Audio Course in Physiology
With relevant Anatomy

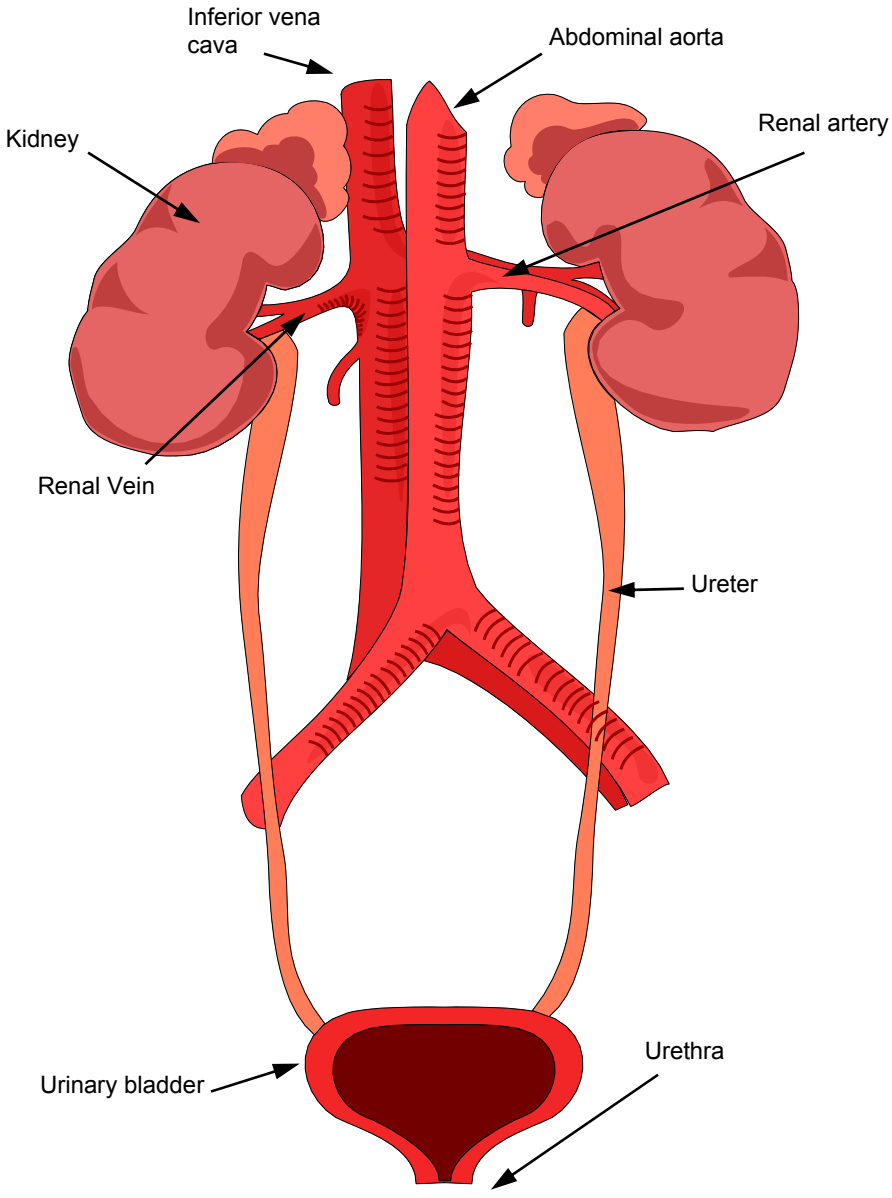
The Urinary System

courses@plaskett-international.com
www.plaskett-international.com

The Urinary System

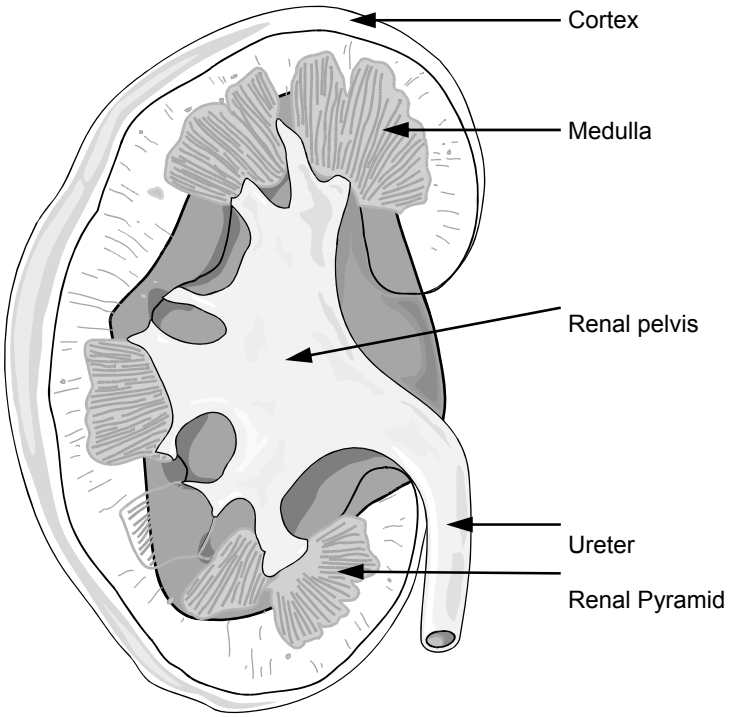
START OF TRACK ONE (*3:15*)

THE URINARY SYSTEM—MAIN STRUCTURES—SLIDE NO 1



END OF TRACK ONE

Longitudinal Section of a Kidney—Slide No 2



The cortex is granular. The medulla comprises concentrations of ducts or striations (grouped into renal pyramids) which empty into to the central area or renal pelvis.

The function of the kidney begins with filtration of the blood.

START OF TRACK TWO(*12:55)*

Kidneys receive about 1.1 litre/min of blood flow – a larger fraction of cardiac output than the brain. It represents as much as 20% of cardiac output.

The process is one of filtration of the blood plasma. The filtration rate is 200 litre/day or 8.333 litre/hr or 139ml/minute. About 99% of filtered plasma is reabsorbed – urine only accounts for 1-2ml/min or 1440-2880ml/day. Fluid is needed to dispose of body toxins.

END OF TRACK TWO

START OF TRACK THREE (*10:09)*

Sodium is retained very efficiently. Sodium is an essential mineral and it is necessary to maintain a high sodium concentration in the blood. It is difficult to produce a sodium deficiency even when on a low sodium diet (e.g. one comprising solely of plant foods such as cereals, pulses and some fruits) because the kidneys are so adapted as to produce sodium free urine. However, sodium loss can occur through diarrhea and vomiting. Excessive sodium consumption is the problem of the modern western diet.

END OF TRACK THREE

START OF TRACK FOUR (*12:19)*

The three main function of the kidneys are:

1. Excretion of urine, comprising: urea, uric acid, creatinine, ammonia, phosphate, sulphate, some chloride (depending on intake).
2. Homeostasis of the body fluid volume and solute composition – balancing dietary intake of water and mineral ions, chloride, sodium, potassium and calcium.

END OF TRACK FOUR

START OF TRACK FIVE (*4:55)*

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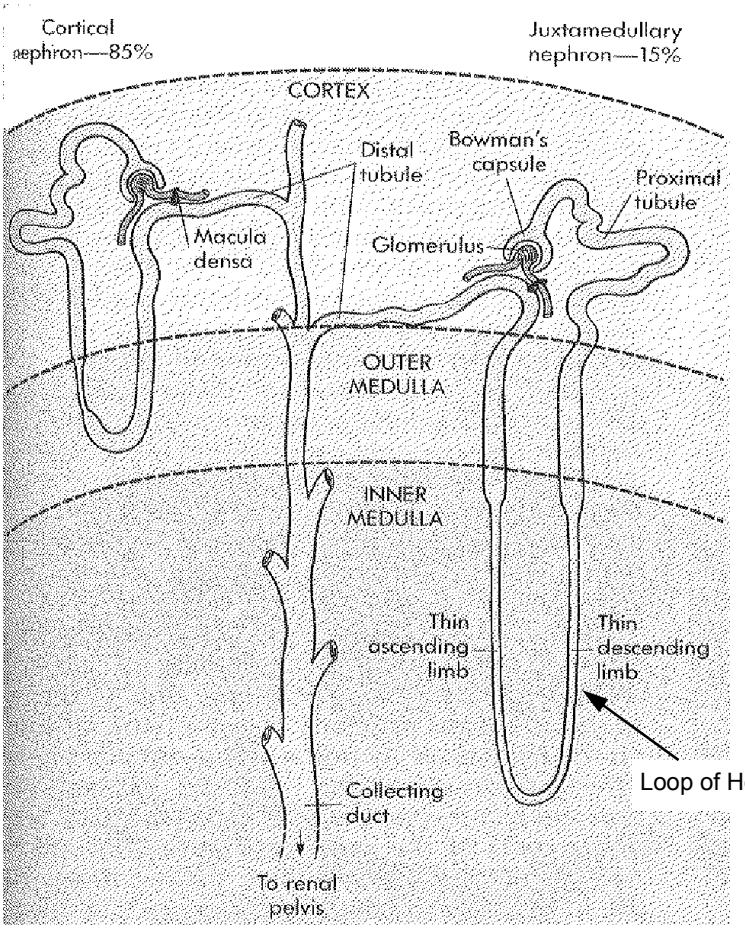
3. Control of the plasma pH.

Without kidneys or with kidneys in chronic failure people only last a few days whilst solutes and toxins accumulate. Such people need dialysis to survive.

END OF TRACK FIVE

The Type Types of Nephron (functional kidney unit)—Slide No 3

START OF TRACK SIX (*9:40)*



Each kidney has 1.2 million nephrons

The concept of glomerular filtration—note that most of the blood proteins are held back in the blood by virtue of their molecular weight, which exceeds about 40,000. daltons. What passes out in the glomerular filtrate is a thin fluid containing mostly small molecules present in blood plasma. Thus it is that blood sodium concentration, for example, remains unaltered.

END OF TRACK SIX

START OF TRACK SEVEN (*9:06)*

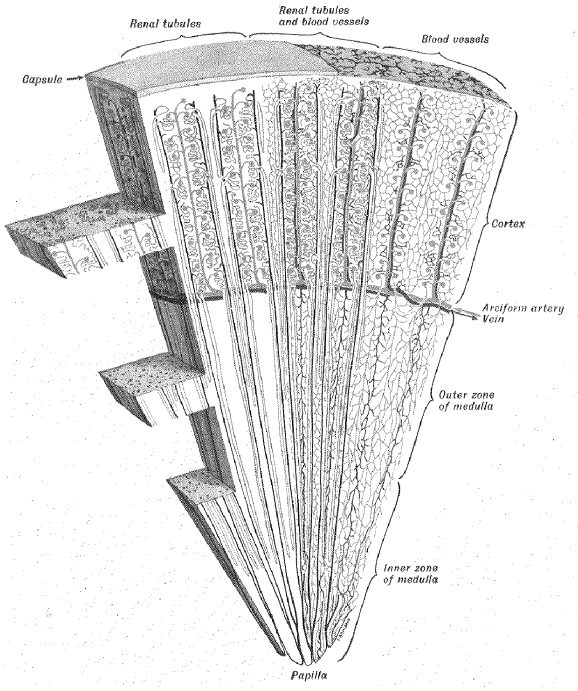
There are two classes of nephron based upon their position within the kidney.
85% are "cortical nephrons".
15% are juxtamedullary nephrons.

Cortical: have glomeruli in the outer cortex – most of their length is in the cortex – only a small portion of the Loop of Henle descends into the outer part of the medulla.

Juxtamedullary: located deeper within the cortex – their Loops of Henle have long thin descending limbs that plunge deeply into the medulla. Ascending limbs have thin walls within the medulla but greater thickness in the cortical region.

END OF TRACK SEVEN

Section of Kidney Showing Layout—Slide No 4

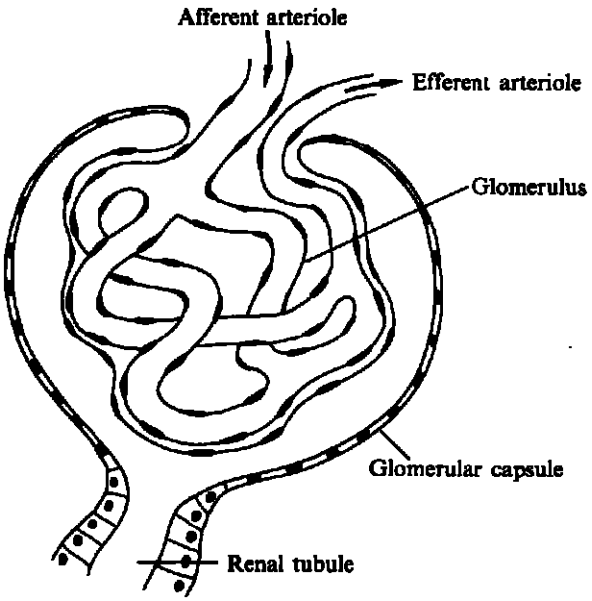


Note distinction between the cortex and medulla. Cortex is very densely populated with glomeruli and associated tubules. Medulla is composed of a mixture of loops of Henle and collecting ducts.

Bowman's Capsule and Glomerulus—Slide No 5

Note that the capsule epithelium is reflected over the outside of the capillaries of the glomerulus (in reality there are many more capillary loops than are shown).

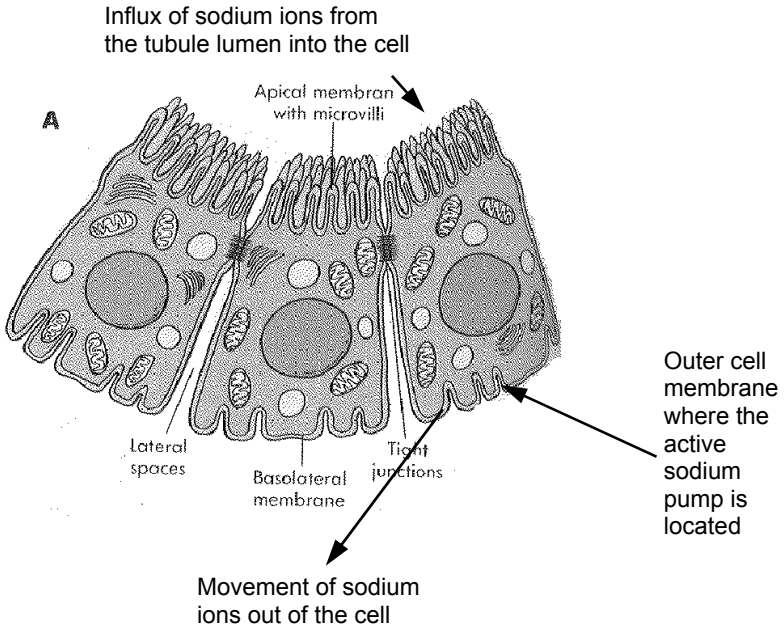
Blood enters the glomerulus by the afferent arteriole and leaves by the efferent. The former is larger than the latter.



The Urinary System

START OF TRACK EIGHT (*17:20)*

Fluid Homeostasis* in the Proximal Convoluted Tubule—Slide No 6



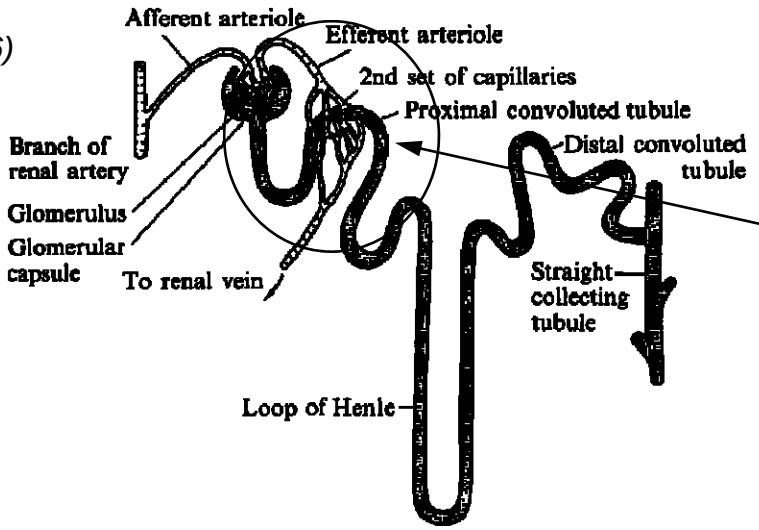
An illustration of the cells of the proximal convoluted tubule that are engaged in the active pumping mechanism that takes sodium out of the convoluted tubule back into the blood stream. This active pump is located in the outer membrane. This therefore pumps sodium ions out of the cytoplasm of the cells into the blood through that outer membrane. A relative dearth of sodium is thus created within the cells and this is filled by a passive influx of sodium ions from the tubule lumen, across the inner cell membrane. In this way the sodium pump of the outer cell membrane sets up a movement of these ions that, as it were "drags" sodium from the tubule lumen right through the cells and into the blood stream. Chloride ions have no option but to follow, being "dragged" through the cell In their turn. If this did not happen a grossly uneven distribution of electrical charge would occur.

In addition to sodium and chloride, various other solutes are absorbed by active transport mechanisms. There are 5 or 6 different such mechanisms accounting for the 20 amino acids. Such substances have a transport maximum. Glucose (with a blood concentration of 80—100 mg/100 ml) is recovered in this way. 375 mg/min is the saturation threshold, after which glucose will end up in the urine—a wasted resource.

END OF TRACK EIGHT

*__Homeostasis__: automatic self-regulation of the body to maintain the normal state under variations in the environment.

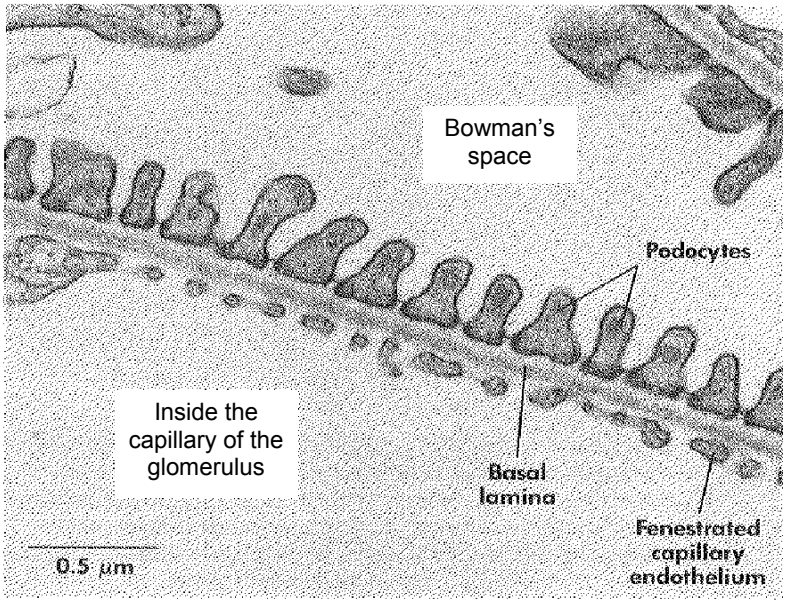
START OF TRACK NINE (*11:06*)



Note that the active secretion of drugs (e.g. penicillin) or toxins takes place in the proximal convoluted tubule.

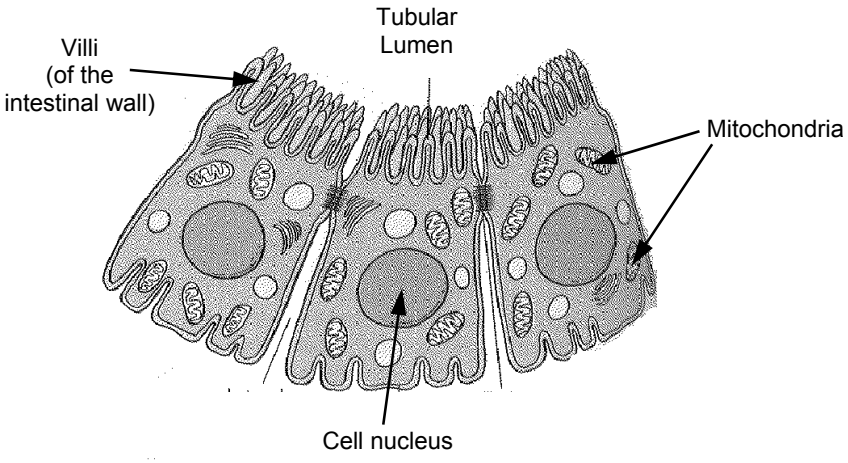
Recovery of hormones is also important in this region.

Membrane of the Capillary Wall inside the Glomerulus—Slide No 7

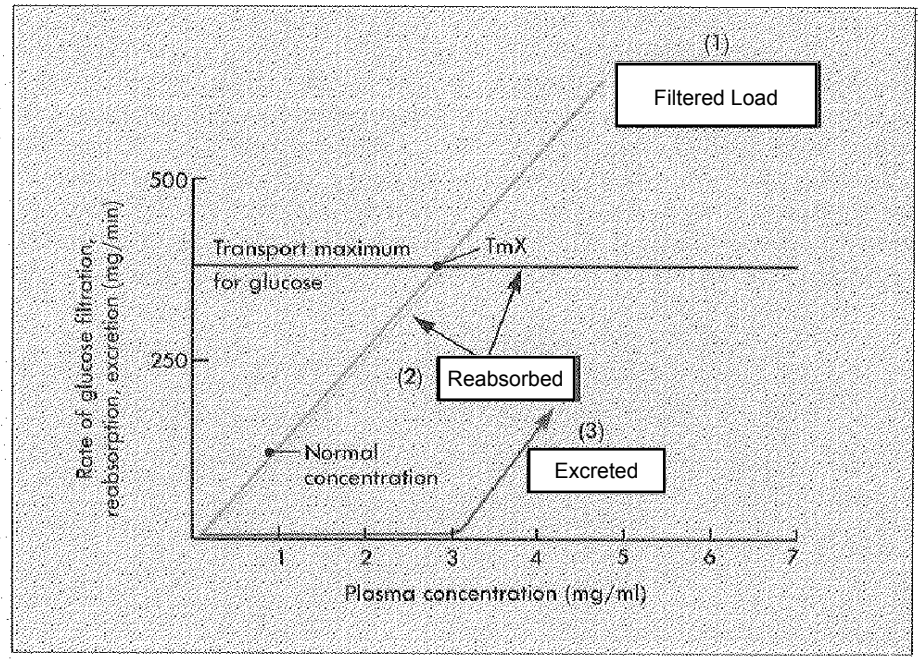


High power magnification showing semi-permeable membrane through which filtration occurs.

View of the Cells of the Convoluted Tubule—Slide No 6



The Relation of Glucose Reabsorption and Excretion to Plasma Glucose Concentration—Slide No 8



Curve 1—the filtered load of glucose depends upon plasma glucose concentration. The filtered load rises at the same rate as the plasma concentration, i.e. it is directly proportional.

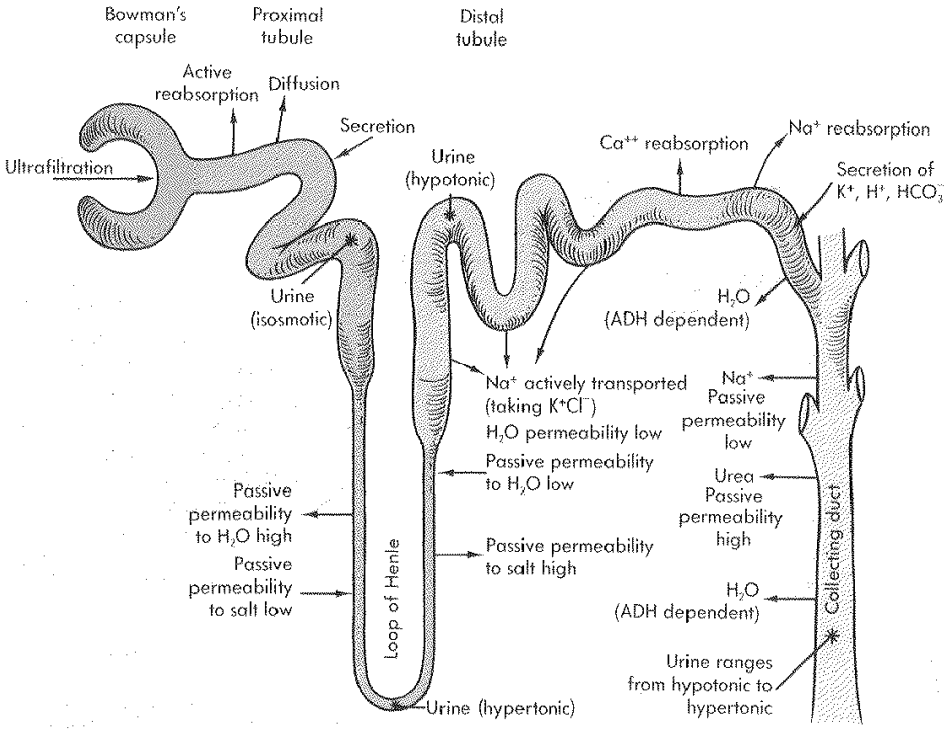
Curve 2 shows how the rate of glucose reabsorption depends in part upon plasma glucose concentration. Reabsorption equals the filtration rate up to a certain value and then does not increase any further.

Curve 3 shows how glucose excretion depends upon plasma glucose concentration. The rate remains negligible until a certain value of plasma concentration is reached, called the threshold value. Then it increases in proportion to any further increase in plasma concentration.

END OF TRACK NINE

START OF TRACK TEN (*9:40)*

The Major Sites of Solute and Water Movement Across the Nephron—Slide No 9



Follow the commentary round the nephron, referring to the chart above. In particular note that by the time the fluid reaches the start of the collecting duct the fluid is hypotonic (weaker than the plasma strength) and much of its remaining solute is urea. The collecting duct continues to dispose of Na+ but at a low rate. But water cannot necessarily pass. The permeability of the collecting duct is determined by antidiuretic hormone (ADH or vasopressin).

ADH increases water permeability by opening water channels in the membrane of the epithelial cells. Water passes out but not solute, into the hypertonic medullary fluid (i.e. the fluid that surrounds the part of the nephron that is in the kidney medulla). When ADH is very high, so much water passes out that the urine concentration approaches that of the medullary fluid. In the absence of much ADH most of the remaining water stays in the duct and dilute urine is produced. Diabetes insipidus ensues when there is a malfunction of the posterior pituitary and ADH is therefore lacking.

END OF TRACK TEN

HELPFUL DEFINITIONS

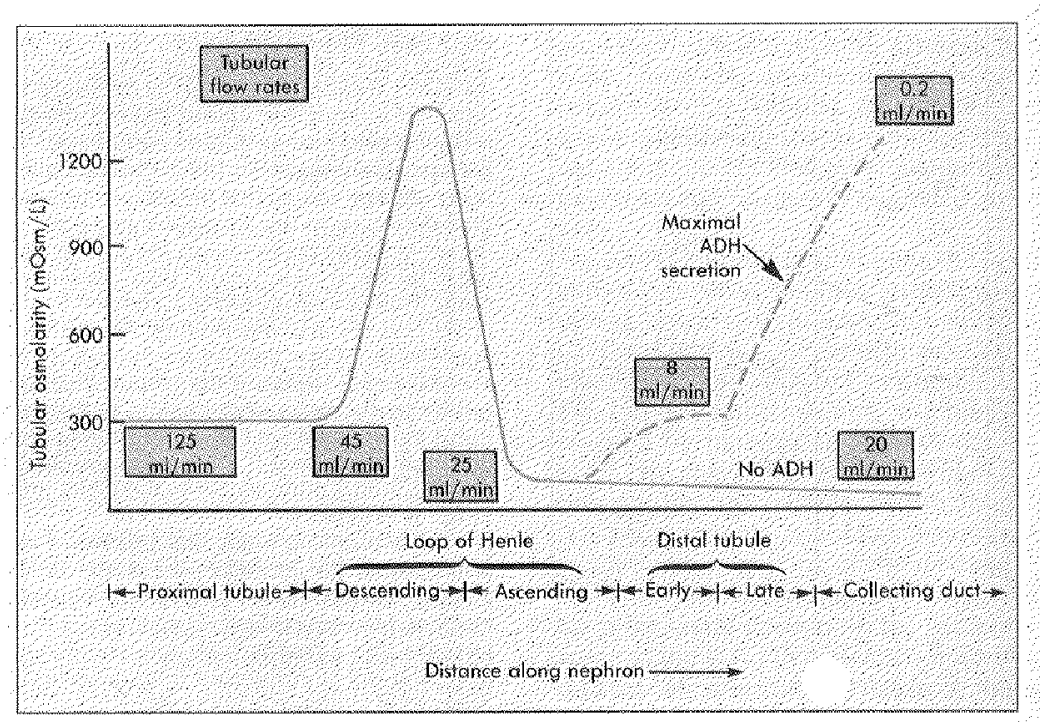
Osmosis—the passage of a pure solvent from a solution of lesser to one of greater solute concentration when the two solutions are separated by a membrane which selectively prevents the passage of solute molecules but is permeable to the solvent.

Osmotic pressure—the pressure generated to move the solute

Osmolarity—the concentration of osmotically active particles in solution.

START OF TRACK ELEVEN (*7:32*)

Osmotic Pressure and Volume Flow Changes Along the Nephron in the Presence and Absence of ADH—Slide No 10



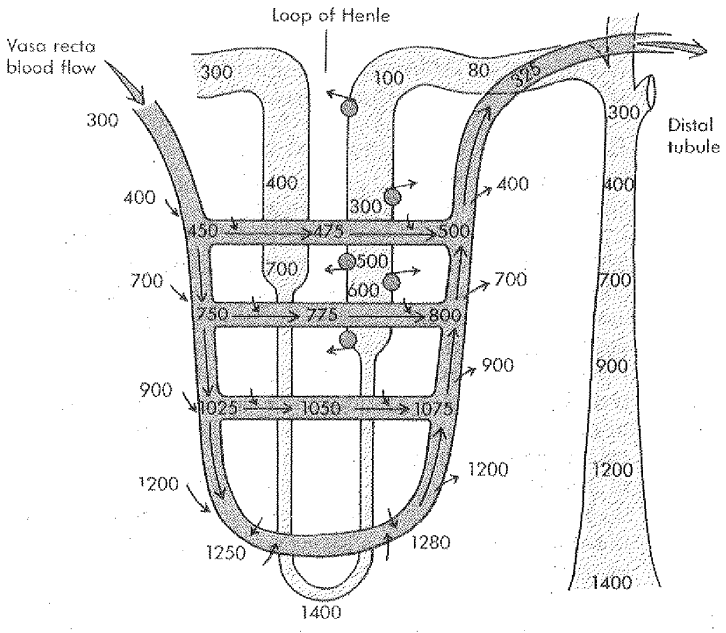
Line plots the strength of the solution present in the tubule as it moves from the left hand to the right side of the chart.

It shows that In the proximal tubule the total concentration of the solute does not change. Then in the Loop of Henle concentration sores, coming down again as the fluid rises up in the ascending limb. After that a low level of fluid concentration is evident, depending upon the secretion of ADH—if present see dashed curve, if absent see solid line.

END OF TRACK ELEVEN

START OF TRACK TWELVE (*14:59*)

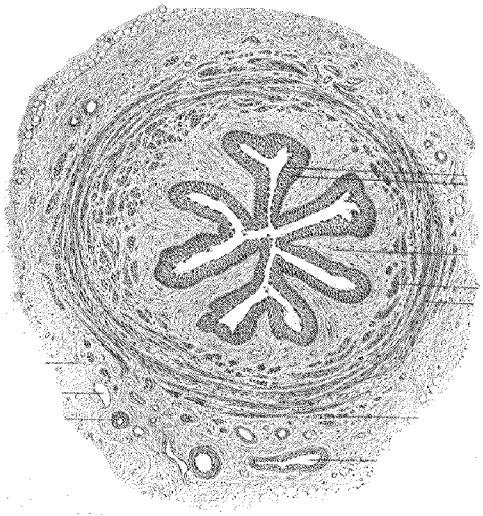
Units of Osmolarity in Loop of Henle, Distal Tubule and Collecting Duct—Slide No 11



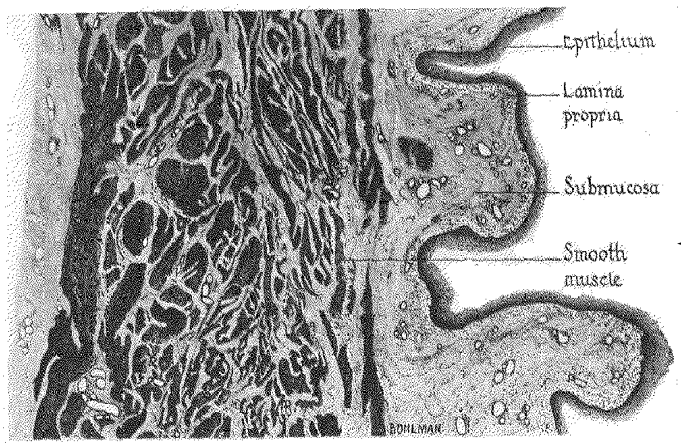
Renal Handling of some Representative Solutes					
Substance	Plasma Concentration	24-hour Filtered Load	Actively reabsorbed (R)/ secreted (S)	Typical per cent of filtered load excreted	24-hour clearance (litres)
Glucose	100 mg%	174 gm	R	0	0
NA^+	142 mEq/ L	24.7 Eq	R	1	1.7
Urea	30 mg%	47.5 gm	variable	60	105
Phosphate	2 mEq/ L	348 mEq	R	20	35
K^+	5 mEq/ L	518 mEq	R + S	10	17
H^+	$10^{(-4)}$mEq/ L	O.1 mEq*	S	800*	1394
Bicarbonate	24 mEq/ L	4.2 Eq	variable	0	0
Cl^+	103 mEq/ L	18 Eq	R	1	1.7
Creatinine	1 mg%	1.4 m	neither	100	171
* Essentially all H^+ loss is the result of tubular secretion					

START OF TRACK THIRTEEN (*7:20)*

END OF TRACK TWELVE



CROSS SECTIONAL VIEW OF THE URETER – SLIDE NO 12



VIEW OF CONTRACTED URINARY BLADDER—SLIDE NO 13

END OF TRACK THIRTEEN

Addendum to recording

Acid-based Regulation

The western diet is highly acid-producing. Carbon dioxide from respiration is responsible for one of the acids, namely carbonic acid, which is formed from it in the blood. However, you can ignore the carbon dioxide from the standpoint of long term addition to body acidity. So long as the cardiovascular system and the respiratory system are working properly the carbon dioxide is expelled from the lungs and cannot affect acidity in the longer run.

About 70-100mM/day (millimoles) of fixed acids – hydrochloric, phosphoric and sulphuric are produced daily on this kind of diet from sulphur amino acids, phospholipids and other sources.

Active secretion of hydrogen ion by tubular epithelium occurs in proximal tubule, cortical collecting tubule and collecting duct , enabling the body to excrete excess acid.

Filtered bicarbonate in the kidney tubules is converted to carbon dioxide by carbonic anhydrase and this diffuses in solution out into the blood. The enzyme is located on the apical surface of proximal tubule cells. Under normal conditions almost all of the 4 moles of bicarbonate filtered each day is recovered in that way. This reabsorption is a component of the overall acid-base regulation.

Upon hydrogen ion being secreted by the tubules it is buffered in the urine by phosphate. In making the hydrogen ion the kidney releases bicarbonate into the blood, rendering it relatively more alkaline.

Ammonia—The body transports ammonia that comes from the breakdown of amino acids, to the kidney as glutamine. When this glutamate is broken down it yields up two molecules of ammonia. These form ammonium ions, NH_4+, with free hydrogen ions, H+. An equilibrium is set up between H+ and NH_4+ and at lower pHs, like about 5.5, there is considerable NH_4+.

Book reference—Ross & Wilson page 346

Mechanisms of Action of Diuretic Drugs

Drugs that bring about a diuresis are used principally to reduce blood volume in the treatment of congestive heart failure, pulmonary oedema, cerebral oedema and hypertension. There are several different types. These work in different ways any by mentioning these mechanisms one sees a little further into how the kidney works. These are:

Osmotic diuretics, eg mannitol. Mannitol works to promote extra production of urine because it cannot be re-absorbed tubules and thereby it limits the absorption of water. In the process this makes sodium absorption more inefficient. This is typically used in cerebral oedema.

Thiazide diuretics. These diuretics work by inhibiting sodium transport. Unresorbed sodium acts like an osmotic diuretic. This is used principally in hypertension.

Some diuretics, like **acetazolamide**, work by inhibiting bicarbonate re-absorption. But in this process the blood gets more acid. These are relatively little used.

Loop diuretics. These inhibit solute re-absorption at the top of the ascending Loop of Henle. This results in potassium loss and extra potassium may have to be given to compensate. An example is Frusemide. It used mainly for breathlessness with pulmonary oedema due to left ventricular failure or longstanding heart failure

Some non-drugs known for diuretic properties are inhibitors of antidiuretics hormone (ADH) secretion, eg alcohol or caffeine.

ASSESSMENT ON THE URINARY SYSTEM

1. Produce your own diagram of the urinary system showing the main structures and the main blood vessels supplying the kidneys. (Do not spend too much time on this or the following sketch.)

2. Draw a sketch of the longitudinal section of the kidney and label the main structures that one would expect to be exposed.

3. In terms of its microstructures, what distinguishes the kidney cortex and its function from the medulla and its function?

4. What are the consequences of inadequate fluid intake?

5. It is stated that the kidney retains sodium very efficiently. What situations therefore, could lead to a sodium deficiency, given a normal sodium-rich westernised diet?

6. A vital function of the kidneys is the extraction of compounds of nitrogen formed via the breakdown of proteins into amino acids. How is this dealt with in the body, and why does this have such importance when considering Westernised-eating habits?

7. Explain the mechanism for blood glucose recovery in the kidney and how this changes in diabetes mellitus. How does kidney function change in the case of diabetes insipidus?