Kidney – structure and function

Biological principles in action

Learning Outcomes

- 5.4.6 (a), (b) and (d).
- List main components of 3 body fluids
- Describe how to test for glucose, protein and urea
- Describe how to find concentration of urea in a solution
- Determine the urea concentration of a fluid
- Outline the roles of the kidney in excretion and osmoregulation

Kidney – structure and function

- Where are they?
- What are they for?

Roles of the kidney

- excretion
- homeostasis
- osmoregulation
- regulation of salts in the body
- regulation of pH
- production of a hormone (EPO)

Testing Body fluids

- You have three fluids labelled as X, Y and Z
- You are provided with:
  - Clinistix / Diastix
  - Albustix
  - Urease and litmus paper
- Find out what is in each of the three fluids.

Testing Body fluids

- Draw out a flow chart to show how you would identify the following fluids using observations and simple laboratory tests like those you have just used:

whole blood, plasma, serum, tissue fluid (filtrate), urine, bile, saliva.

Urea Determination

Follow the instructions to produce a graph to determine the urea concentration of an unknown solution (U).

Urea Determination

Answer questions (a), (b) and (c) and 8.

Present as a coherent report.

No need to reproduce the instructions, but you may if you wish.

Homework materials

- Today's work sheets
- Homework Exercises
- Useful Links

Go to www.rfosbery-biology.co.uk

Use: life, line, lifeline to enter the site

Click on OHS, username is oxford,

password is soapysam

Kidney dissection

Learning outcomes

- Describe the external features of the kidney
- Describe the position of the kidneys in the body and relationships with blood supply and rest of u/g system
- Draw and label LS kidney
- Recognise different parts of the kidney
- Make a drawing to scale

Kidney functions

- filtration of blood
- selective reabsorption by
  - active transport
  - passive absorption
- secretion

Kidney - structure

Gross structure – what you can see with the naked eye

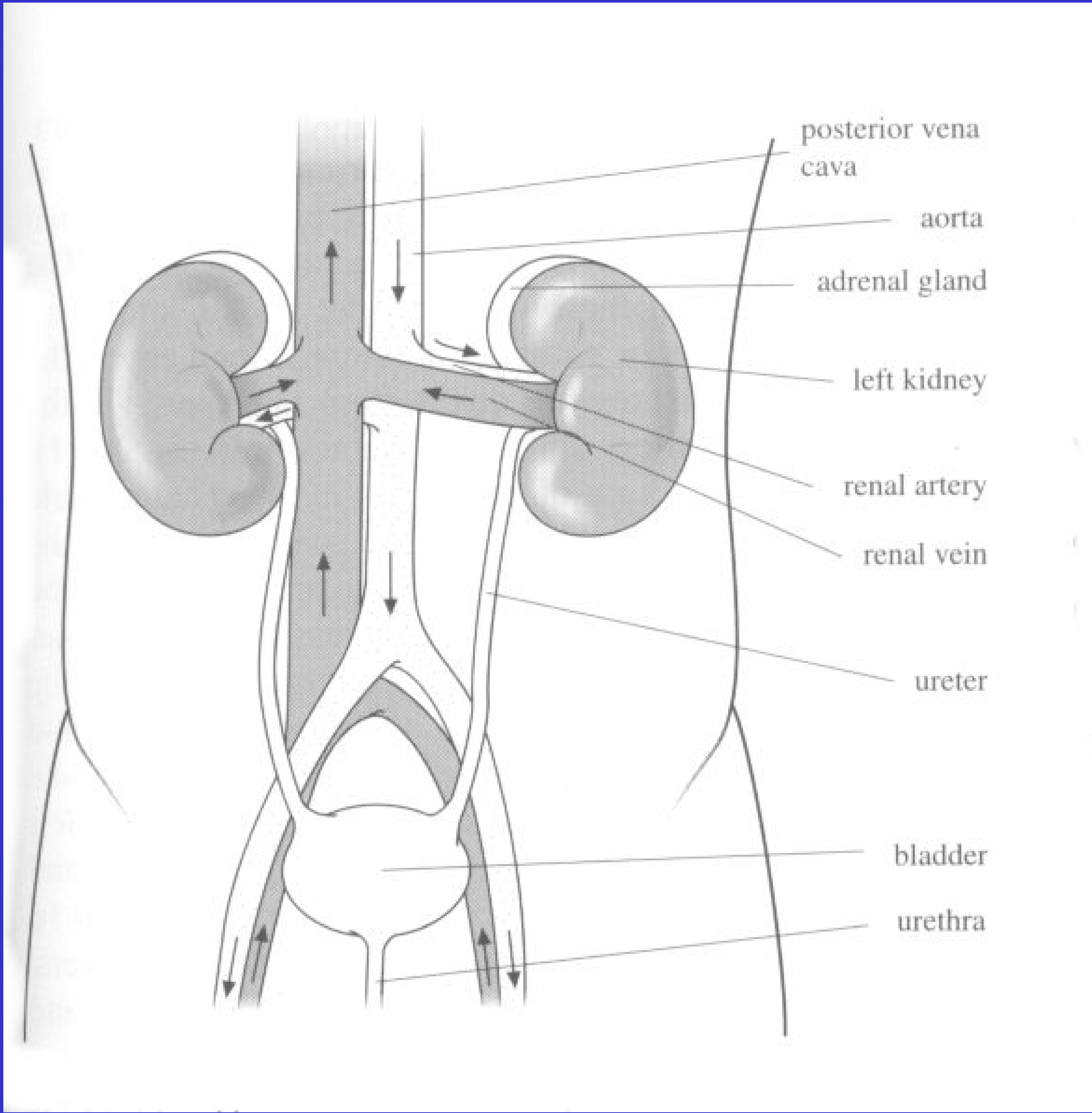
Histology – what you can see through the microscope

Kidney – gross structure

Position of kidneys in the body

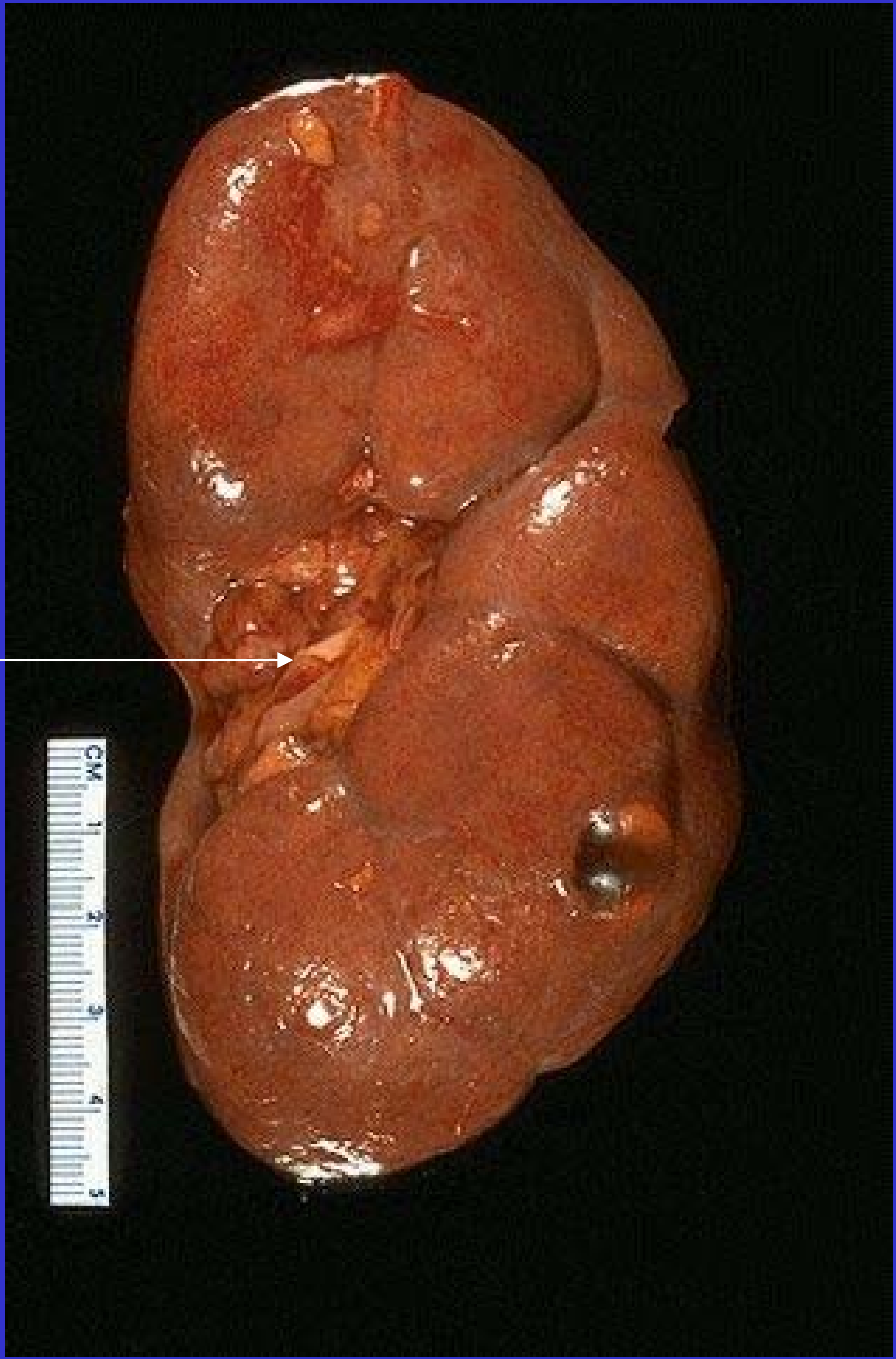
External structure

Internal structure


posterior vena cava
aorta
adrenal gland
left kidney
renal artery
renal vein
ureter
bladder
urethra

Human kidney

ureter
renal artery
renal vein
attached
here



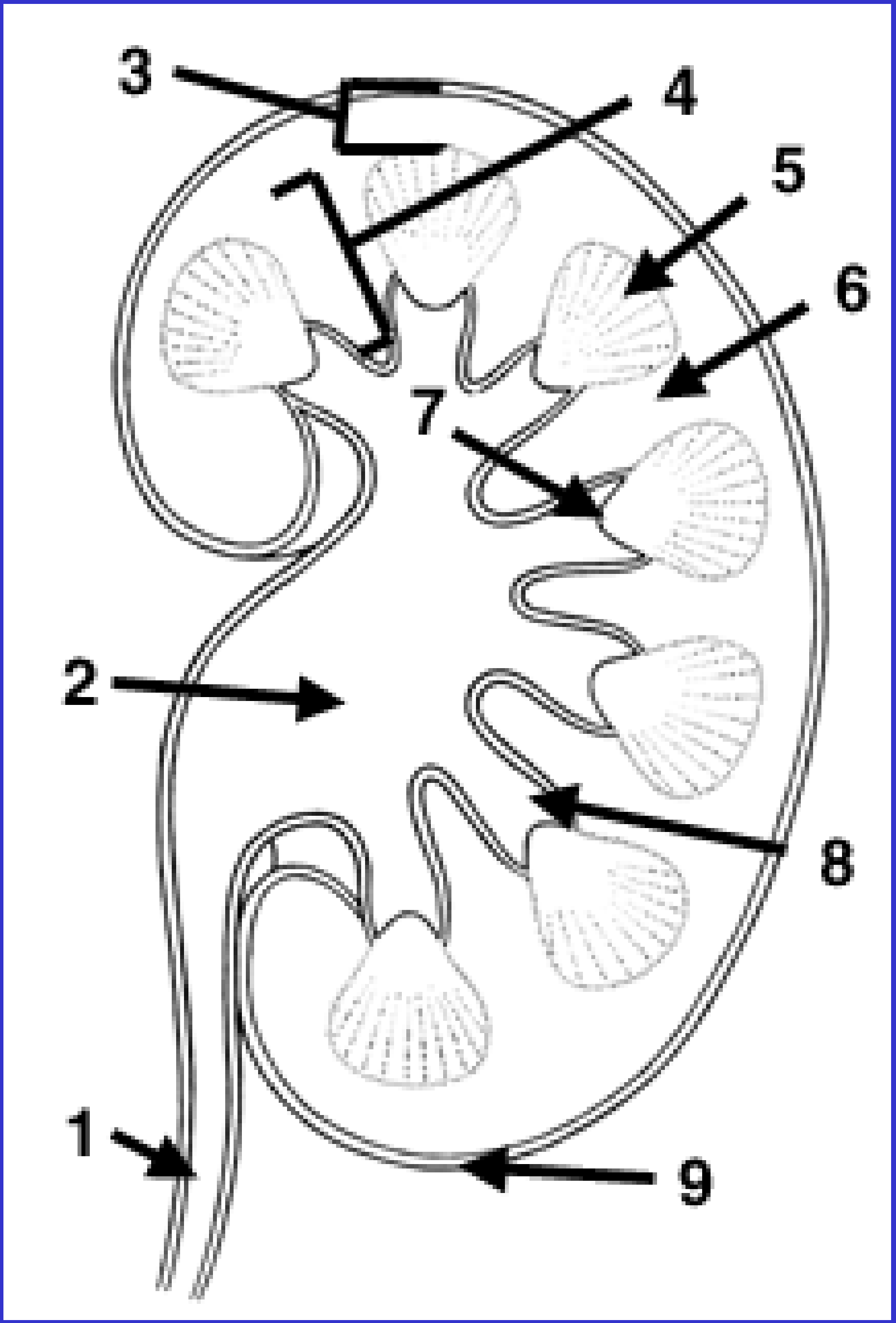
Kidney – vertical section

1 = ureter

2 = pelvis

3 = cortex

4 = medulla



Histology of the kidney

Learning outcomes

- Find cortex, medulla and pelvis under the microscope
- Describe the internal structure of the kidney
- Draw a low power plan
- Draw high power, labelled drawings of Mb, PCT, thick and thin loops, DCT and CD
- Relate structure to function for the above
- Make measurements with graticule eyepiece

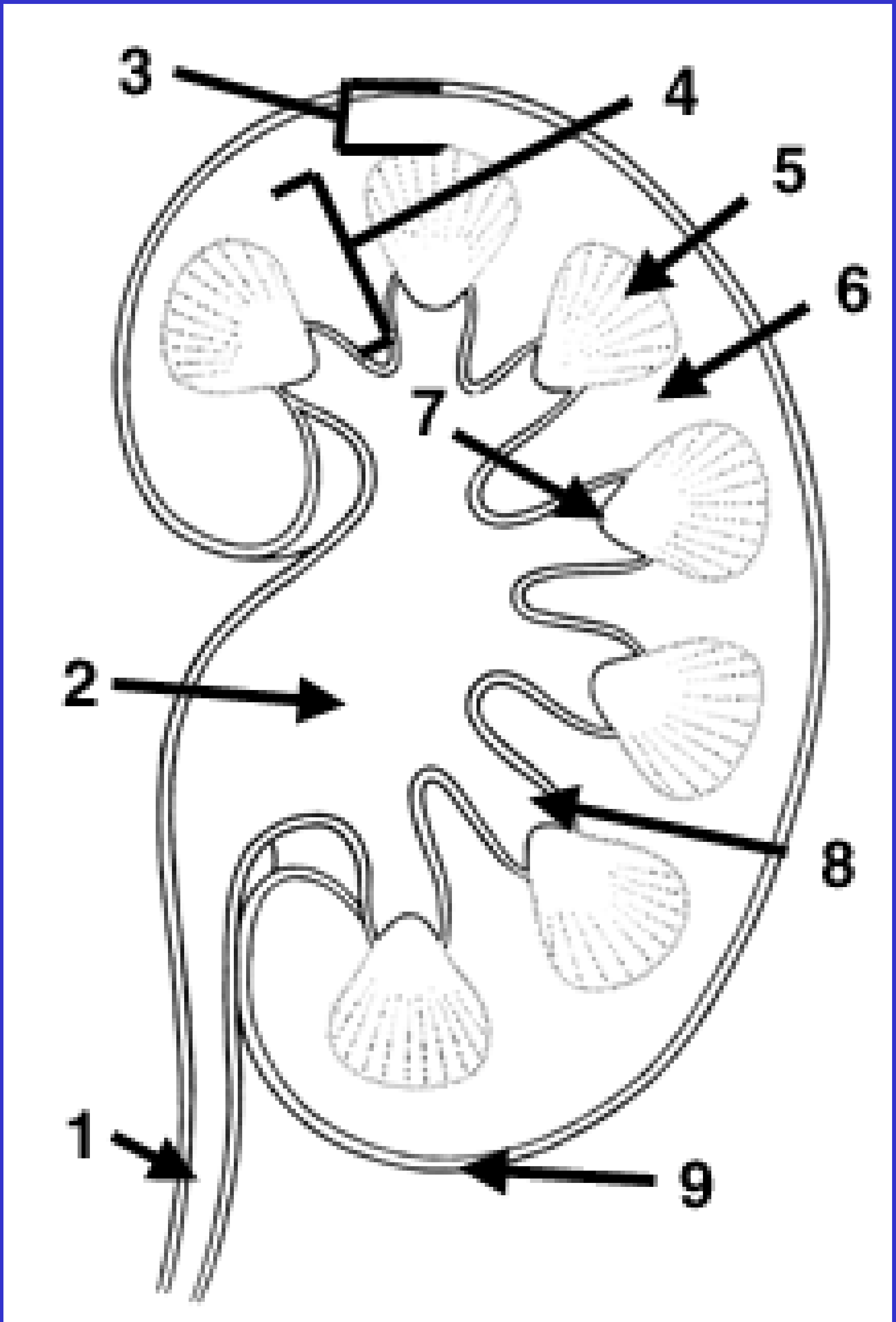
Kidney – vertical section

1 = ureter

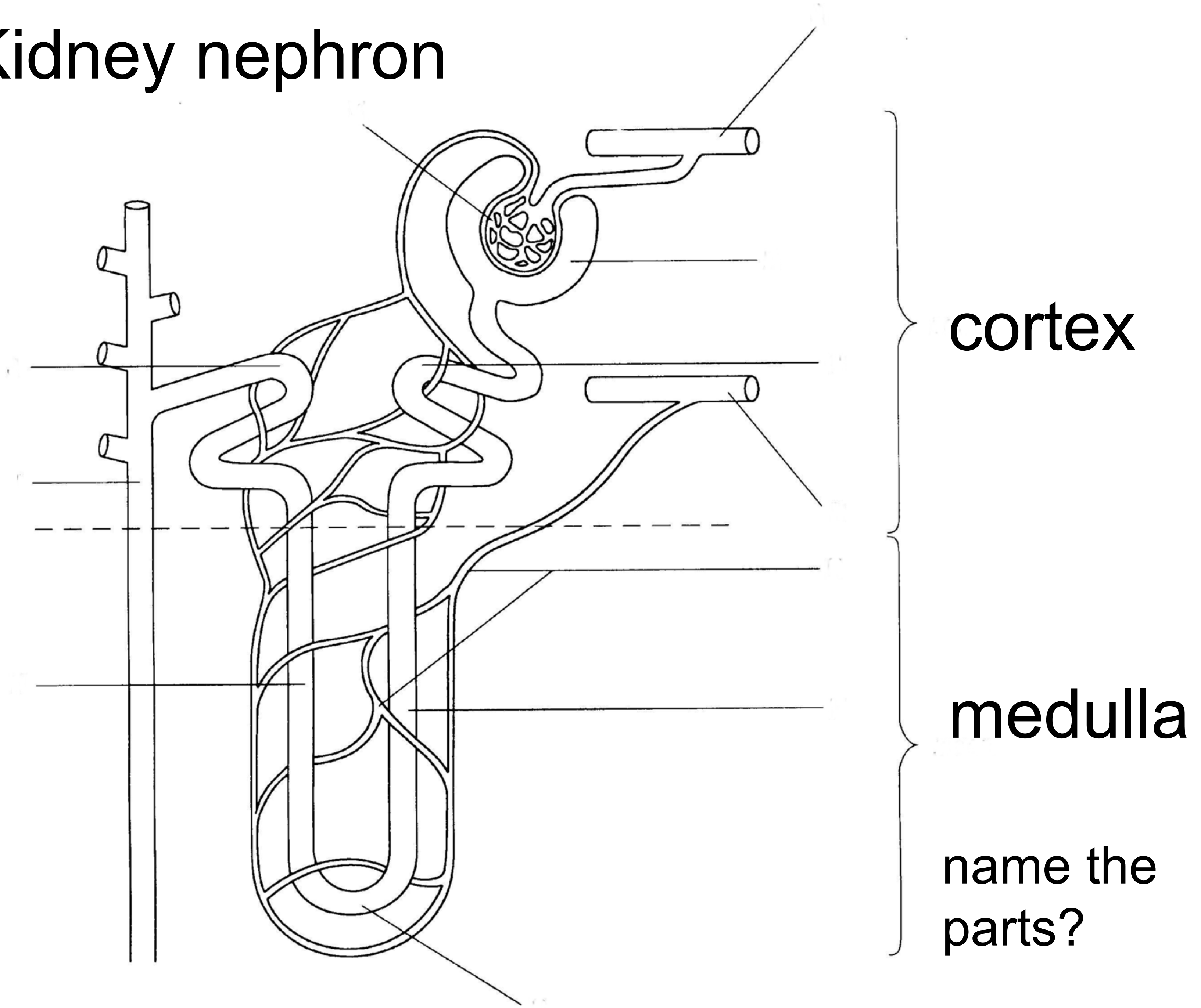
2 = pelvis

3 = cortex

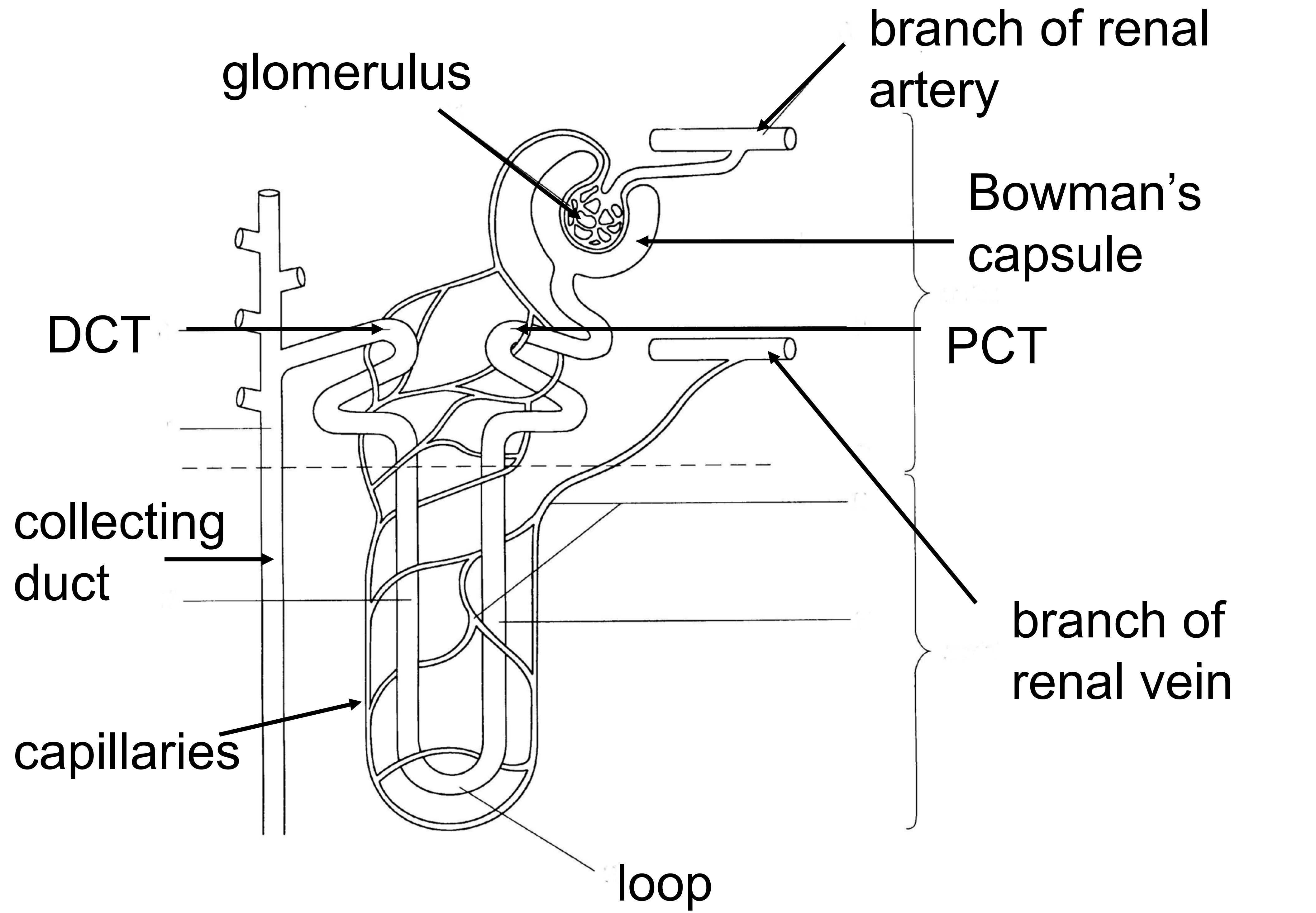
4 = medulla



Kidney nephron



name the parts?



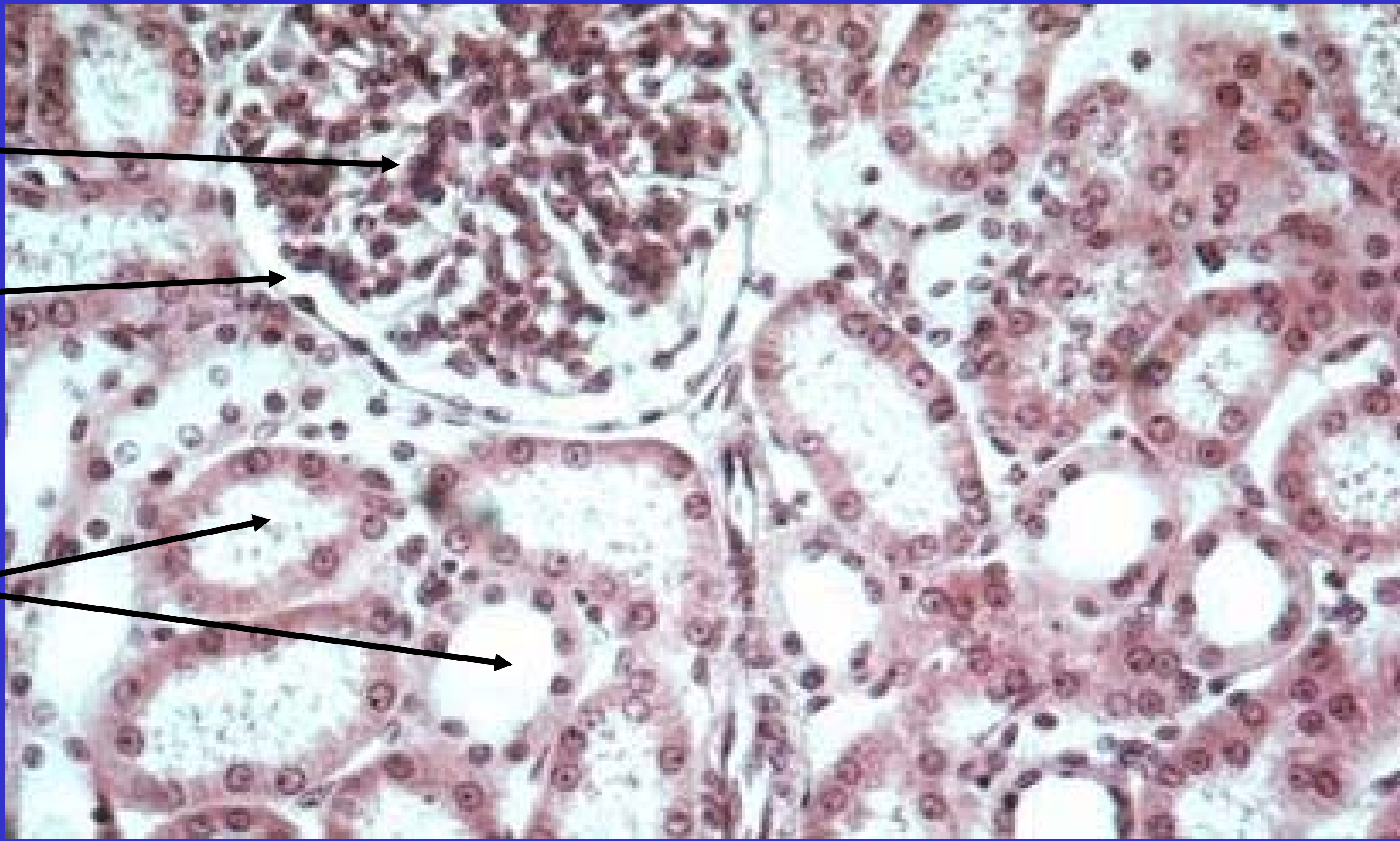
glomerulus
branch of renal artery
Bowman's capsule
DCT
PCT
collecting duct
branch of renal vein
capillaries
loop

Kidney – cortex (LP)

glomerulus

Bowman's capsule

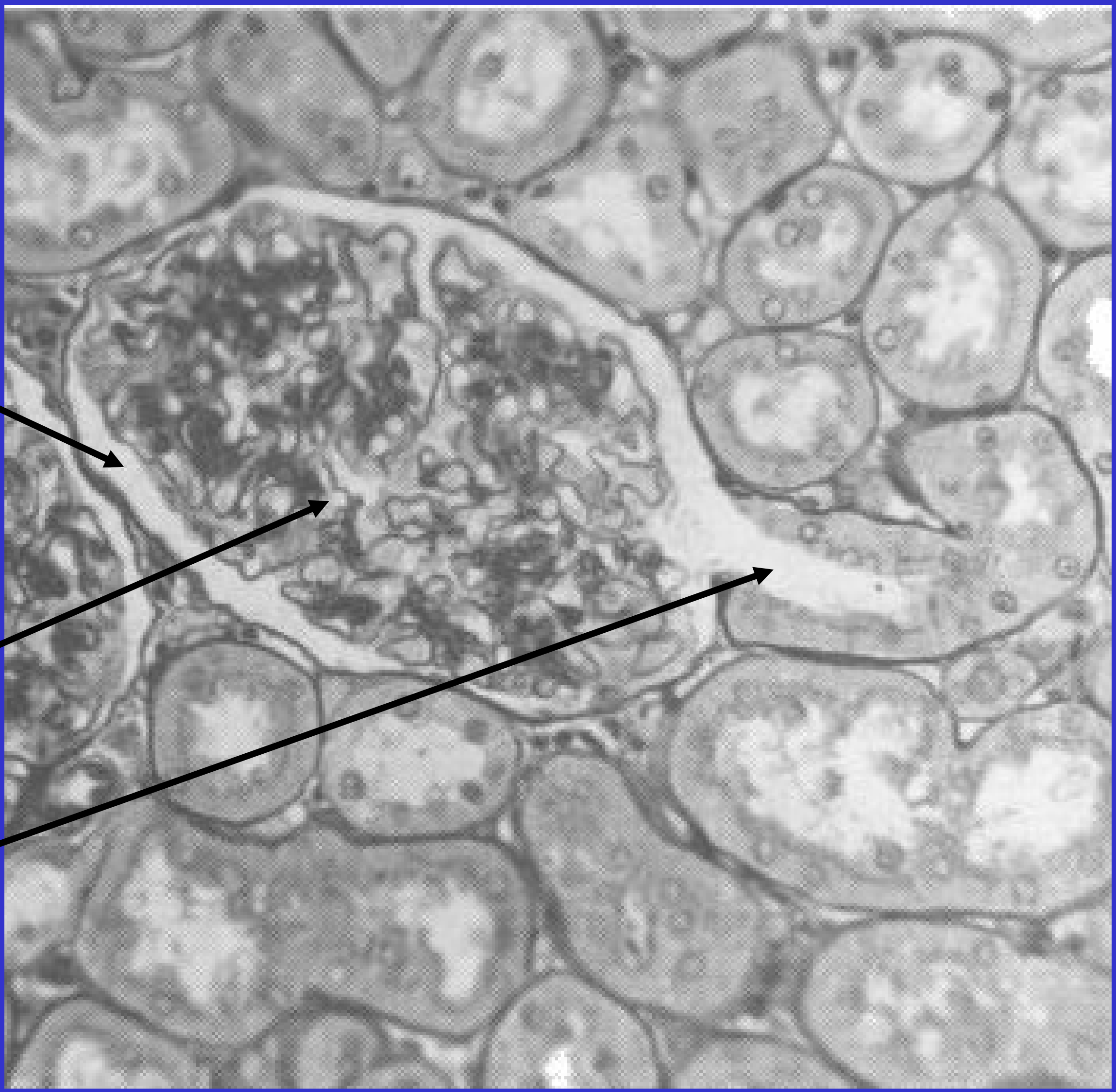
proximal and distal convoluted tubules



Bowman's capsule

Glomerulus

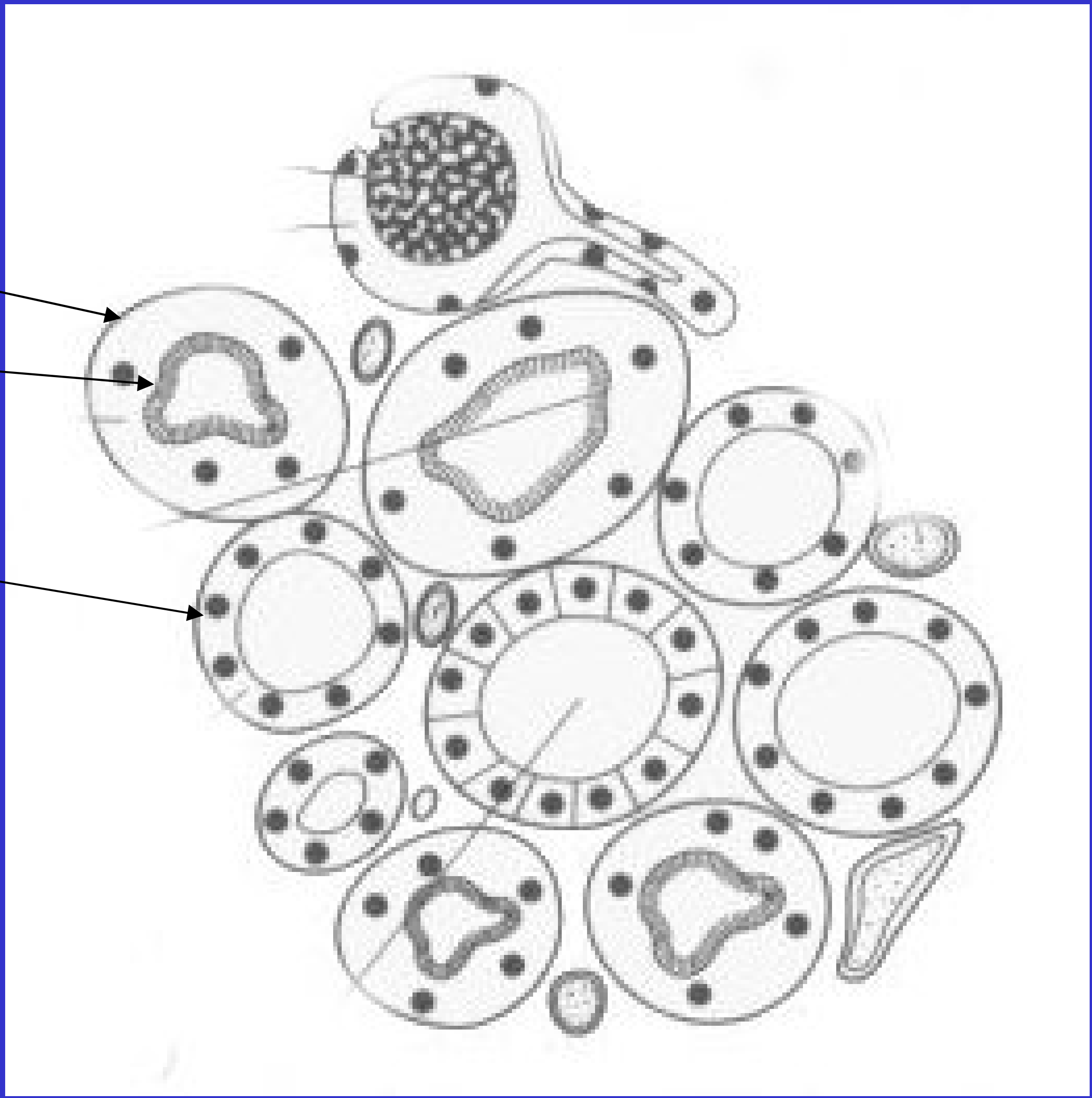
PCT



PCT

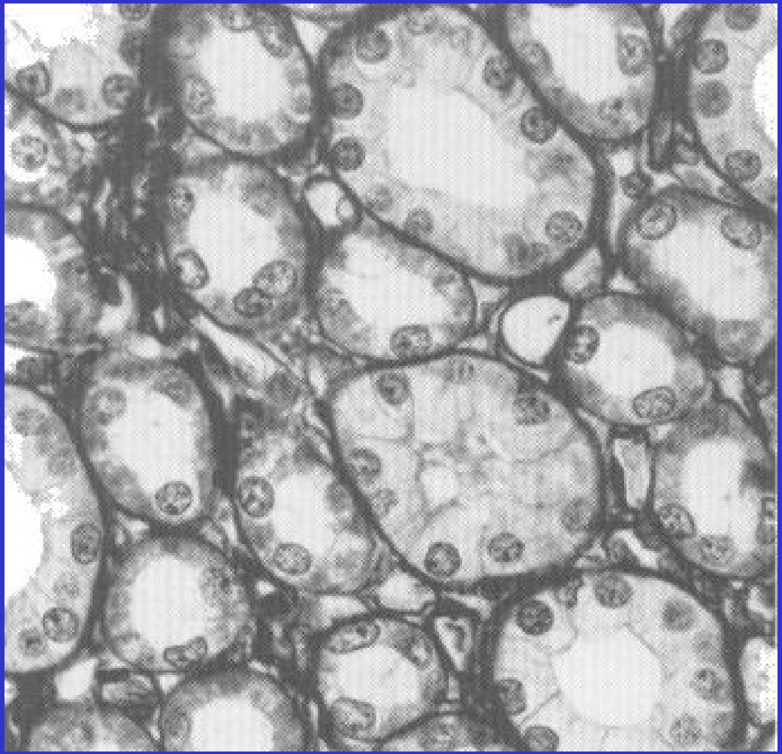
microvilli

DCT



Kidney - medulla

- loops
- collecting ducts
- capillaries



Excretion and the kidneys

Learning outcomes

- State main excretory substances
- Describe production and transport of urea
- Explain why urea is produced
- Explain why [salts] are regulated

Composition of urine

Substance	Plasma / %	Urine / %	Increase
Water	90	95	-
Protein	8	0	-
Glucose	0.1	0	-
Urea	0.03	2	67x
Uric acid	0.004	0.05	12x
Ammonia	0.0001	0.04	400x
Creatinine	0.001	0.075	75x
Na^+	0.32	0.35	1x
K^+	0.02	0.15	7x
Cl^-	0.37	0.60	2x
PO_4^{3-}	0.009	0.27	30x
SO_4^{2-}	0.002	0.18	90x

Sources

Where do these come from?

- Water
- Protein
- Glucose
- Urea
- Uric acid
- Creatinine
- Ammonia

Sources

- Water ingested drink and food / metabolic water
- Protein ingested food / tissue breakdown
- Glucose ingested food / glycogen / other compounds
- Urea deamination / urea cycle
- Uric acid metabolism of nucleotide bases
- Creatinine metabolism of creatine (creatine phosphate)
- Ammonia deamination

Urea formation

- Excess protein / excess amino acids
- Where from?
- Deamination
- Where?
- Urea formation
- Where?
- Transport and excretion

Deamination

- Oxidative deamination
- Aerobic!
- Liver (and other tissues)
- Amino acid (glutamic acid) + oxygen
- Keto acid + ammonia
- Coupled with reduction of NAD (co-enzyme)
- Ammonia!! Beware.
- Ammonia enters the urea cycle
- What happens to the keto acid?

Deamination

Deamination is part of protein metabolism

Catabolic reaction

Details are at:

http://www.elmhurst.edu/~chm/vchembook/632oxdeam.html

Urea/ornithine cycle

- Ammonia comes from
  - deamination
  - and from aspartic acid produced from transamination
- Carbon dioxide comes from link reaction and Krebs cycle
- Urea is excreted
- Requires ATP

Urea/ornithine cycle

- Linked to:
  - deamination
  - transamination
  - Krebs cycle
  - phosphorylation of ADP (because ATP is required)
- Details are at:

http://www.elmhurst.edu/~chm/vchembook/633ureacycle.html

Protein metabolism

- Deamination and urea cycle are part of the metabolism of proteins and amino acids in the body.

More details of biochemistry (useful for MPB) at:

http://www.elmhurst.edu/~chm/vchembook/index.html

The link is on my web site for you.

Question 5

(a) Name?

(b) Purpose?

(c) Where?

(d) Product

(e) Intermediate (that gives its name to the cycle)

Sources

Where do these come from?

- Sodium
- Potassium
- Chloride
- Phosphate
- Sulphate

Sources

Where do these come from?

• Sodium	extracellular cation
• Potassium	intracellular cation
• Chloride	extracellular anion
• Phosphate	bone / tissue fluid
• Sulphate	amino acids

Functions of the nephron

Learning outcomes

- Explain how ultrafiltration occurs relating structure to function
- Explain how selective reabsorption occurs relating structure to function
- Explain how structure of medulla is related to water potential gradients
- Explain how water is reabsorbed throughout the nephron

Build a nephron

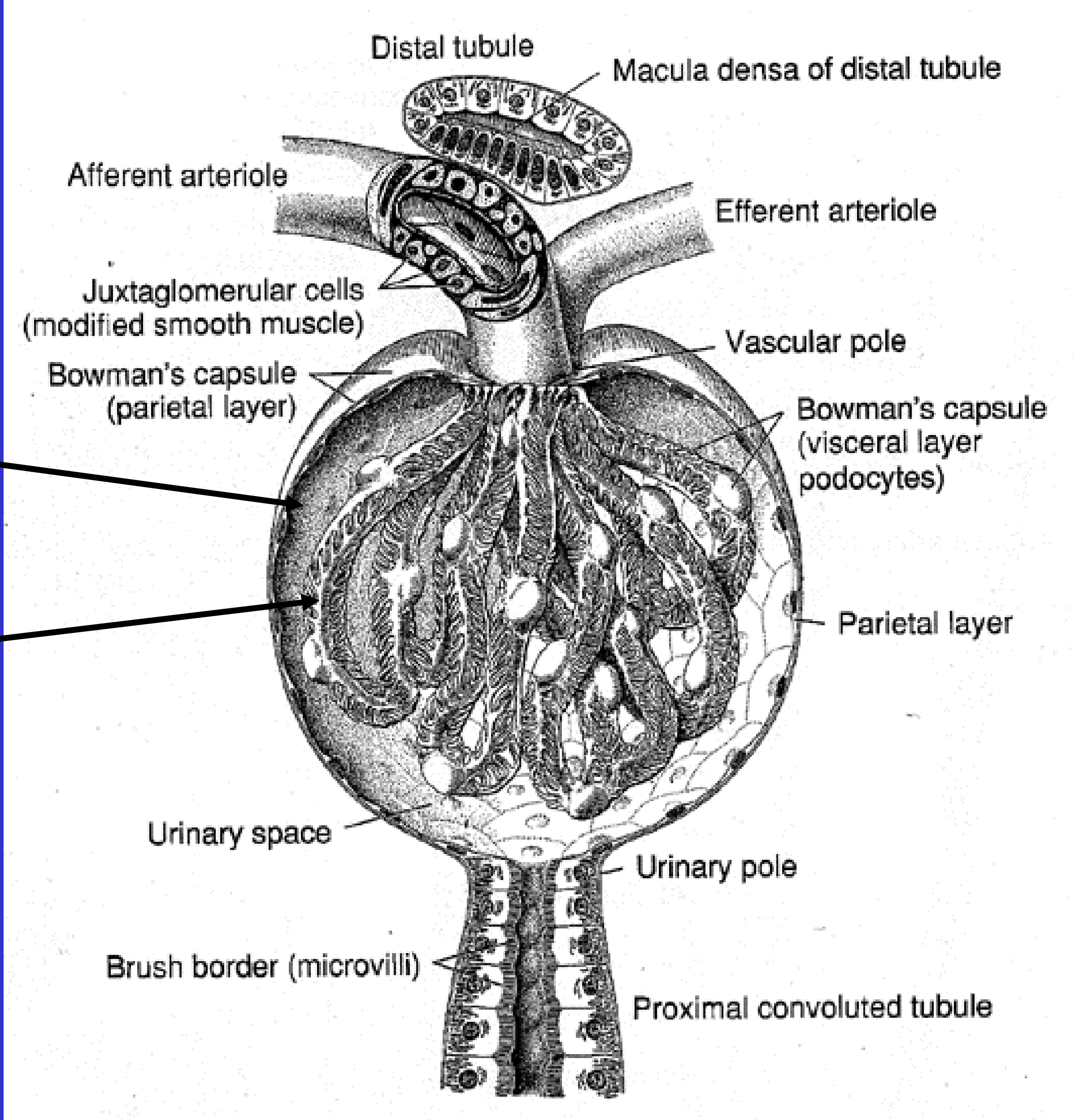
- Sort the cards into three groups:
  - structures
  - substances
  - processes
- Make a drawing/diagram of a nephron.
- Use the structure cards to label it
- Which ones are left over?
- Use the substance cards to identify those carried into the kidney
- Use the process cards to locate where these processes occur
- You could use this approach to one of the tasks in your homework – BUT you don't have to!

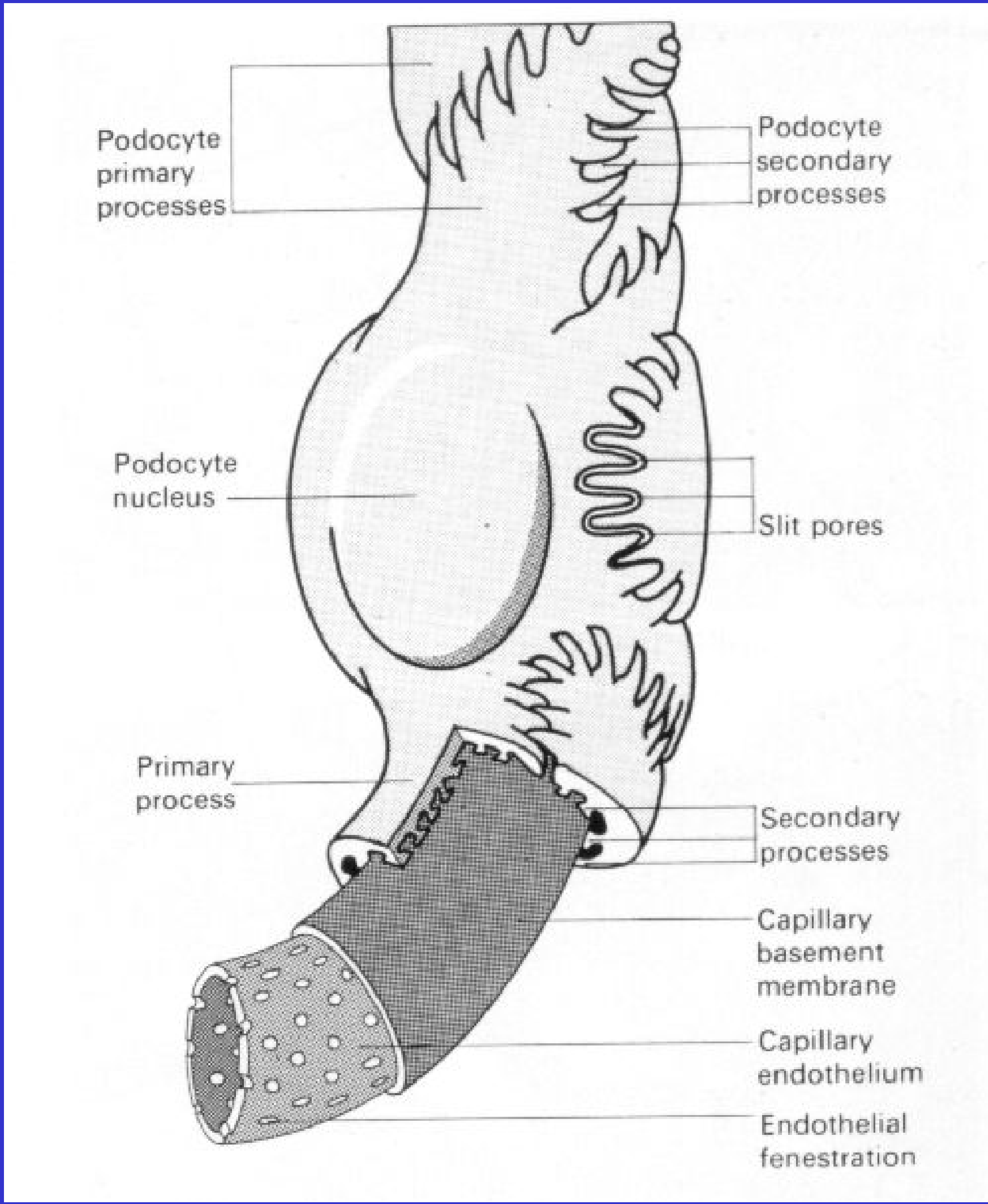
Processing in the kidneys

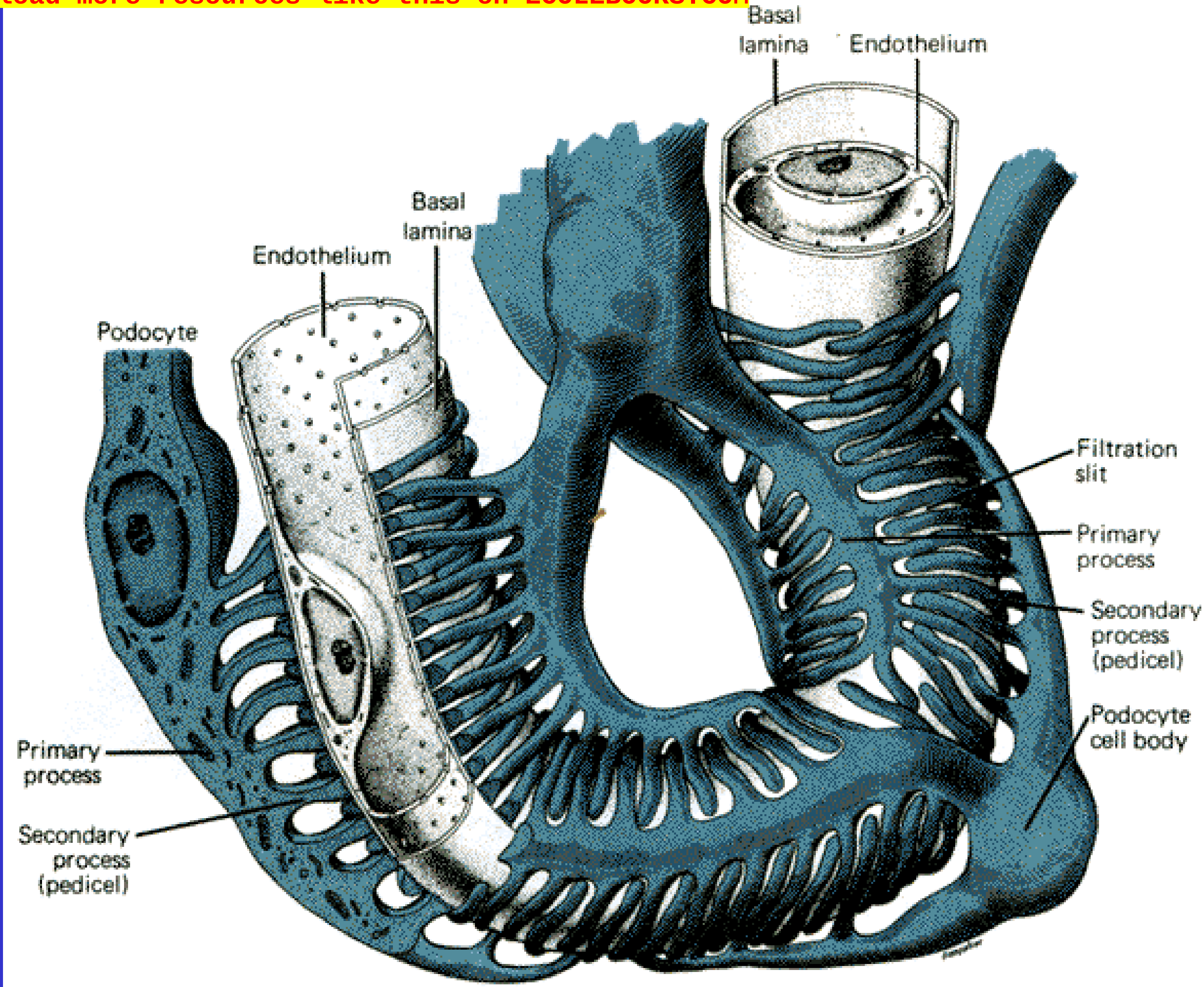
- Ultrafiltration
- Selective reabsorption
- Secretion
- Osmoregulation

Bowman's capsule

capillaries in the glomerulus




Podocyte primary processes
Podocyte secondary processes
Podocyte nucleus
Slit pores
Primary process
Secondary processes
Capillary basement membrane
Capillary endothelium
Endothelial fenestration


Basal
lamina
Endothelium
Basal
lamina
Endothelium
Podocyte
Filtration
slit
Primary
process
Secondary
process
(pedicel)
Podocyte
cell body
Primary
process
Secondary
process
(pedicel)

Ultrafiltration

- blood pressure gives hydrostatic pressure that brings about filtration
- capillaries have endothelium with pores
- basement membrane is the filtration membrane
- podocytes give support and do not provide resistance to filtration

lumen of Bowman's capsule

glomerulus

Ultrafiltration

- Relate structure to function
- Similar to filtration elsewhere in the body to produce tissue fluid
- Composition of filtrate is similar to blood plasma.
- What is missing?

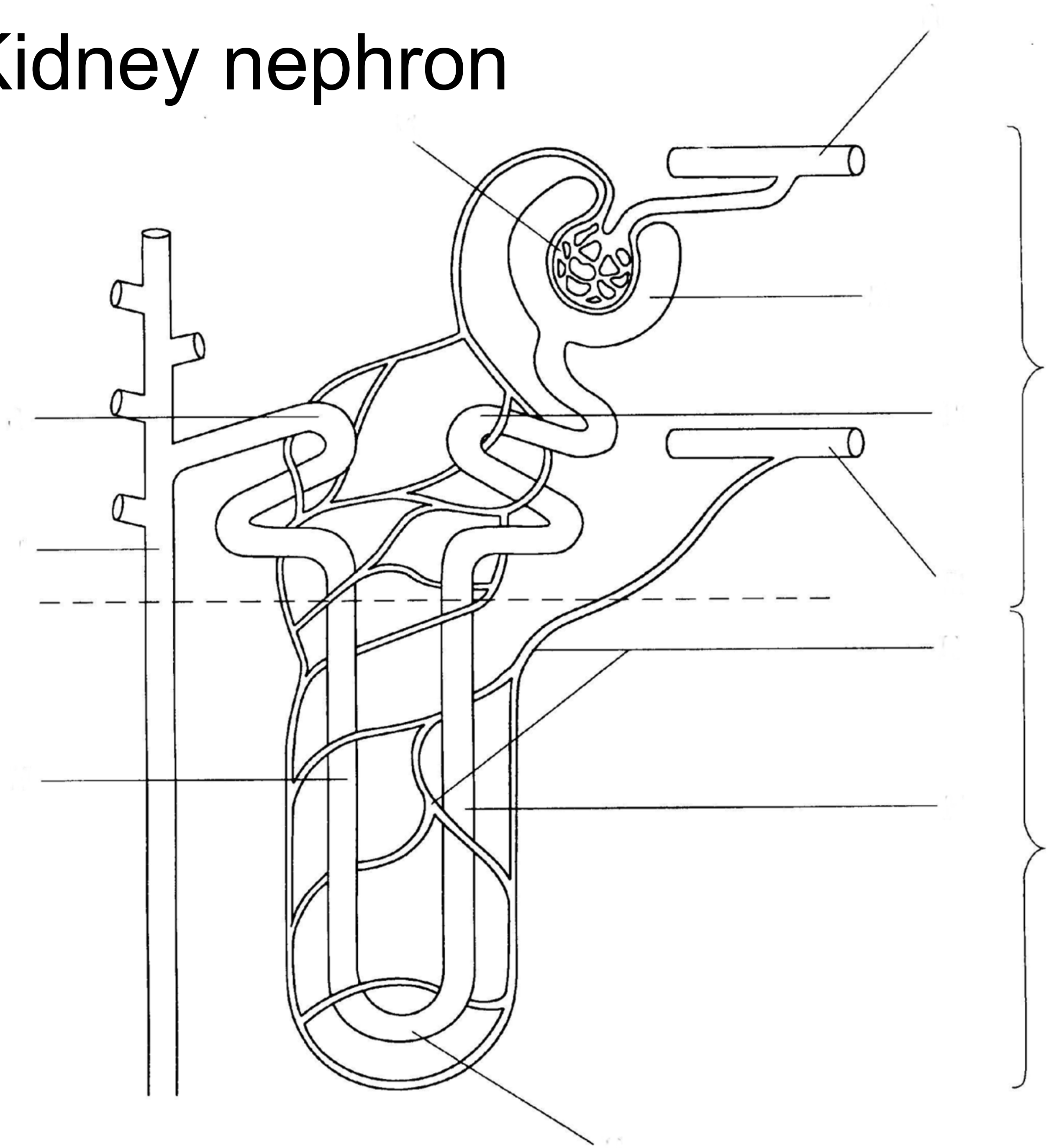
Question 6

- X?
- Y?
- Z?

Bullet points for (b)

Explain…..

Kidney nephron



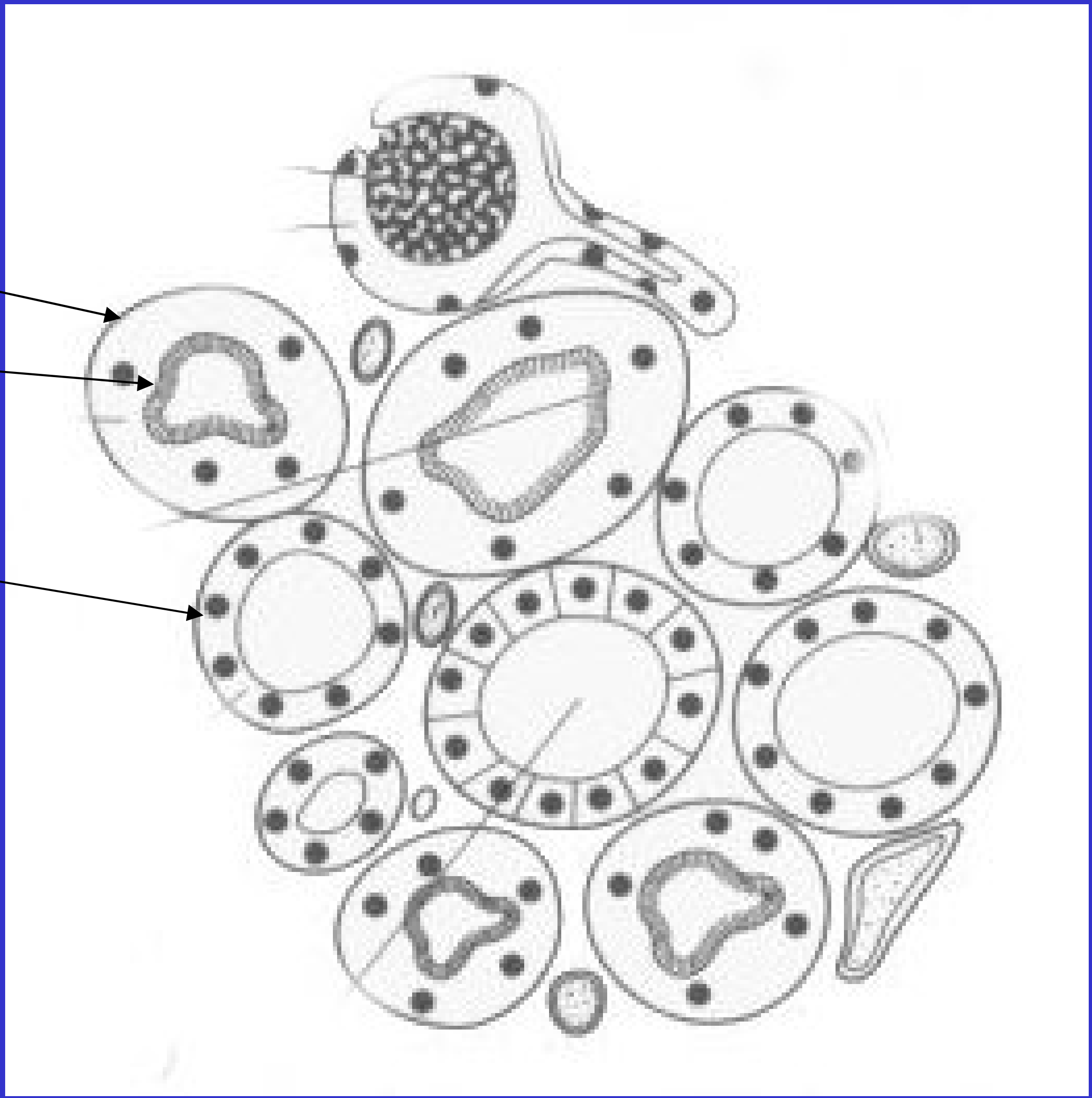
cortex

medulla

PCT

microvilli

DCT



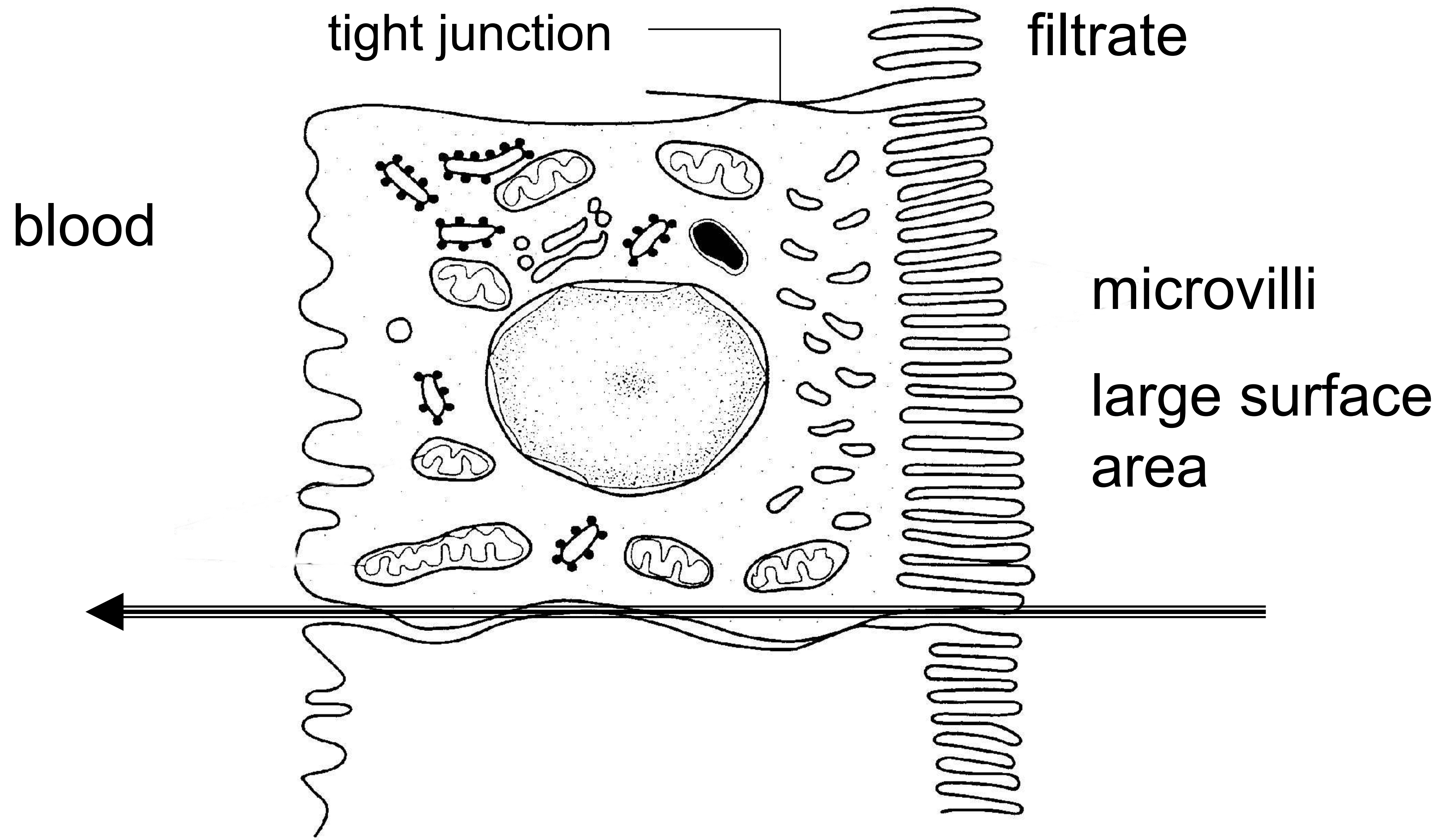
Selective reabsorption

- absorption of glucose, amino acids, ions, vitamins by PCT
- absorption of ions by DCT

these are substances required by the body

Selective reabsorption

- Proximal convoluted tubule
- Returning substances to the blood
- Active uptake
- Requires energy
- Co-transport
- Passive uptake
- Endocytosis



mitochondria – ATP for active transport

PCT cells are adapted to their functions

- tight junctions between cells to ensure transcellular movement
- microvilli to give a large surface area for absorption
- mitochondria to form ATP for active transport
- infoldings of basal membrane to allow movement of substances into the blood

Selective reabsorption

- Relate structure to function (see q. paper)
- Note outline of PCT cell. Describe
- Note detail inside cell. What?
- Edge of adjacent cells
- Draw in blood capillary
- Show direction by which substances are reabsorbed
- How is the composition of the filtrate changed?

Movement across membranes

- Driven by ATP
- Driven by sodium pumps that create low intracellular concentration of sodium ions
- Require specialised membrane proteins
- Occurs across two cell membranes – that have different permeability/pumping properties

http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/D/Diffusion.html#indirect

Co-transporter

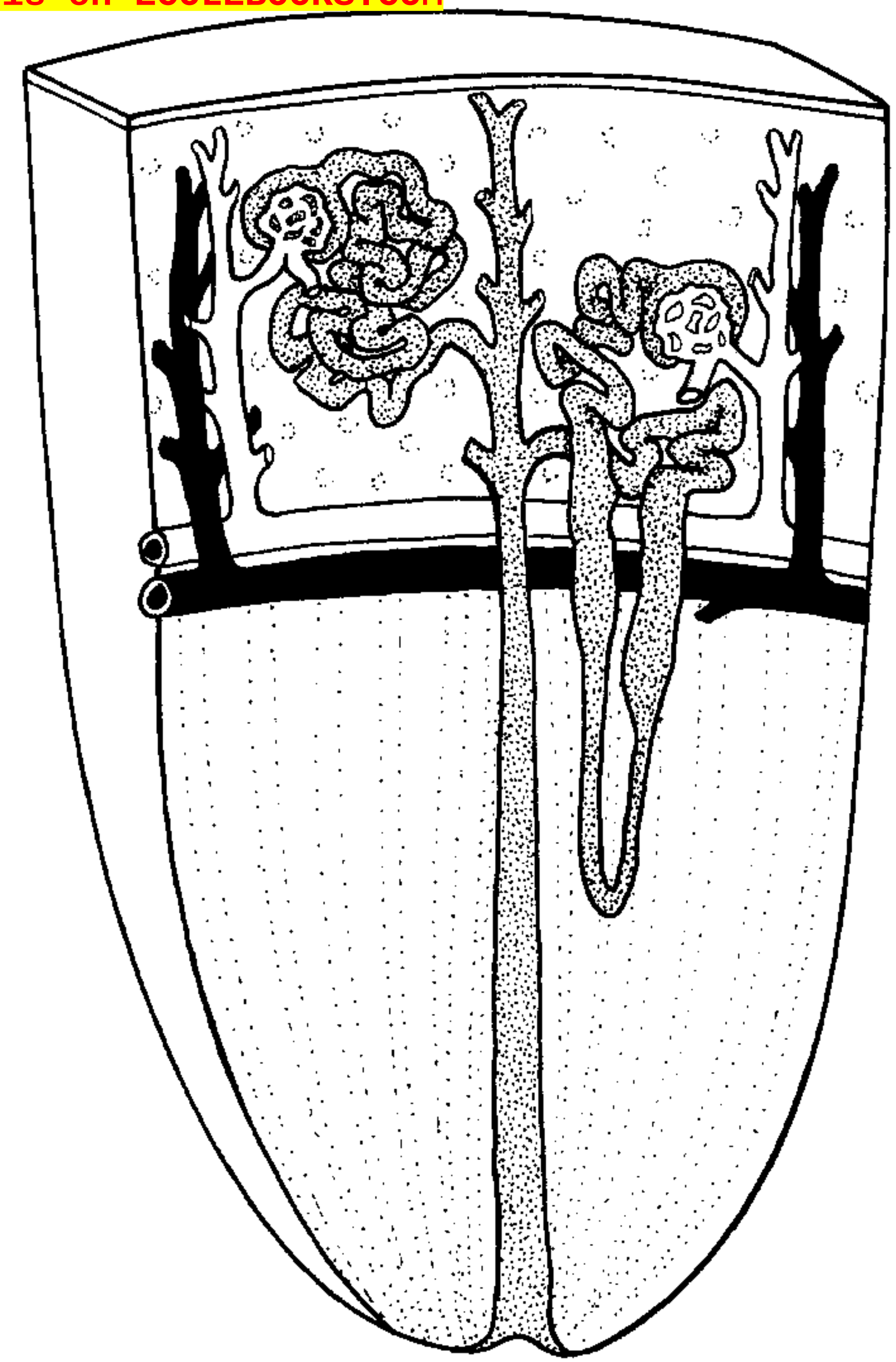
- Binding sites for two substances
- E.g. Na^+ and glucose
- Absorption of glucose driven by electrochemical gradient for Na^+
- This gradient is maintained by sodium pumps in basal and lateral membranes
- The pumps maintain a low *intracellular* concentration of Na^+

medulla:

loops and

collecting ducts

arranged in parallel



Question 5 (b)

- Describe the relationship between the length of part D and water potential of the urine
- Suggest an explanation for the relationship you have described.

Differential permeability

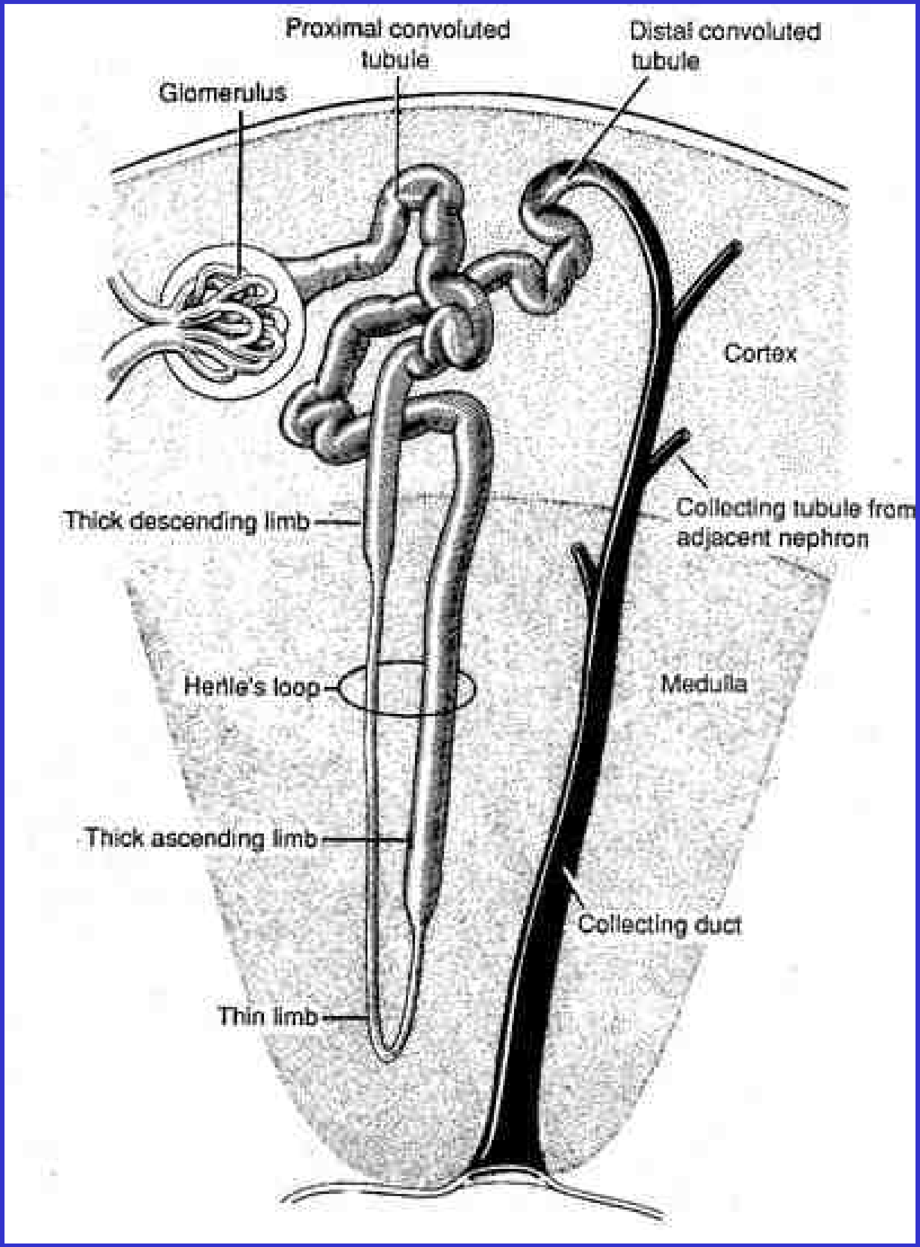
- Descending loop is permeable to sodium ions and water
- Ascending loop is permeable to sodium ions but not to water
- Upper part of ascending loop pumps sodium ions *out* of the filtrate into the tissue fluid

- Sodium and chloride ions move from ascending limb of loop to tissue fluid
- Ions move from tissue fluid to descending limb of loop
- Urea diffuses out of the urine from the collecting ducts into the tissue fluid
- Urea and ions lower water potential of tissue fluid
- Actual water potential depends on depth of medulla and so lengths of loops

U-shaped loops help to retain solutes (ions and urea) in tissue fluid of medulla

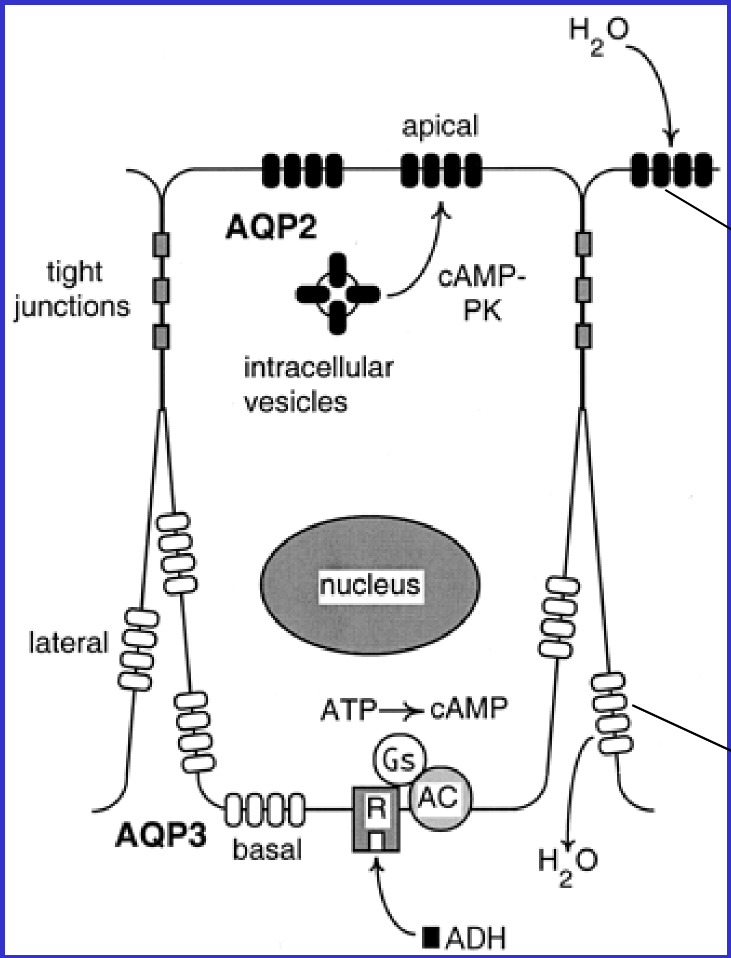
This gives a low water potential in this area

When water is conserved – collecting ducts become permeable and water diffuses from urine into the tissue fluid and into the capillaries


Proximal convoluted tubule
Distal convoluted tubule
Glomerulus
Cortex
Collecting tubule from adjacent nephron
Thick descending limb
Henle's loop
Medulla
Thick ascending limb
Collecting duct
Thin limb

Collecting duct cell with aquaporins

When open 3 billion molecules of water a second move through each aquaporin



AQP 2

present when needed

AQP 3

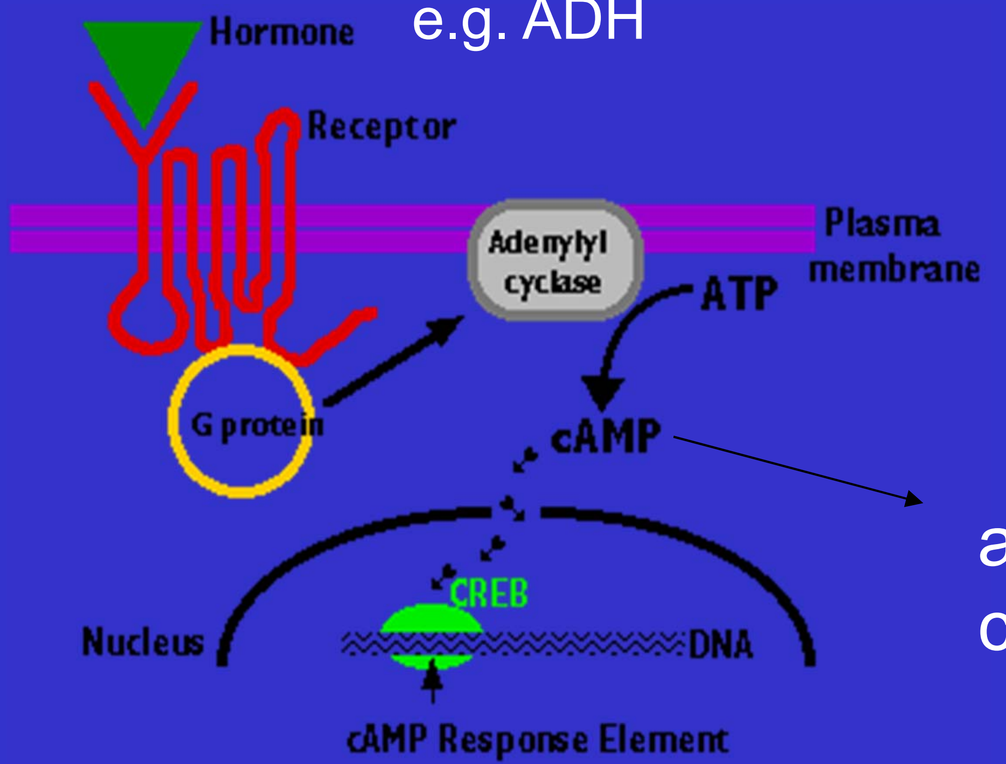
present all the time

Aquaporin

- Animation 1
- Animation 2

Mode of action of ADH

e.g. ADH



acts within cytoplasm

cyclic AMP is a secondary messenger

Match these statements to areas in the diagram

site of ultrafiltration

deoxygenated blood

oxygenated blood

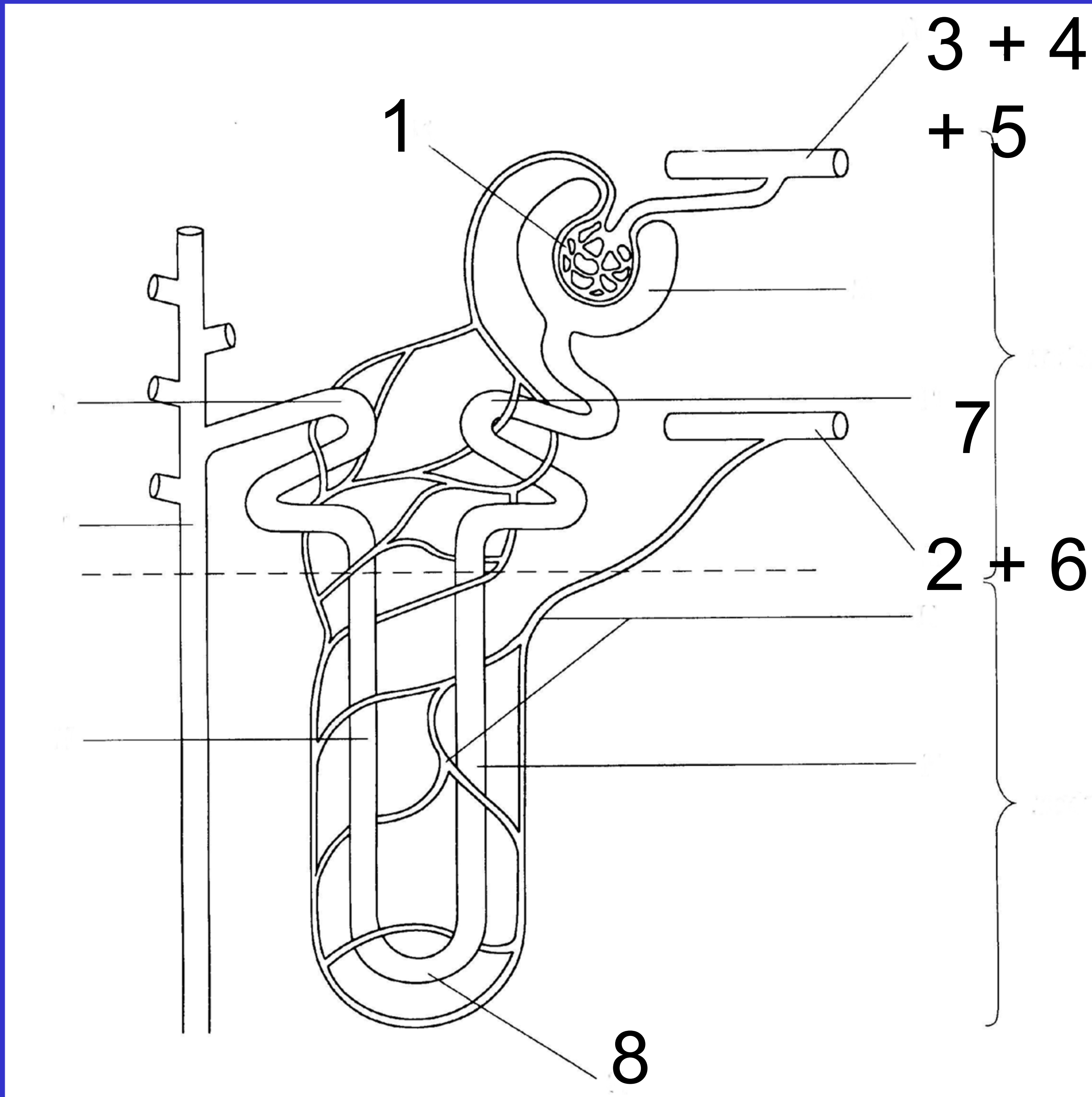
blood at highest pressure

blood vessel with highest concentration of urea

blood vessel with lowest concentration of urea

site of selective reabsorption

area with lowest water potential (highest concentration of solutes)



3 + 4
+ 5
1
7
2 + 6
8

The Kidneys

receive

20-25% of the total output of the heart

filter

170 000 cm^3 filtrate a day

reclaim

1300 g of NaCl each day

180 g glucose each day

almost all the water (180 litres) that is filtered each day

produce

1200 to 2000 cm^3 urine a day

expect to carry out calculations on these sorts of figures