Q9 Describe how the kidney maintains the medullary concentration gradient (March 2011)

The medullary concentration gradient is a physiological process, which produces a concentration gradient of up to 1400mOsmol/kg from the renal cortex through to the medulla. This enables the variable concentration of urine in order to maintain body water homeostasis. It is achieved through 2 main processes:

1. COUNTERCURRENT MECHANISM

a. Countercurrent multiplier →

- All tubular fluid enters at the proximal tubule at the same osmolality as plasma (300mOsmol/kg)
- There is active transport of solutes out of the ascending loop of Henle via the triple symporter, creating a gradient of 200mOsmol across the membrane. This portion of the tubule is impermeable to water movement.
- Fluid entering the proximal tubule and thin descending limb of Loop of Henle is now hypo-osmotic compared to the interstitium, favouring water movement out of the tubule, rendering the luminal fluid now entering the hairpin turn hypertonic
- Process repeats with further solutes reabsorbed in the TAL such that the osmolality of both luminal fluid and interstitium around the hairpin turn rises, falling significantly by the early distal tubule

b. Countercurrent exchanger

- Blood supply to the renal medulla is via vasa recta, a thin network of capillaries with slow blood flow that descends from the cortex to the medulla then loop back up to the cortex
- The vasa recta are permeable to water and solutes
- On the descent, the vasa recta resorb solutes from the medullary interstitium and secrete water into it. On the ascent, the solutes diffuse back into the interstitium and water moves back into the vessel → hence vasa recta do not wash away the concentration gradient

2. ROLE OF UREA

- Urea is a breakdown protein of amino acid metabolism that is freely filtered at the glomerulus
- Filtered urea is reabsorbed within the thick ascending limb as well as in the renal medulla, where it is actively reabsorbed by UT-A1 and UT-A3 (the latter under the influence of ADH).
- Some urea diffuses back into the thin ascending limb of the LOH → urea recycling
- The presence of urea in the interstitium contributes approximately half of the medullary concentration gradient.

The final concentration is dependent on the length of the loop, flow of luminal fluid and the capacity of the active pumps in the thick ascending limb. The result of the concentration gradient is that the kidney is able to produce urine with a concentration of up to 1400mOsmol in the presence of ADH. In the absence of ADH, a large amount of dilute urine will be excreted.