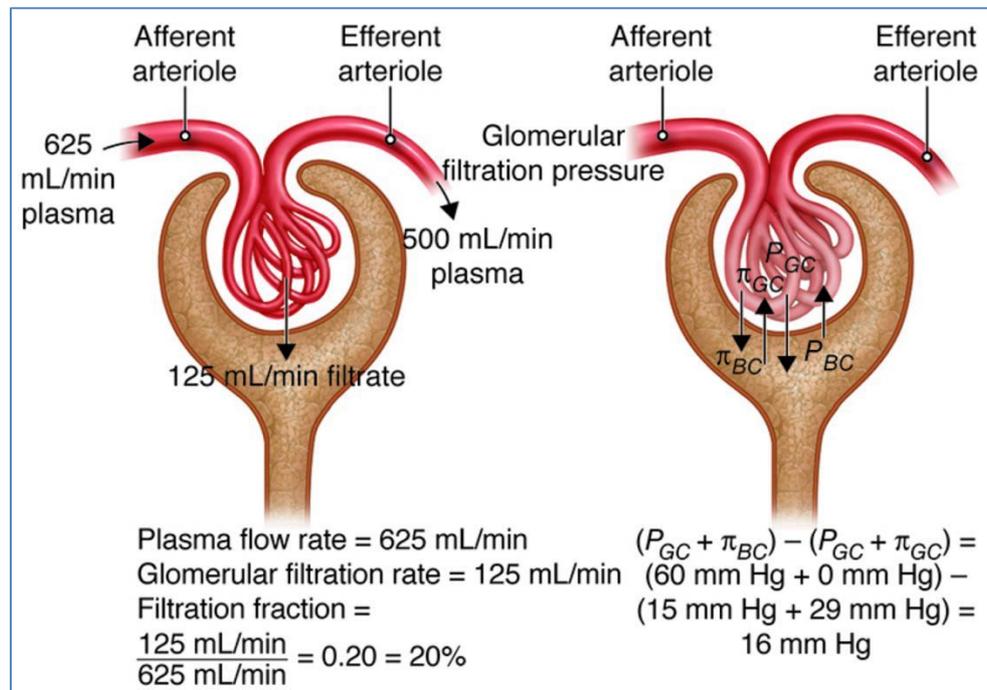
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- **Glomerular Filtration Rate:** = **Total Filtrate Formed/Per Minute**
 - **Determined by Net Hydrostatic Pressure and Net Colloid-Osmotic Pressure** Across Membrane.
 - **Capillary Hydrostatic Pressure:**
 - The force the blood exerts against the capillary wall.
 - Tends to force fluids through the capillary
 - *Net Hydrostatic Pressure = Capillary Pressure – Interstitial Pressure.*
 - **Colloid Osmotic Pressure:**
 - Opposes hydrostatic pressure
 - Due to non-diffusible molecules (In Plasma) drawing fluid into capillaries.
 - *Net Osmotic Pressure = Capillary Osmotic Pressure – Interstitial Osmotic Pressure.*



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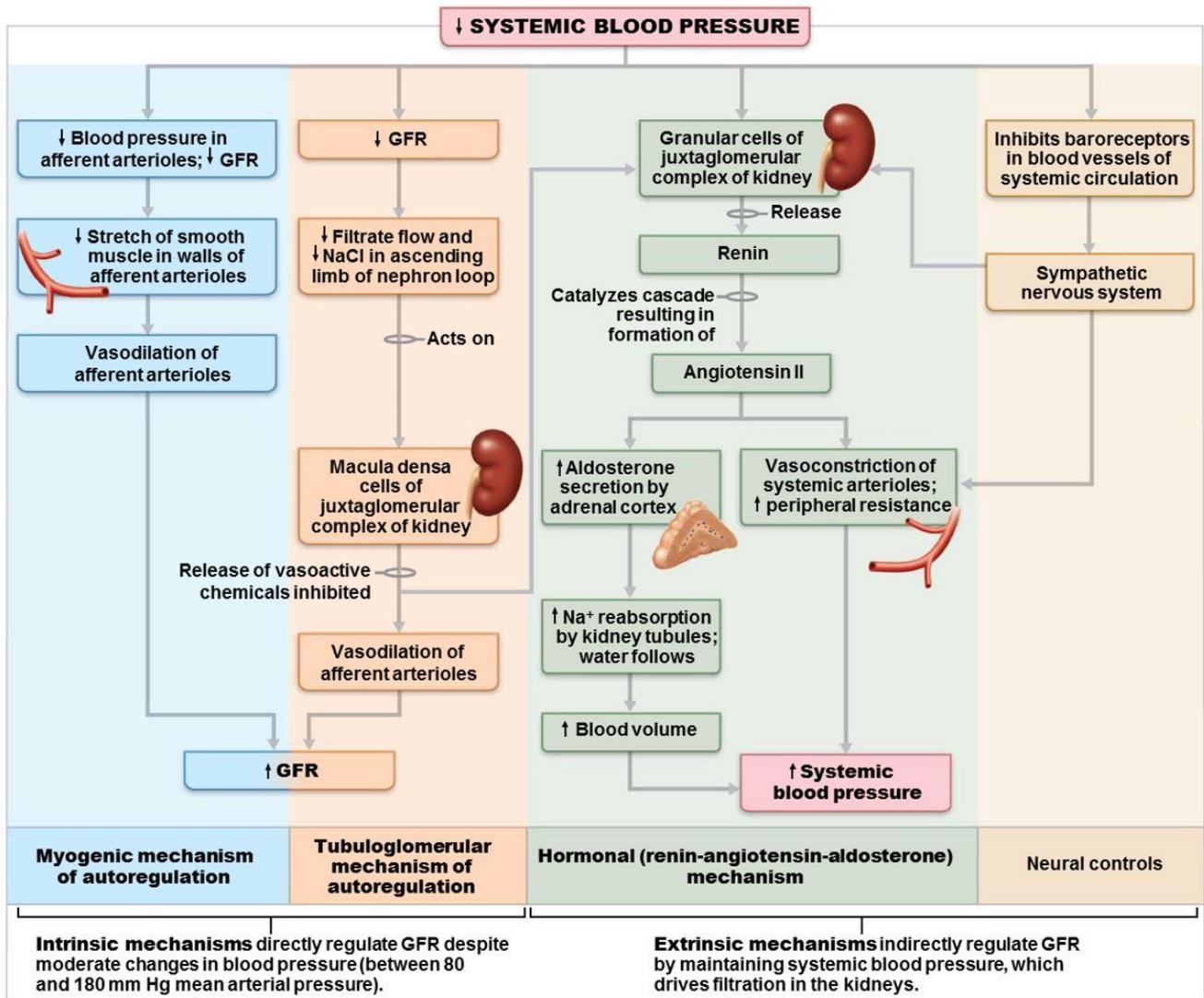
- **GFR Also Determined By:**
 - **Total Surface Area for Filtration**
 - **Membrane Permeability**
- **Kidneys receive ≈1/4 of Cardiac Output (1L of Blood/min);**
 - Of that ≈125mL of Filtrate is Generated/Min → 180L of Filtrate/Day (From only 3L of Plasma)
 - →Hence, The Blood Is Extremely Well Filtered.
 - Note: Most of Filtrate is Reabsorbed into Blood (Via Renal Tubules)



Glomerular filtration process. This work by Cenvo is licensed under a Creative Commons Attribution 3.0 United States (<http://creativecommons.org/licenses/by/3.0/us/>).

- **Control of GFR:**

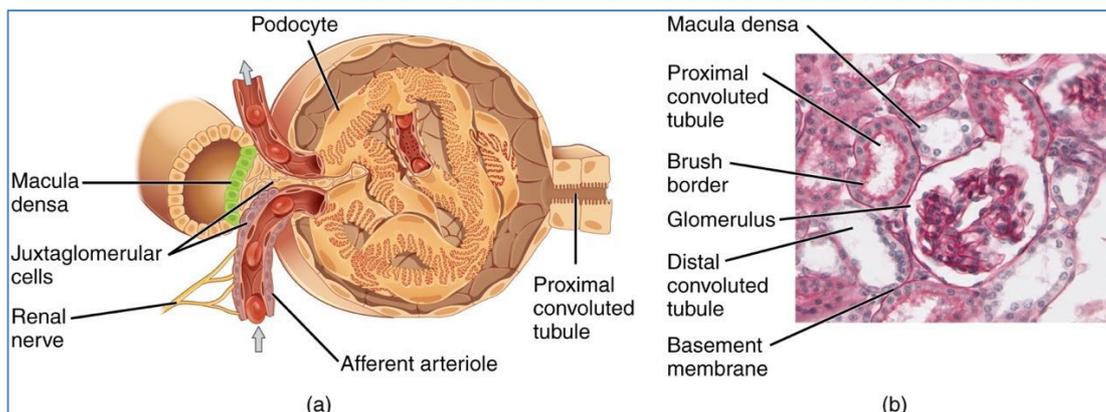
- **Sympathetic NS: (Fight/Flight)**
 - Constriction of Afferent & Efferent Arterioles.
 - →↓Renal Blood Flow
 - →↓GFR
- **Hormones & Autocrine Secretions:**
 - **Causing Arteriole CONSTRUCTION:**
 - (ADRENALINE, ENDOTHELIN...others)
 - →↓Renal Blood Flow
 - →↓GFR
 - **Causing Arteriole DILATION:**
 - (NITRIC OXIDE, PROSTAGLANDINS, BRADYKININ...others)
 - →↑Renal Blood Flow
 - →↑GFR
- **Angiotensin II:**
 - Constriction of *EFFERENT ARTERIOLES*
 - →↓Renal Blood Flow
 - BUT – Maintains GFR (By keeping Glomerular Hydrostatic Pressure Up)



<https://www.emr.ac.uk/wp-content/custom/case-72/blood-pressure-regulation.php>

- **'Autoregulation' of Renal Blood Flow:**

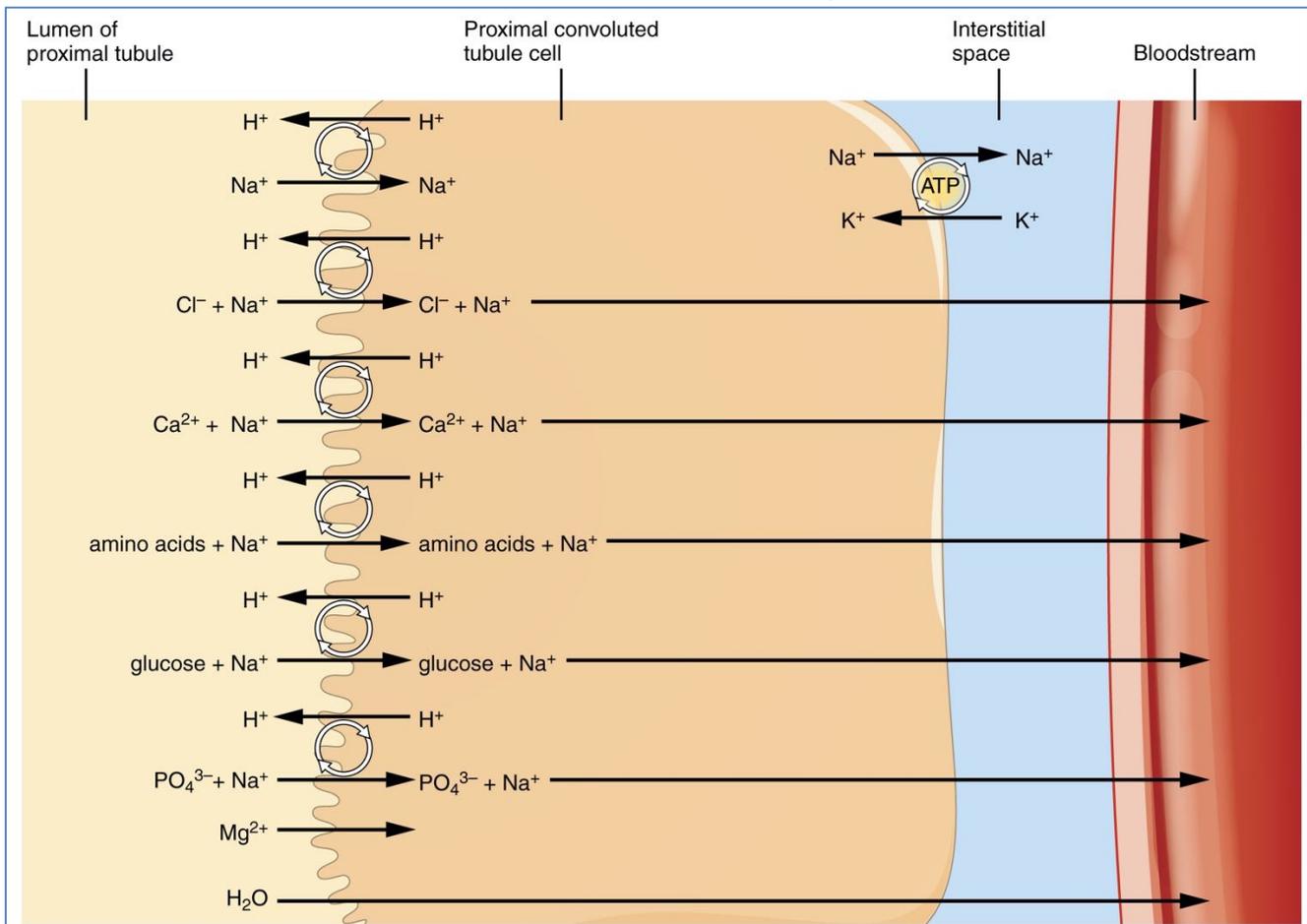
- (The first of the body's regulators of Mean Arterial Pressure)
- Automatic Adjustment of Blood Flow to a Capillary Bed Relative to the Tissue's Requirements
 - Maintains Normal Renal Function (GFR) Despite Changes in Arterial Pressure.
- **How? - Juxtaglomerular Apparatus is Sensitive to:**
 - **Metabolic Controls: → Vasodilation:**
 - Low Oxygen / Nutrient levels
 - Nitric Oxide
 - Endothelin
 - **Myogenic Control: → Vasoconstriction:**
 - Shear Stress: Vascular Smooth Muscle Contracts When Stretched



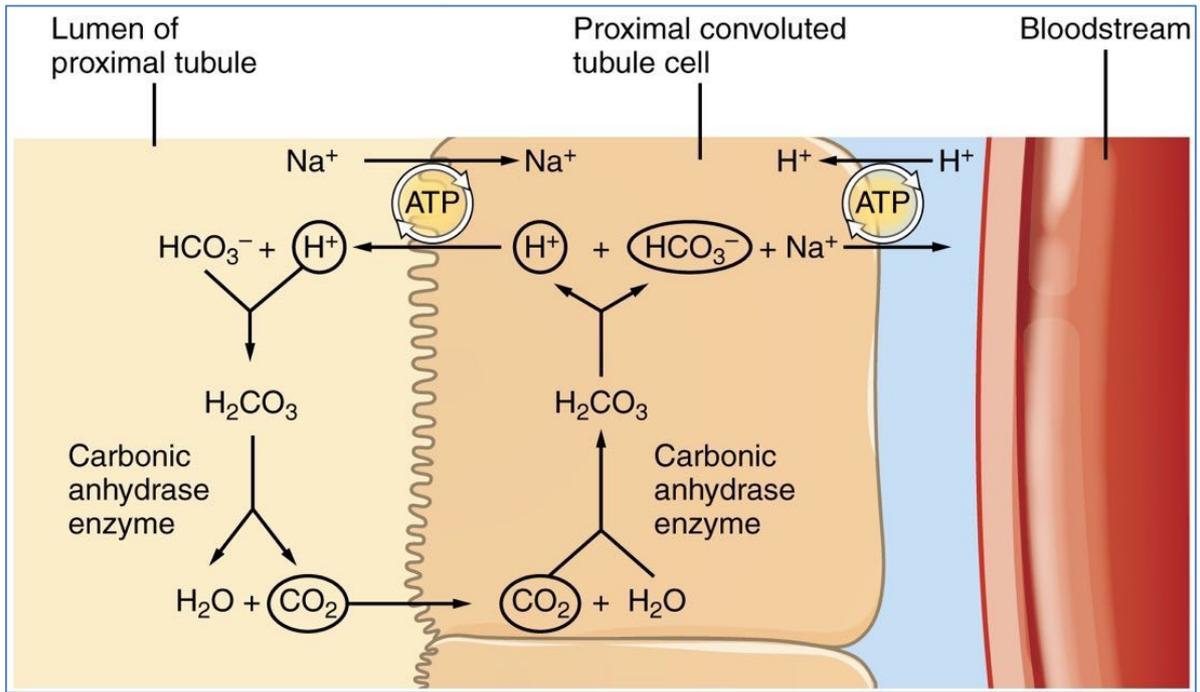
STEP 2 – TUBULAR REABSORPTION:

- Reabsorption of Certain Filtered Substances (In Renal Tubules) → Back into Blood
- Normally, 99% of Filtrate is Reabsorbed
- **-Is Highly Selective:**
 - o Some Substances (Eg: Glucose) are Almost Completely Reabsorbed.
 - o Some Substances (Eg: NaCl) are Variable.
 - o Some Substances (Eg: Urea) are Not Reabsorbed at All.
- **-Is Passive & Active:**
 - o **Passive:**
 - Eg: Water – Via Osmosis
 - o **Active:**
 - Ie: Moving Solutes Against an Electrochemical Gradient. (Either Primary/Secondary)
 - Eg: Na^+ - (By Na^+/K^+ -ATPase)
 - o Remember that all Active & Passive Transporters (Excluding Channels) Reach Saturation. (Max.V)
 - Eg: Glucose doesn't normally appear in urine. However, if Filtered Load Exceeds Reabsorption, Urinary Excretion Occurs (Ie: In Uncontrolled Diabetes.)
- **Solutes May Be Reabsorbed Via 1 of 2 Routes:**
 - o 1- Transcellular Pathway – Through The Cells
 - o 2- Paracellular Pathway – Between Cells
- **Active Na^+ Reabsorption:**
 - o Occurs in Ascending Limb of Loop of Henle.
 - o TransCellular Pathway
 - o Involves 3 Steps:
 - Na^+ *Passively* Diffuses from Tubule Lumen (Down an Electrochemical Gradient)→ Tubule Cell
 - Na^+ *Actively* Transported across Basolateral Membrane → Interstitium (By Na^+/K^+ -ATPase)
 - Na^+ (+Water & Other Solutes) Reabsorbed from Interstitium → Peritubular Capillaries.

Substances Reabsorbed & Secreted by the PCT



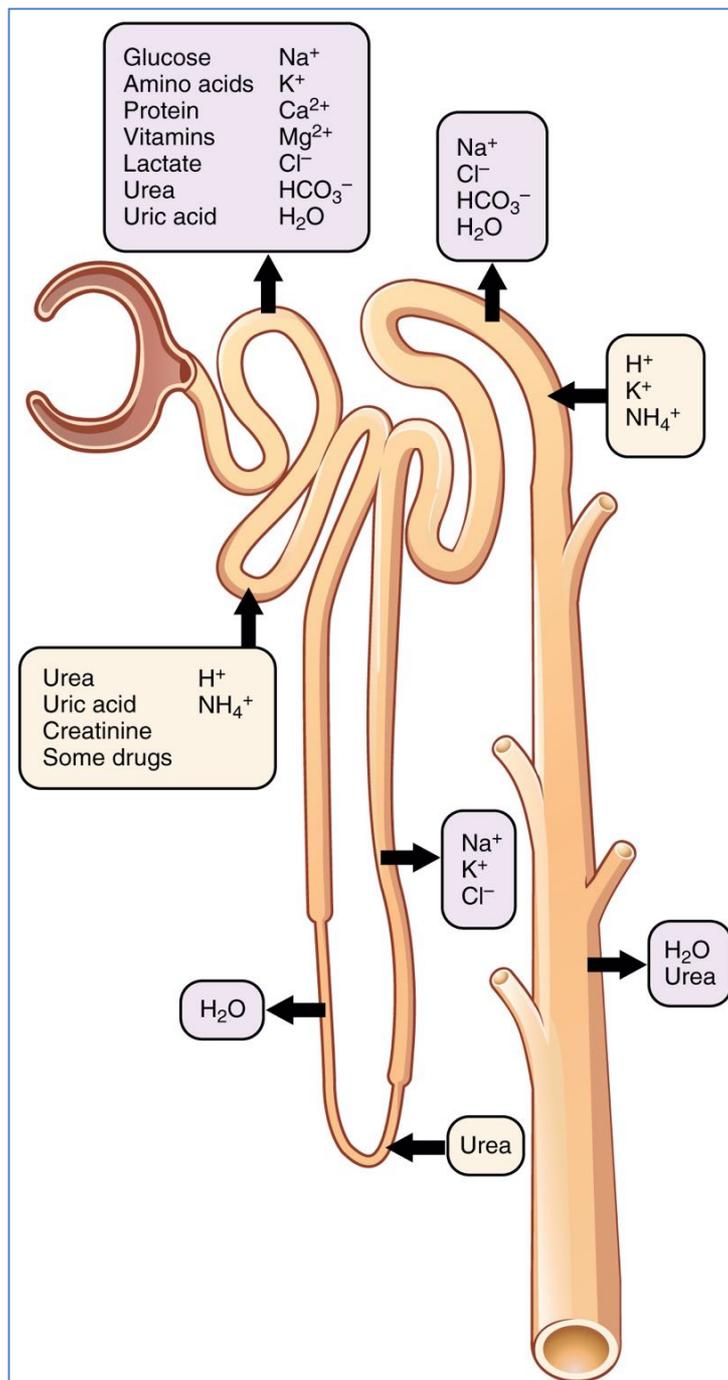
Reabsorption of Bicarbonate from the PCT

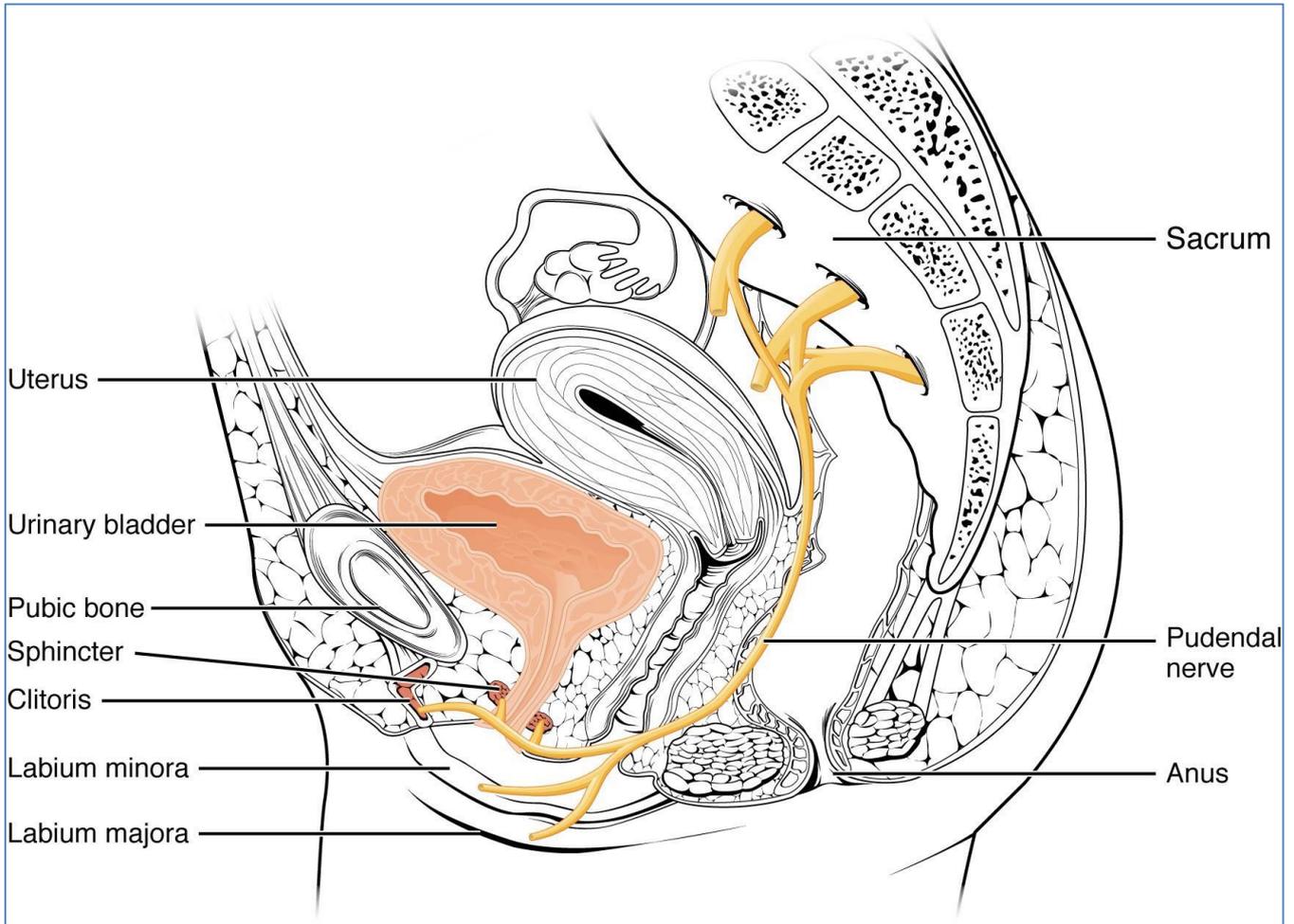


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STEP 3 – TUBULAR SECRETION:

- Active Secretion of Substances From Peritubular Capillaries (Blood) → Into Renal Tubules
- **Important For:**
 - o Disposing of Substances That Weren't Filtered (or Weren't Filtered Enough)
 - Eg: Drugs (Eg: Penicillin)
 - o Eliminating 'Bad' Substances that have been Passively Reabsorbed
 - Eg: Urea, Uric Acid, etc.
 - o Removing Excess K^+ ions
 - o Controlling Blood pH
- **Proximal Tubules:**
 - o Site of Secretion of **Organic Acids/Bases** (Bile Salts, Oxalate, Uric Acid, etc)
- **Renal Tubules:**
 - o Secretion of K^+
 - o Secretion of H^+
 - o Secretion of Drugs/Toxins (Eg: Penicillin)





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