SODIUM BALANCE

1. What is the major distribution of sodium in the body?

Sodium is the major extracellular cation of the body:

- 50% is found in the ECF
- 45% found in the bone
- 5% in the intracellular compartment
- Note that 70% of this ion is found in a readily-exchangeable form

2. What is the major physiological role for this ion?

This is the ion that generates the greatest osmotic force. For this reason, it is vital for the internal water balance between the intracellular and extracellular spaces. The osmolality that it generates also influences the control of the ECF volume that is under renal control.

This osmotic role occurs because this ion is so abundant in the body.

3. What is the daily sodium requirement?

1 $mmol kg^{-1}$ per day.

4. Give some causes for hyponatraemia.

- *Water excess*
  - *Increased intake:* polydipsia, iatrogenic, e.g. TURP syndrome, excess administration of dextrose
  - *Water retention:* syndrome of inappropriate ADH (SIADH)
  - *Retention of water (with a bit of salt):* nephrotic syndrome, cardiac failure, hepatic failure
- *Water loss (with greater sodium loss)*
  - *Renal losses:* diuretics, Addison's disease
  - *Gut losses:* diarrhoea, vomiting

- *Pseudohyponatraemia:* measuring the sodium inaccurately in the presence of hyperlipidaemia

5. What does the *inappropriate* in SIADH refer to?

In SIADH, there is an excessive and pathological retention of water in the absence of renal, adrenal or thyroid disease. The 'inappropriate' refers to the fact that the urine osmolality is inappropriately high in relation to the plasma osmolality.

6. Which conditions may trigger the SIADH?

- *Lung pathology:* pneumonia, lung abscess and TB
- *Malignancy:* small cell carcinoma of the lung, brain tumours, prostatic carcinoma
- *Other intra-cranial pathology:* head injury, meningitis
- *Alcohol withdrawal*

7. What are the causes of hypernatraemia?

- *Water loss*
  - Diabetes insipidus
  - Insufficient intake or administration
  - Osmotic diuresis, e.g. hyperglycaemia
- *Excess sodium over water*
  - Conn's or Cushing's syndrome
  - Excess hypertonic saline

8. What is diabetes insipidus?

This is a syndrome of polyuria with hypernatraemia and dehydration with compensatory polydipsia caused by an insensitivity to (nephrogenic form) or deficiency of (cranial form) ADH. Characteristically, fluid deprivation fails to concentrate the urine.

SODIUM AND WATER BALANCE

1. What are the main fluid compartments of the body, and what are their volumes?

- *Intracellular space:* 28 L
- *Extracellular space:* 14 L
  - *Plasma:* 3 L
  - *Interstitium:* 10 L
  - *Transcellular space:* 1 L

Therefore, the total body water is ~42 L.

2. What are the two main systems of water balance in the body, and what important feature do they have in common?

- *Internal water balance:* this system governs water balance between the intracellular and extracellular compartments. It relies on the balance between the osmolalities of the two compartments
- *External water balance:* this governs the extracellular fluid volume. The point of control is at the plasma-interstitial, and plasma-renal tubule interfaces. The *Starling forces* are important in this system of control
- Both systems are reliant on sodium balance since this is the most osmotically influential ion. It follows that since sodium determines plasma osmolality, it also plays an important role in regulation of the extracellular circulating volume

3. List the hormones that are important in maintaining the ECF volume.

- *ADH:* also known as arginine vasopressin. Produced by the posterior pituitary gland, and increases free water absorption by the collecting duct
- *Atrial naturetic peptide:* produced by the cardiac atria when distended. This has the opposite effect to ADH, but also increases sodium excretion

- *Hormones of the R-A-A axis:* broadly speaking, these have a long-term effect on the control of the circulating volume and arterial pressure
- *Glucocorticoids:* these increase sodium and water reabsorption
- *Catacholamines:* through altering the arterial pressure, they stimulate the release of the hormones of the R-A-A system. These are secreted by renal sympathetic nerves when there is a fall in the renal perfusion pressure

4. How does the body monitor the ECF volume?

Through a series of receptors that monitor the intravascular volumes and pressures.

5. Where in the body are these located?

- *Low-pressure receptors:* baroreceptors are located in the walls of the cardiac atria and pulmonary vessels, and they respond to distension that occurs with an increase in the circulating volume
- *High-pressure volume receptors:* these are baroreceptors located in the aortic arch, carotid sinus and afferent arteriole of the kidney. Also there is the *juxtaglomerular apparatus* of the kidney

6. What is the juxtaglomerular apparatus composed of?

This is formed from three components:

- *The macula densa:* of the thick ascending limb
- *Granular cells of the afferent and efferent arterioles*
- *Mesangial cells:* these act as antigen-presenting cells

7. Why is this structure so important to the control of the circulating volume and sodium balance?

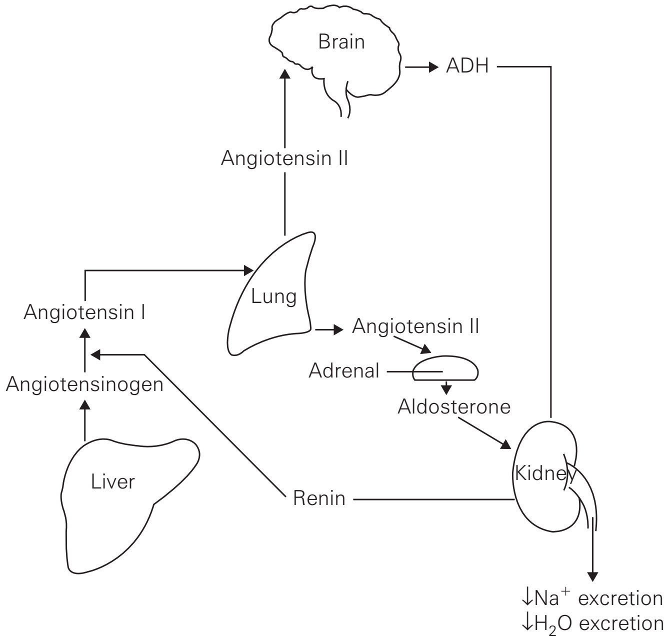
The granular cells of this apparatus produce *renin*, which goes on to initiate the R-A-A cascade.

8. Under what conditions is the R-A-A system stimulated?

The trigger to the release of renin by the juxtaglomerular apparatus is three fold:

- *Fall of renal perfusion pressure:* this is principally detected by the baroreceptors of the afferent arterioles
- *Activation of the SNS:* this occurs when there is a fall in the arterial pressure
- *Reduced sodium delivery to the macula densa:* this also occurs when there is a fall in the renal perfusion pressure

Below is a summary of the components of the R-A-A system



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9. What is the effect of activation of this system?

- Stimulation of aldosterone release by the adrenal cortex, this increases sodium and water reabsorption, helping to maintain the arterial pressure
- Angiotensin causes vasoconstriction, increasing the peripheral vascular resistance, and so the arterial pressure. Resulting vasoconstriction also reduces the GFR at a time when water has to be conserved
- Stimulation of ADH secretion by the posterior pituitary, which leads to increased solute-free water reabsorption and thirst
- Enhanced NaCl reabsorption by the PCT