Greater Manchester
Critical Care
Skills Institute

Critical Care Programme

Fundamentals Module
Renal Workbook

Acknowledgements

This document has been adapted from the core workbooks associated with the Greater Manchester Multi-professional Critical Care Programme (2001-2011). As such, all original contributors are acknowledged by the Greater Manchester Critical Care Skills Institute.

This version of the workbook has been compiled and completed by our team of practice educators involved in the delivery and development of our current Critical Care Programme.

Aim of the workbook

To act as a support tool for pre-course preparation and on-going learning. It is a vital resource for students on our Critical Care Programme preparing for the Fundamentals Module Renal Study Day.

It is advisable that you continue to expand on this information using references given.

Further sources of information

Anatomy & Physiology text book
Practice supervisor/Mentor
Nurse Specialist
Pharmacist
Anaesthetist
Dietician
Library Internet

List of contents

References

CC3N (2013) National Competency Framework for Adult Critical Care Nurse Education

Renal physiology

The kidneys are complex organs. The primary roles of the kidneys are to maintain homeostasis by removing metabolic waste, excrete foreign substances, maintain fluid and electrolyte balance and help achieve acid base balance. The kidneys also have an important role in blood pressure control, red blood cell synthesis, and bone metabolism. (Tortora J.G. & Derrickson, B.H, 2009, Urden, L.D. Stacy, K.M. & Lough, M.E, 2006).

What other organs are there involved in waste excretion?

The Urinary System

- Consists of two kidneys, two ureters, bladder and urethra.
- Kidneys situated between parietal peritoneum and posterior abdominal wall (retroperitoneal)
- A ureter originates from each kidney and connects the kidneys to the bladder.
- Ureters are composed of a smooth muscle layer and mucous producing epithelial cells
- Urine is transported along the ureters by hydrostatic forces, gravity and peristalsis
- The urinary bladder is a hollow muscular organ situated retroperitoneal in the pelvic cavity
- Stretch receptors in the wall of the bladder initiate the “micturition reflex” a spinal cord reflex when urine volume exceeds 200-400mls
- This leads to relaxation of the urethral sphincter and contraction of the muscles in the bladder wall (detrusor)
- There is also some voluntary cortical control
- The urethra leads to the exterior of the body

Label the relevant structures

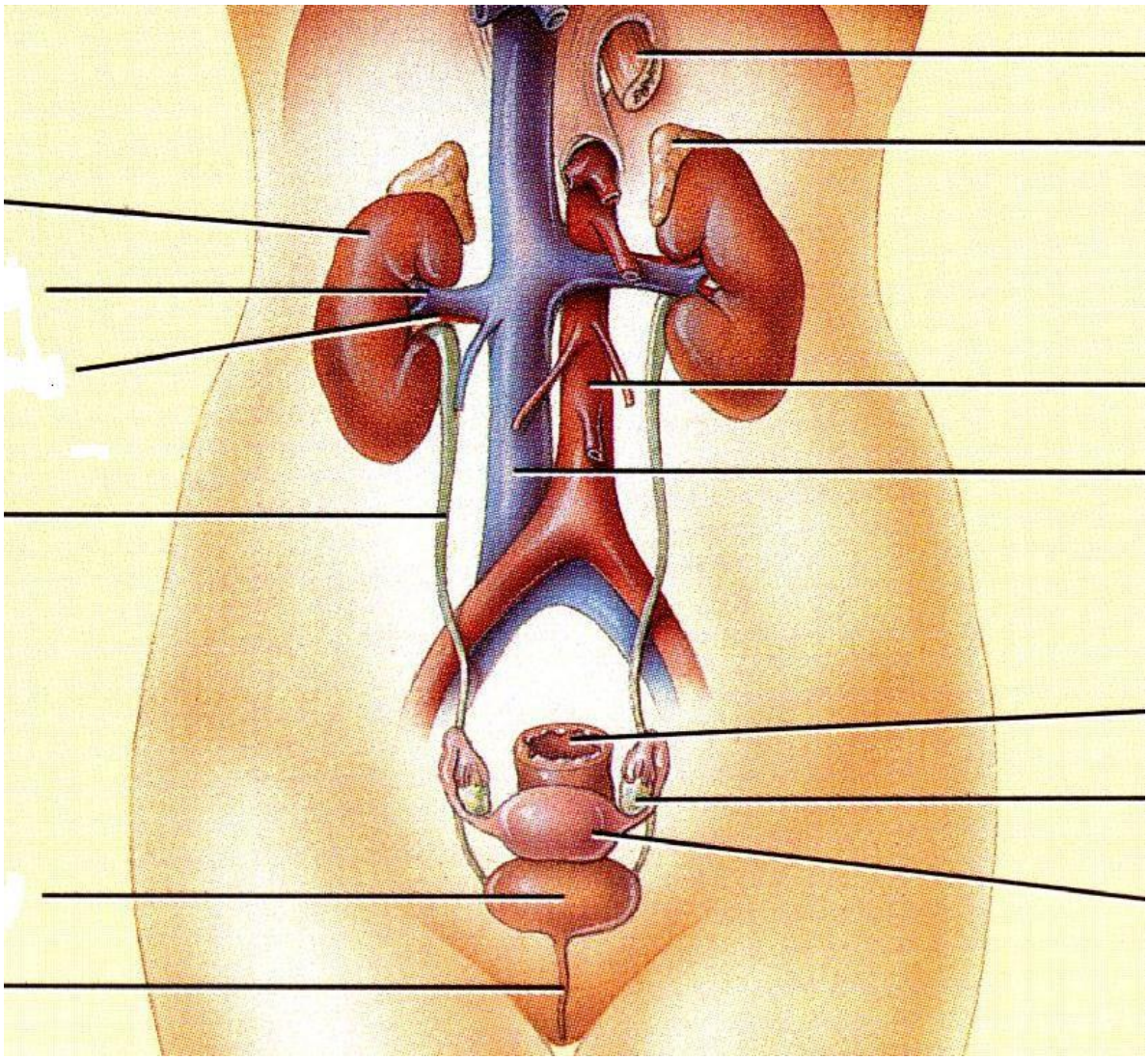


Fig 1

Tortora GJ, Derrickson BH, (2012). Principles of Anatomy and Physiology 10th Ed. John Wiley & Sons, New York

Describe the external anatomy of the kidneys

Renal Hilum

Renal capsule

Adipose capsule

Renal fascia

Describe the internal anatomy of the kidney

Renal cortex

Renal Medulla

Renal Pyramids

Renal Papilla

Parenchyma

Nephron

Minor and Major calyces

Renal sinus

Label the relevant structures of the kidney

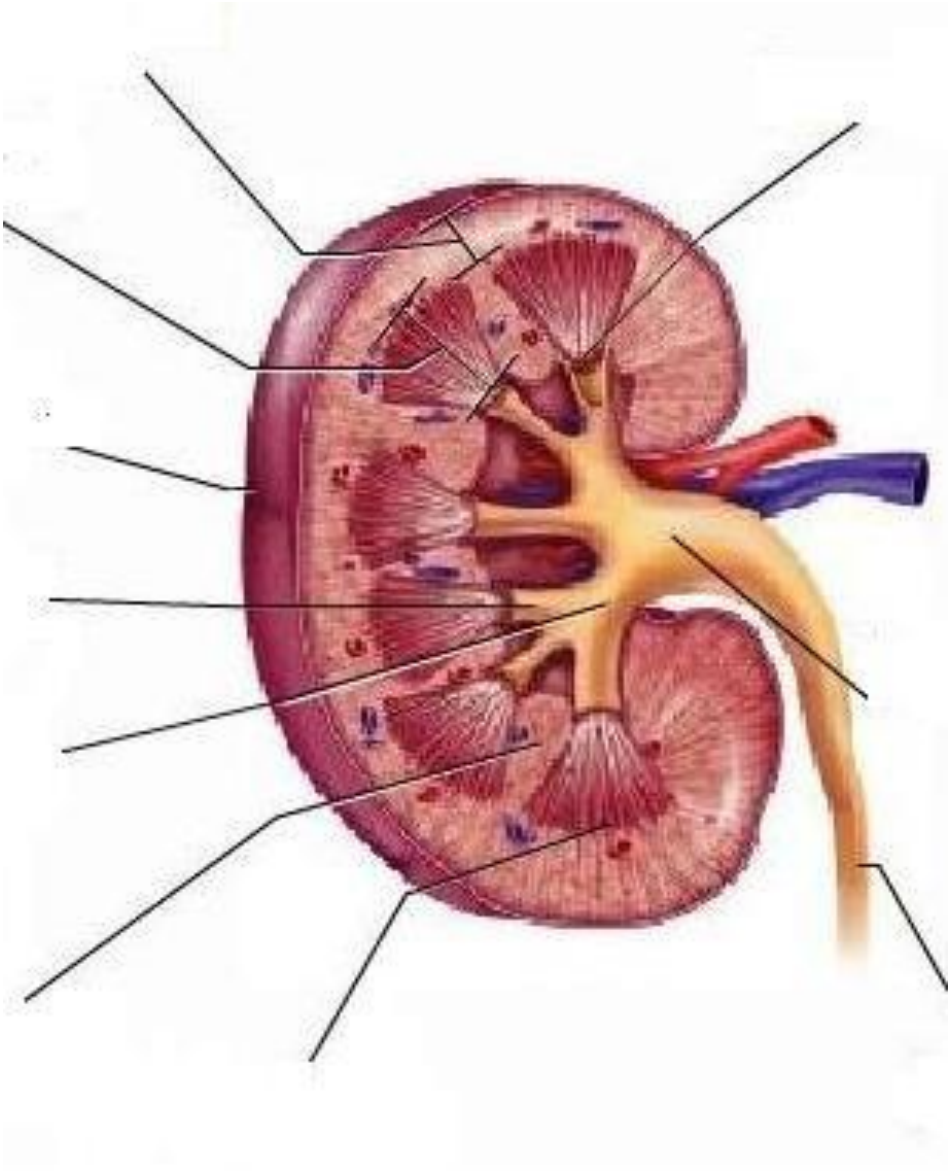
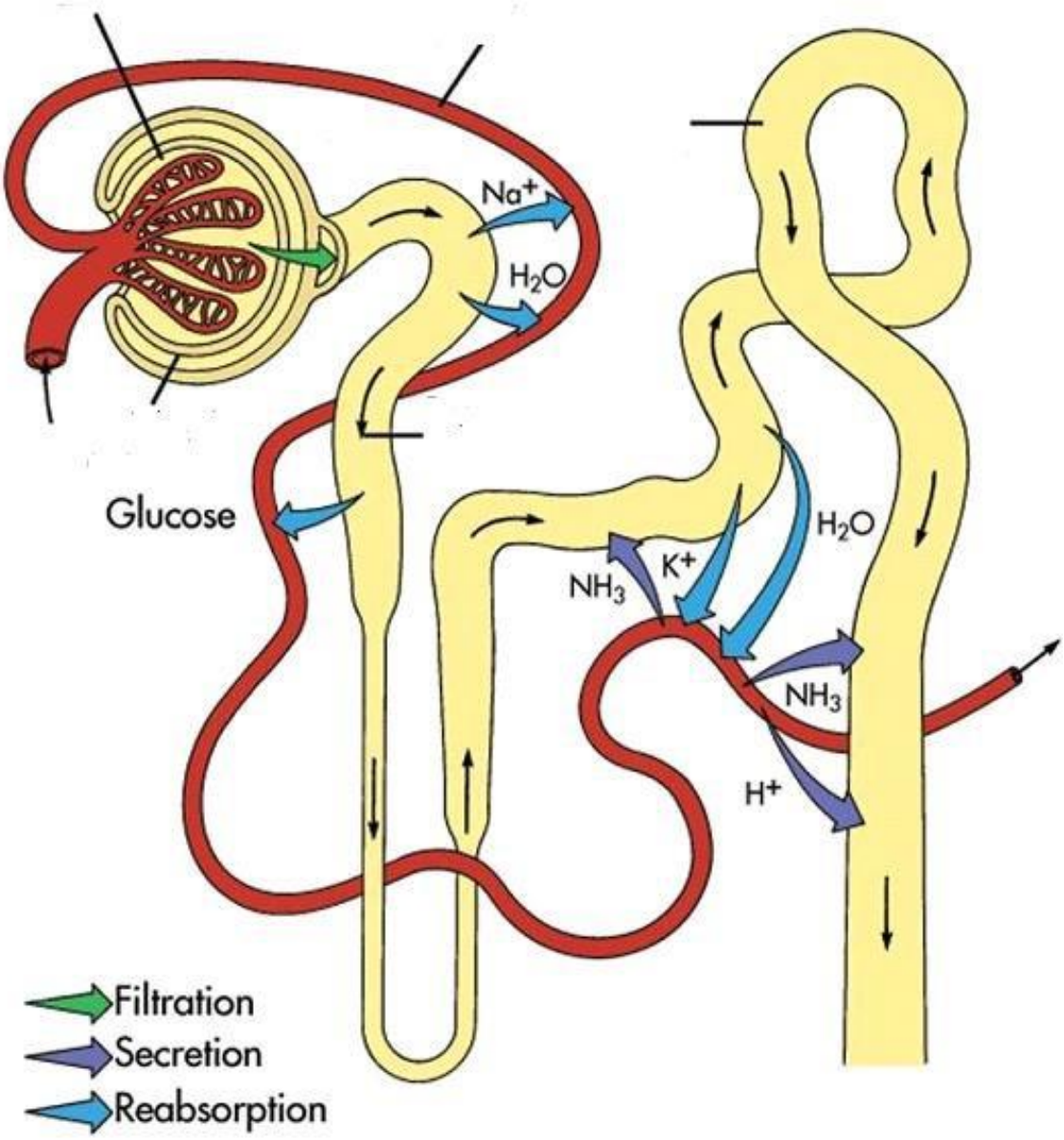


Fig 2

Tortora GJ, Derrickson BH(2009). Principles of Anatomy and Physiology 12th Ed. John Wiley & Sons, New York

Label the structure of the Nephron



om Thibodeau GA, Patton KT: *Anatomy & physiology*, ed 5, St Louis, 2003, Mosby.)

Fig 3

Review and briefly summarise the structure & function of each component

- Glomerulus

- Bowman's Capsule

- Proximal Convoluted Tubule

- Loop of Henle

- Distal Convoluted Tubule

- Collecting Duct

- Juxtaglomerular apparatus

- Vasa recta

Overview of renal physiology

Briefly outline the three processes of urine production performed by the nephron and collecting duct and indicate where each process takes place

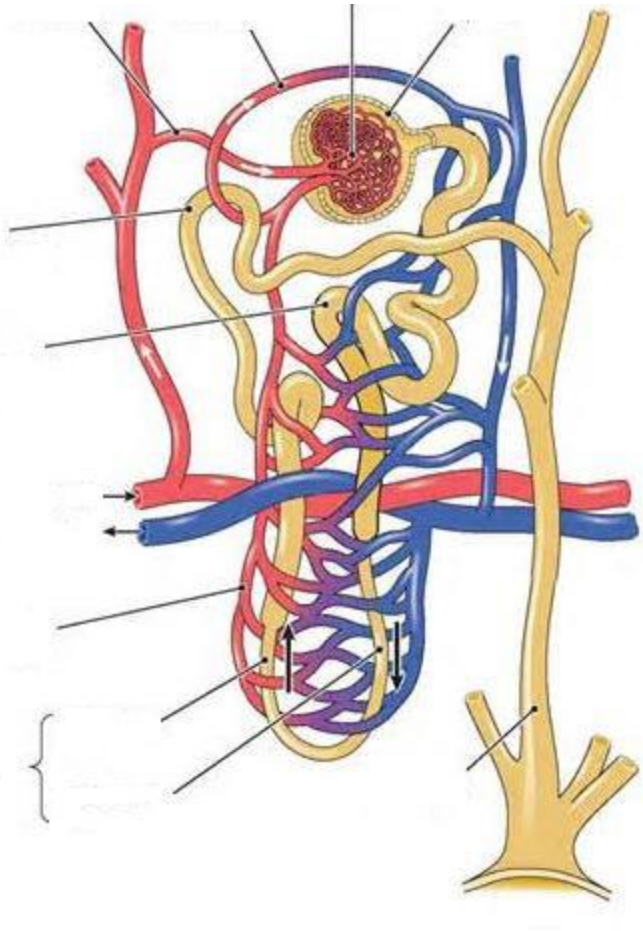
Glomerular filtration

Tubular reabsorption

Tubular secretion

Describe the blood and nerve supply of the kidneys

Label the relevant structures of nephron and associated blood supply



Tortora GJ, Derrickson BH(2009). Principles of Anatomy and Physiology 12th Ed. John Wiley & Sons, New York

Glomerular filtration depends on three main pressures. One pressure promotes filtration and two pressures oppose filtration.

Glomerular blood hydrostatic pressure is the blood pressure in the glomerular capillary. It promotes filtration by forcing water and solutes in blood plasma through the filtration membrane.

Capsular hydrostatic pressure is the hydrostatic pressure exerted against the filtration membrane by fluid already in the capsular space and renal tubular. It opposes filtration.

Blood colloid osmotic pressure is due to the presence of proteins such as albumin, globulins and fibrinogen in blood plasma. This opposes filtration

Glomerular filtration rate the amount of filtrate in all the renal corpuscles of both kidneys each minute is the glomerular filtration rate (GFR).

What is the average GFR and what factors may affect the GFR?

GFR is dependent on systemic blood pressure and the diameter of the afferent and efferent blood vessels

Three principle mechanisms regulate these two factors auto blood pressure, hormone regulation and neural regulation

Discuss auto blood pressure and hormone regulation

Neural regulation

Tubular Reabsorption

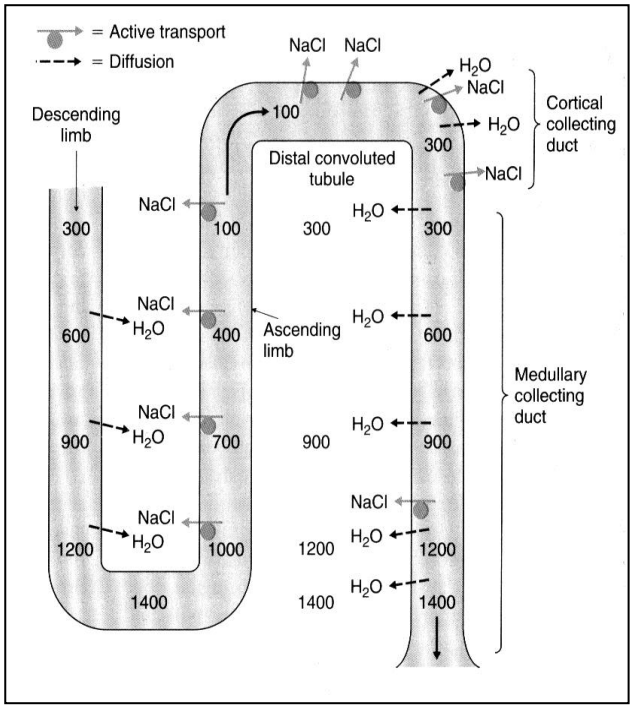
- As the filtrate passes through the renal tubules approximately 99% is reabsorbed
- Solutes are absorbed through both active and passive processes
- Water is absorbed by passive process of osmosis
- Proteins and peptides are reabsorbed by pinocytosis (active process)
- Facilitated and active transport e.g. glucose
- The majority of nutrients and HCO_3 and 65% of Na and H_2O are reabsorbed in the PCT

- Reabsorption continues in the loop of Henle and is responsible along with the DCT for the ability to produce and determine urine concentrate under hormonal control (juxtamedullary nephrons) (counter-current)

Counter-Current Mechanism

- 15 – 20% of nephrons are juxtamedullary nephrons
- These have a long loop of henle descending leaving the proximal convoluted tubule section going into the loop and the ascending merging into the distal convoluted tubule section
- Project into the renal medulla
- Are responsible for the kidneys ability to concentrate urine
- Able to conserve water during low water intake or excessive water loss
- This ability is due to the anatomical arrangement of the loop of henle and its blood supply the vasa-recta

Fig. 4



Vander AJ, Sherman J, Luciano DS(2003). Human Physiology: the Mechanisms of Body Function, 9th Ed. McGraw-Hill Education, London

- Fluid flows in opposite direction setting up a counter-current flow
- The vasa-recta runs alongside the loop
- Descending limb permeable to water but not salts
- Water moves out along concentration gradient
- Fluid in tubule becomes more concentrated
- Ascending limb impermeable to water but salts are actively reabsorbed into interstitial fluid
- Reabsorbed salts are distributed throughout the medullar interstitial fluid by the vasa-recta maintaining an osmotic gradient
- As urine passes into the collecting ducts water can diffuse out down a concentration gradient under the control of hormones
- Therefore the anatomical arrangement sets up an osmotic gradient to allow water to move out of the tubule concentrating the urine

Control of Tubular Re-absorption

When filtrate reaches the DCT 95% of filtered solute and water has been reabsorbed

- The DCT and collecting duct "fine tune" the filtrate under hormonal control
- Hormones act on principle cells within the tubule

Aldosterone

- Secreted by adrenal cortex acts on principle cells and increases Na and water reabsorption.

Anti-diuretic Hormone (ADH)

- Secreted by posterior pituitary in response to chemo-receptors in the hypothalamus
- Increases water permeability in principle cells

Atrial Natriuretic Hormone

- Stretch receptors in atria – distension triggers release
- Decreases Na reabsorption and therefore water reabsorption

Tubular Secretion

- Involves the secretion of substances into the filtrate

Potassium

- Secretion in response to plasma levels and aldosterone secretion

Hydrogen Ions

Maintains acid base balance

- Reabsorb more bicarbonate
- Produce more bicarbonate

Secretion of ammonia and urea

Summary of Urine Production

- Glomerulus produces 180 l/day of filtrate
- GFR regulated by auto regulation, hormonal and neural factors
- 95% of solutes and water are reabsorbed by the PCT and loop of henle
- DCT reabsorbs approximately remaining 4% under influence of aldosterone and ADH
- Various waste products are secreted throughout the tubule
- 1% of filtrate is excreted (1-1.5 l/day)

Blood Pressure Regulation
Renin – angiotensin system

Macular Densa Cells located in the JGA secrete a hormone renin into the blood stream in response to a stimuli.

Stimuli include:

- Increased salt concentration at macular densa
- Decreased stretch on juxtamedullary cells
- Increases sympathetic innervation (β_1 - adrenoreceptors)
- Once released into the blood renin converts angiotensinogen (hormone in the blood) into angiotensin I in the liver
- Angiotensin I is converted to Angiotensin II in the lungs catalysed by angiotensin converting enzyme (ACE)

Angiotensin II

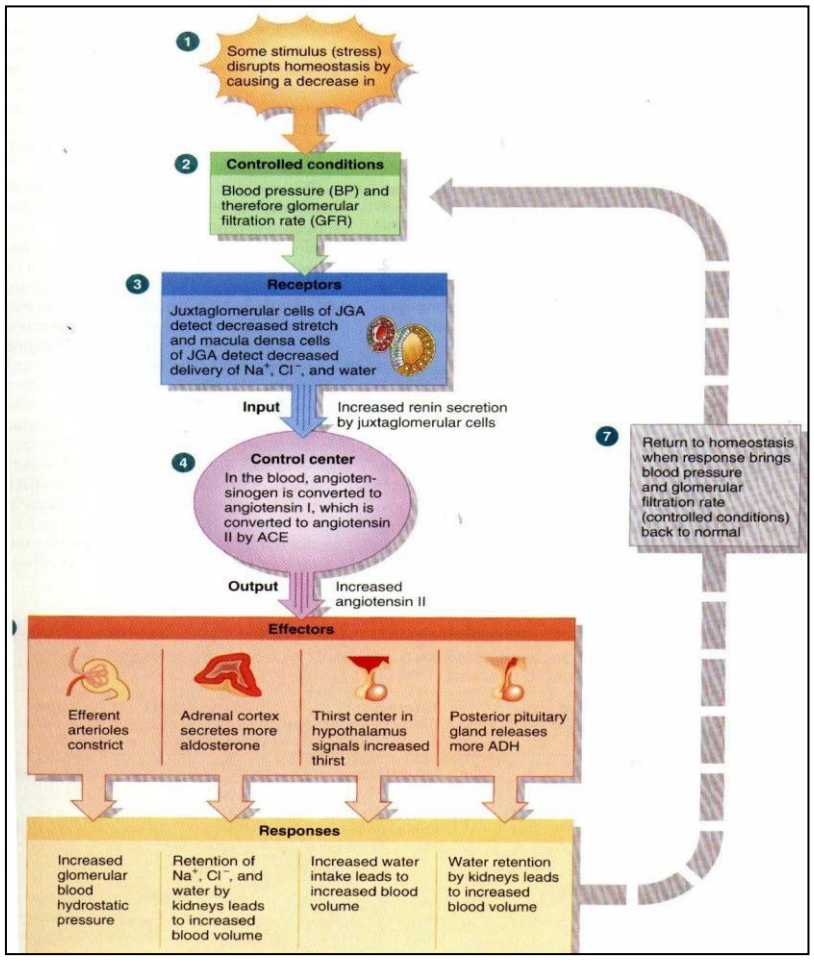
Angiotensin II has several important actions

- Potent vasoconstriction (increases blood pressure)
- Stimulate aldosterone production (increases blood volume)
- Acts on thirst centres in hypothalamus to increase thirst (increases blood volume)
- Stimulates the release of ADH which increases water reabsorption (increases blood volume)
- Renin – Angiotensin System

Endocrine/Metabolic Functions

- Important site of gluconeogenesis (synthesis of new glucose molecule in times of stress and starvation)
- Secretion of erythpoietin stimulated by low oxygen (stimulates the differentiation of red blood cells)
- Participated in the synthesis of calcitriol (Vitamin D important in calcium metabolism)

Fig.4



Vander AJ, Sherman J, Luciano DS(2003). Human Physiology: the Mechanisms of Body Function, 9th Ed. McGraw-Hill Education, London

Review Questions

1. What is the functional unit of the kidney?

2. The kidney is internally divided into three layers. The cortex,_____, and pelvis.

3. The three processes by which urine is produced are filtration, reabsorption and
_____

4. In which region of the nephron does filtration occur? _____

5. In which region of the nephron does the majority of reabsorption occur? _____

6. In which region of the nephron does secretion occur mainly? _____

7. The kidneys main function is the production of urine. Name two other functions of the kidney?

8. What is the primary effect of ADH?

9. Describe the two main actions of angiotensin II.

10. Describe the effect of atrial natriuretic hormone.

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