CIRCULATION and NITROGEN EXCRETION

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2.1 CIRCULATION

2 types of circulation systems

Open Circulatory Systems e.g. in insects

Where there may be some vessels but the circulatory fluid - '**haemolymph**' -flows out of the vessels that form the circulatory system and bathes tissues directly.

Closed Circulatory Systems e.g. in vertebrates such as fish and mammals

Blood within the heart

blood vessels (range of sizes and structures) - arteries, arterioles, capillaries, venules and veins.

Larger blood vessels move blood around the body, taking it from organ to organ (the vascular system)

- it supplies by smallest blood vessels, capillaries.

All closed blood circulatory systems include 3 essential parts (three components)

Blood, Blood Vessels and Heart

2 Types of closed blood circulation systems:

Single Circulation Systems
(Single Blood Circulation)

and

Double Circulation Systems
(Double Blood Circulation)

Single Circulatory System Fish have single circulatory systems

- The blood passes through the heart **only once** each time it completes a full circuit around the fish's body

Double Circulatory System Mammals have double circulatory systems

- The blood passes through the heart **twice** in order to complete a single complete circuit around the whole body, including through the lungs and all other parts of the body.

Double circulatory systems include two circuits of blood flowing to and from the heart.

1. **Pulmonary circulation**

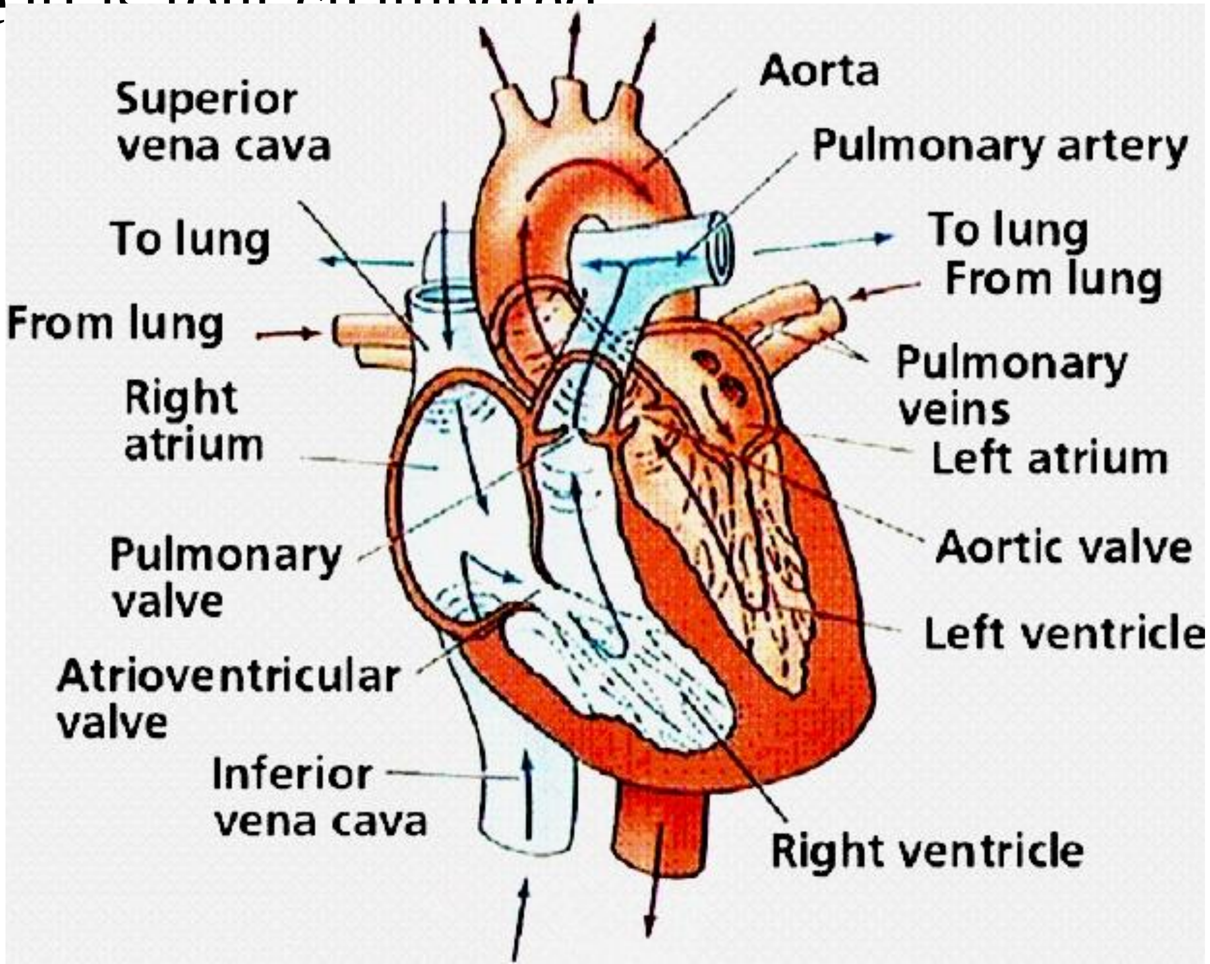
   Pulmonary circulation moves blood between **the heart and the lungs**.

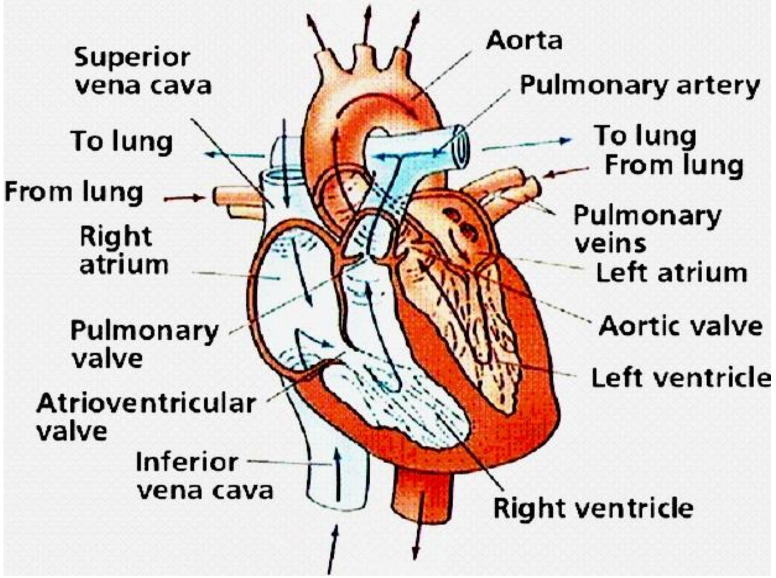
2. **Systemic circulation**

   Systemic circulation moves blood between the **heart (left ventricle)** and the **rest of the body** (except for the lungs).

Heart

- busiest organ of the body _ **conical in shape**.
- present in **thoracic cavity**, 2/3 part of heart is placed towards left side.
- **Weight**_ 250-300 Grams in male and 230-250 Grams in female.
- Human heart is four chambered.





In the systemic loop,

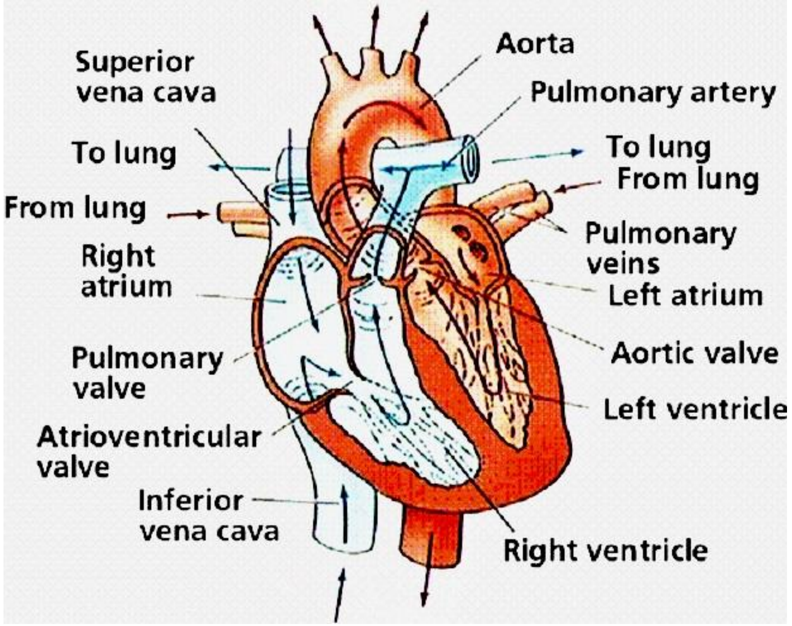
oxygenated blood **left ventricle** - the **aorta (**largest artery in the body) - through the **systemic arteries**, then **to arterioles** and **capillary beds** that supply body tissues.

Here, oxygen and nutrients are released and carbon dioxide and other waste substances are absorbed.

Deoxygenated blood then moves from the capillary beds through **venules** into the **systemic veins**.

The systemic veins feed into the **inferior and superior venae cavae (**the largest veins in the body).

The venae cavae flow deoxygenated blood to the **right atrium** of the heart.



In the pulmonary loop,

deoxygenated blood exits the **right ventricle** passes through the **pulmonary trunk -** splits into the right and left **pulmonary arteries**.

These arteries transport the deoxygenated blood **to arterioles** and **capillary beds** in the lungs.

There, carbon dioxide is released and oxygen is absorbed.

Oxygenated blood then passes from the capillary beds through **venules** into the **pulmonary veins**.

The pulmonary veins transport it to the **left atrium** of the heart.

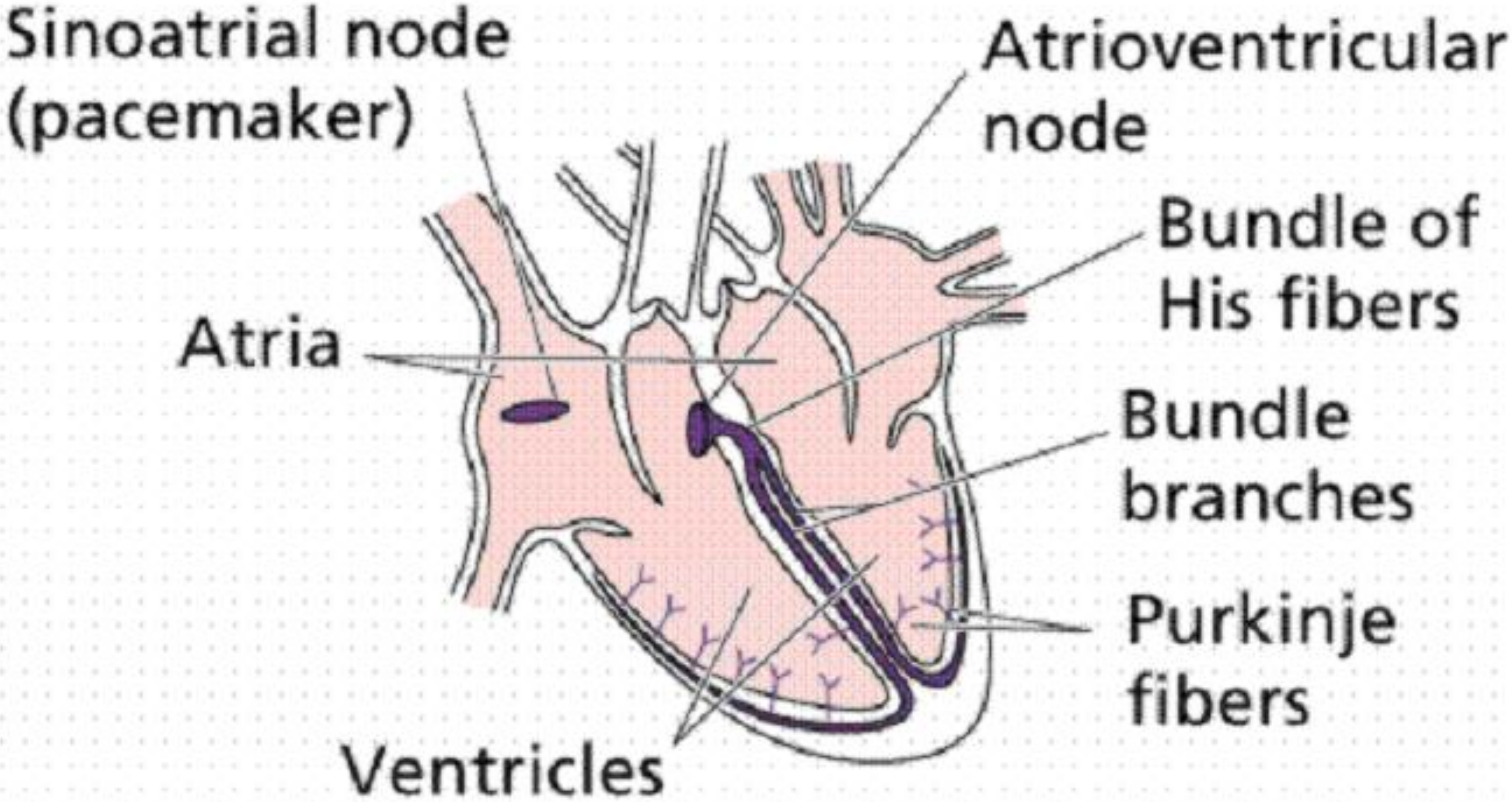
The pulmonary arteries are the **only arteries that carry deoxygenated blood** and **the pulmonary veins** are the **only veins that carry oxygenated blood.**

circulatory systems - respiratory systems

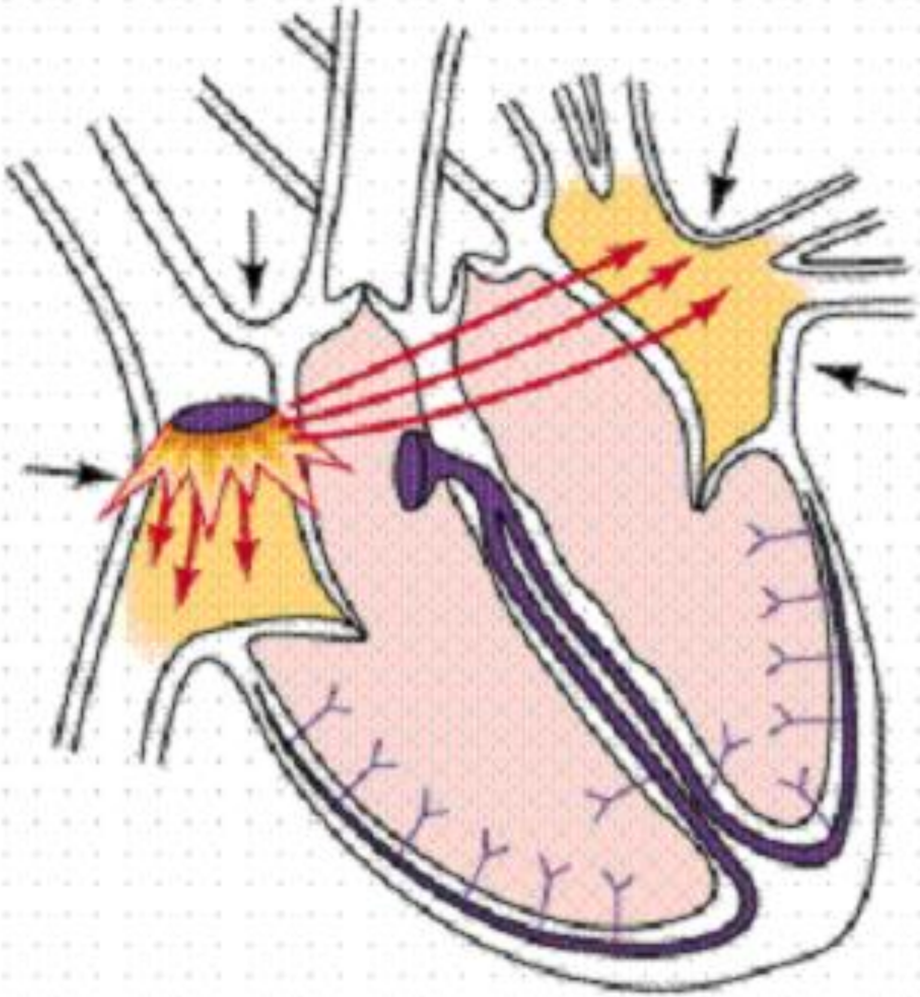
Pulmonary circulation facilitates the **external respiration**:

Deoxygenated blood flows into the lungs, absorbs oxygen from tiny air sacs (the alveoli) and releases carbon dioxide to be exhaled.

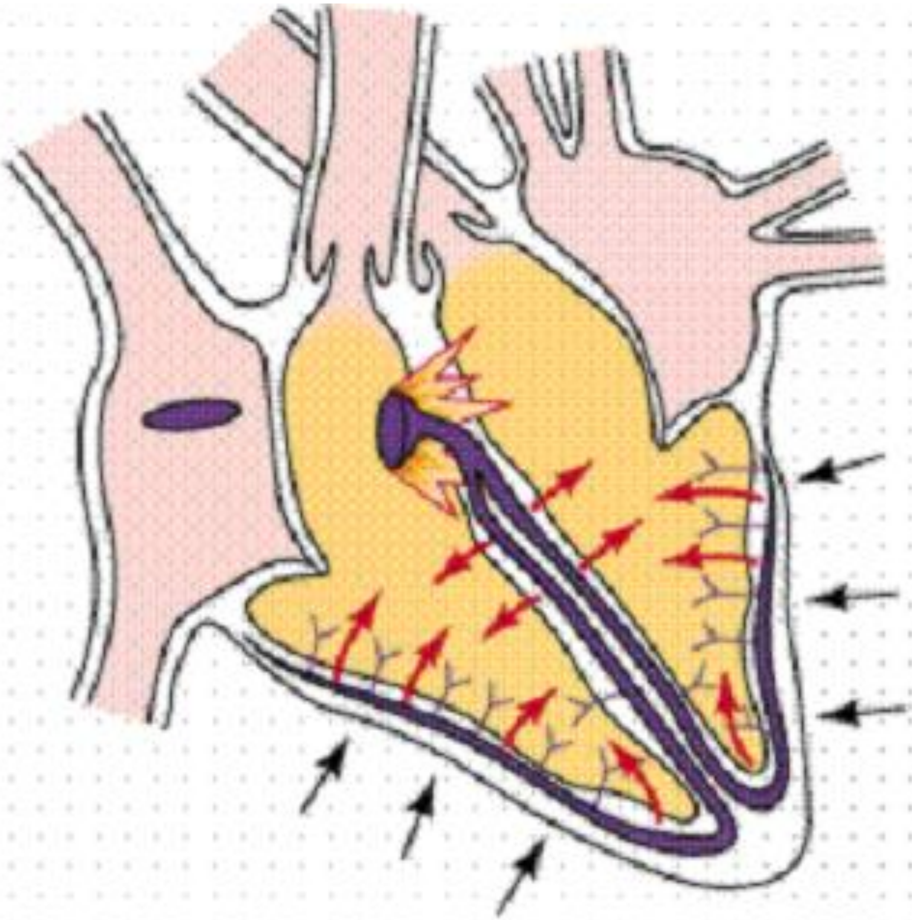
Systemic circulation facilitates **internal respiration**: Oxygenated blood flows into capillaries through the rest of the body, blood diffuses oxygen into cells and absorbs carbon dioxide.



Heart at rest



Sinoatrial node fires, action potentials spread through atria which contract



Atrioventricular node fires, sending impulses along conducting fibers; ventricles contract

Blood pressure

pressure that is exerted by the blood upon the walls of the blood vessels and especially arteries

- mmHg

and

that varies with

the muscular efficiency of the heart,

the blood volume and viscosity,

the age and health of the individual, and

the state of the vascular wall

- peripheral resistance.

  Blood cells and plasma encounter resistance when they **contact blood vessel walls**.

- resistance increases = more pressure is needed to keep blood moving.

- Three main sources of peripheral resistance:

1. blood vessel diameter
2. blood viscosity
3. total vessel length

- Measurement

 - by sphygmomanometer

Asculatory method by using cuff wrapped around to left arm

BP = 120/80 normal

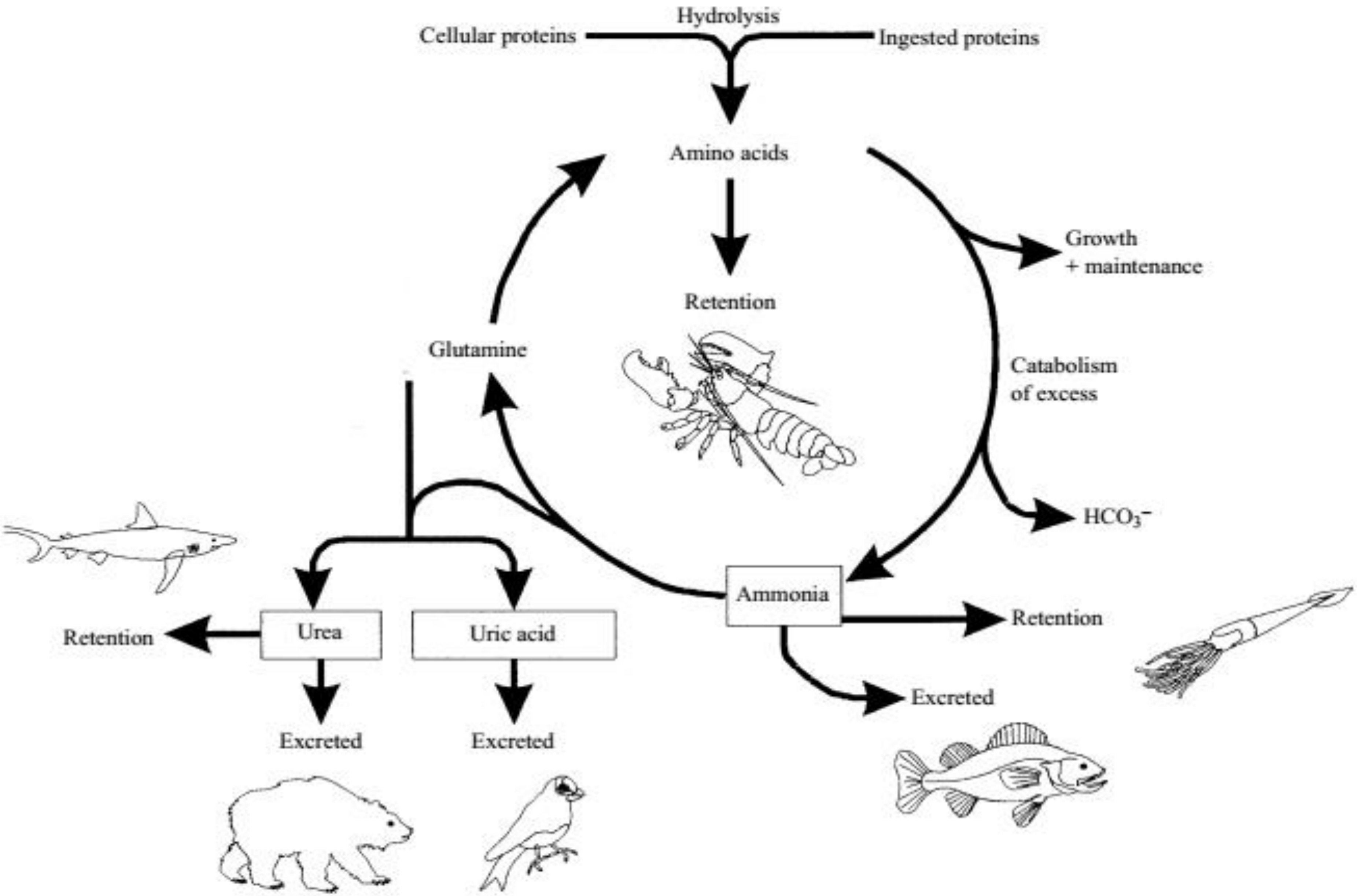
Pulse pressure=120 -80= 40

SBP : DBP: Pulse pressure – 3:2:1

	Systolic (mmHg)	**Diastolic (mmHg)**
Normal blood pressure	Less than 120	Less than 80
Elevated	Between 120 and 129	Less than 80
Stage 1 hypertension	Between 130 and 139	Between 80 and 89
Stage 2 hypertension	At least 140	At least 90
Hypertensive crisis	Over 180	Over 120

Neurogenic and Myogenic heart

NITROGEN EXCRETION



Significance of excretion:

1. Removal of unwanted metabolic byproducts:

   Carbohydrates and fats = produces $CO_2$and H_2O,

   Protein metabolism = produces nitrogenous wastes.

2. Removal of toxic wastes:

   nitrogenous wastes, CO2, pigments formed by the breakdown of haemoglobin, drugs etc.

3. Osmoregulation of the body

4. Regulation of body PH

5. Thermoregulation

- Ammonotelic animals

Proteins

Proteolytic ↓ enzymes

Aminoacids

Deamination ↓ (in liver)

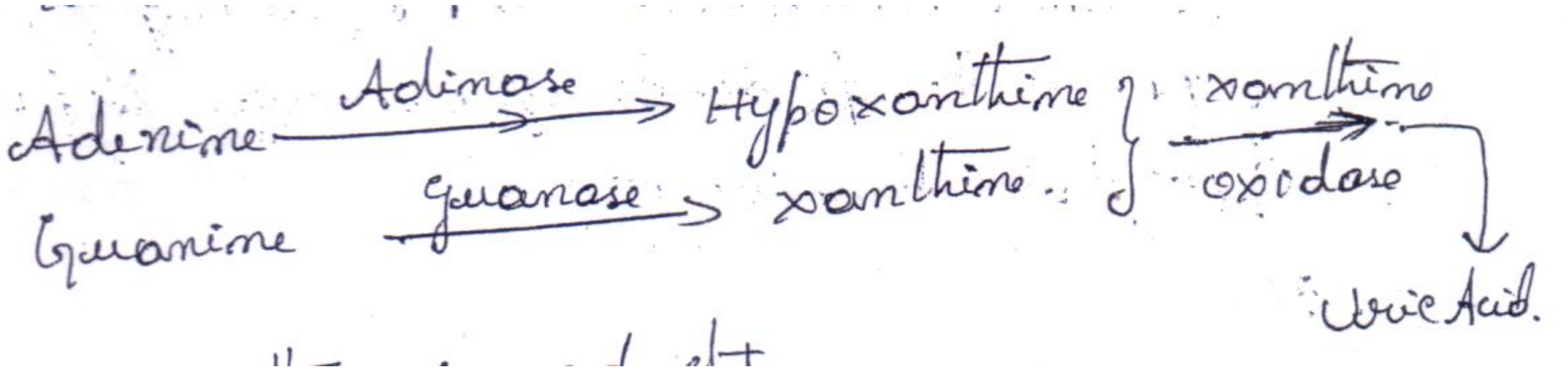
Ammonia

- Ammonotelic to Ureotelic (fishes)

Lung fish- Ammonia – Dry season (aestivates)- Urea

Bivalves (marine)- Urea ------to ammonia(Urease)

- Uricotelic animals



Uric acid

Trimethylamine oxide = marine teleost fishes

Guanine = spiders and swine

Allantoin = from uric acid – oxidation (enzyme uricase) - some mammals, reptiles and molluscs.

Hippuric acid (mammals)= benzoic acid (food) is removed + glycine

Ornithuric acid (birds) = nitrogenous compound ornithine + benzoic acid(food)

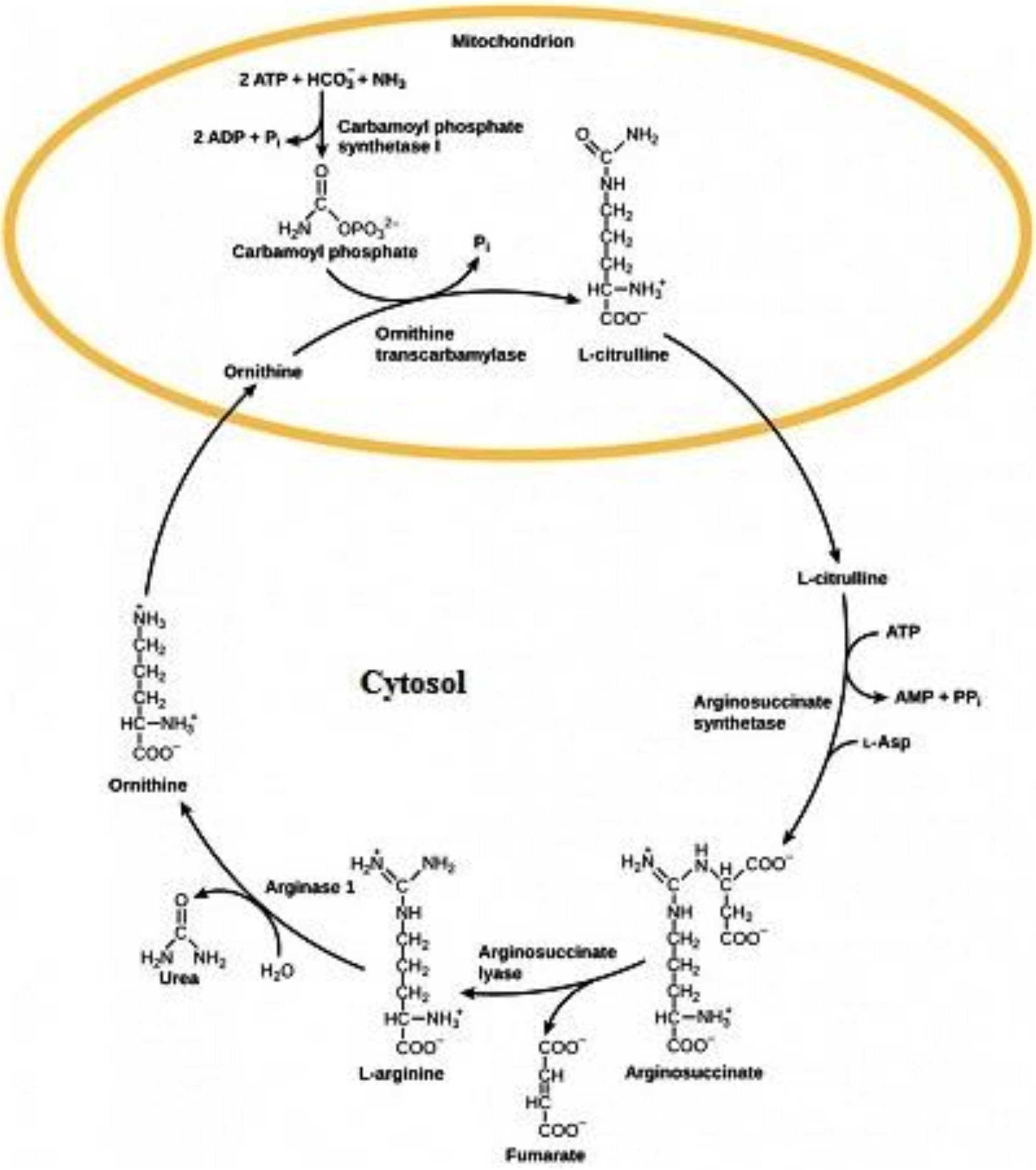
Creatine

synthesized in the liver from 3 aa, arginine, glycine and methionine.

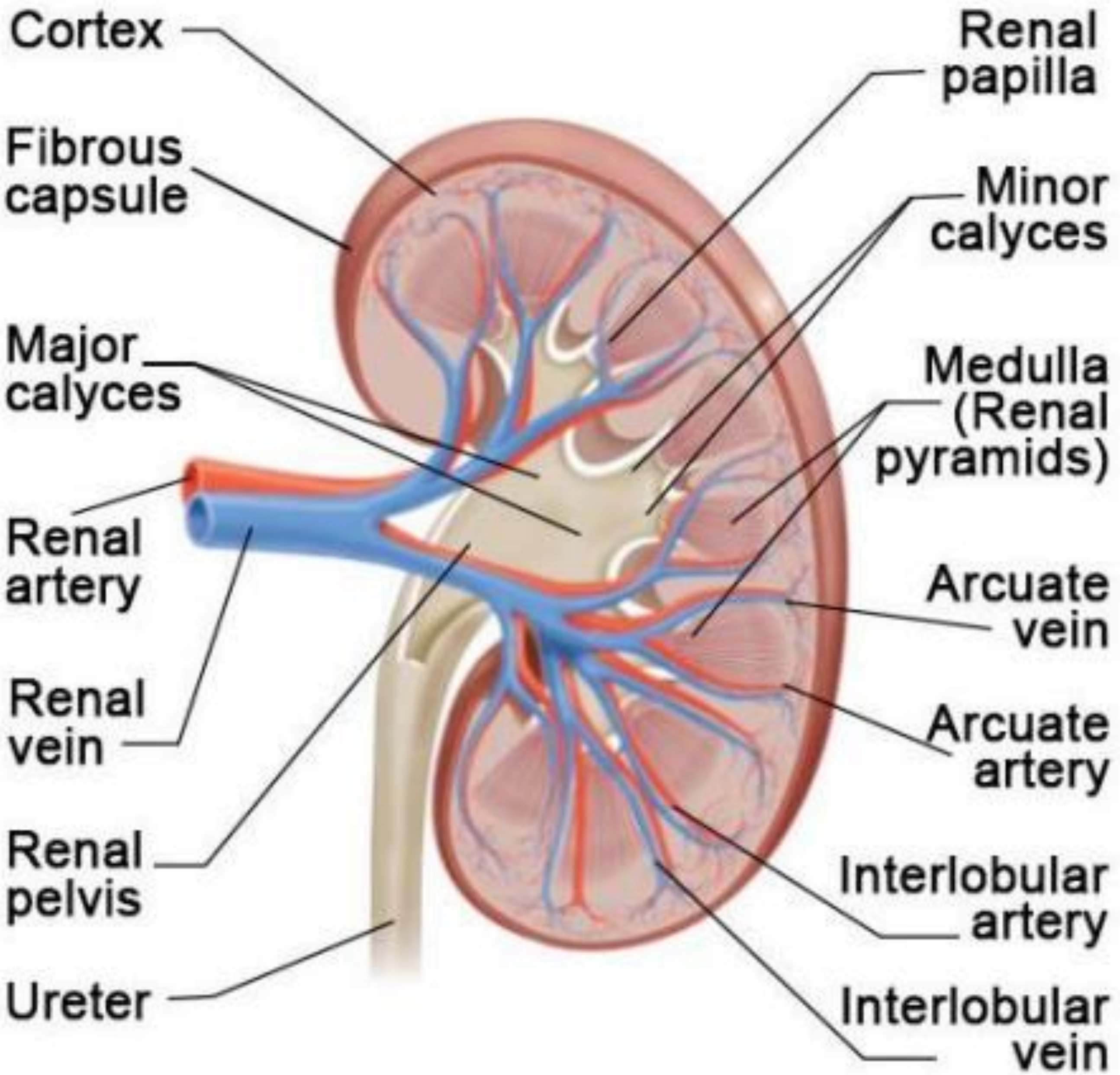
- liberated into the blood and is taken up by the muscle when required.
- In skeletalmuscle, it is phosphorylated to form creatine phosphate, which is an importantenergy store for ATP synthesis.
- The excess of creatine is excreted along with urine.

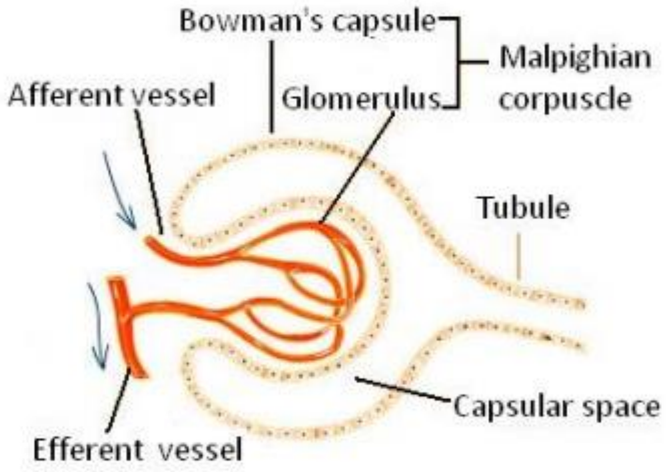
Creatinine

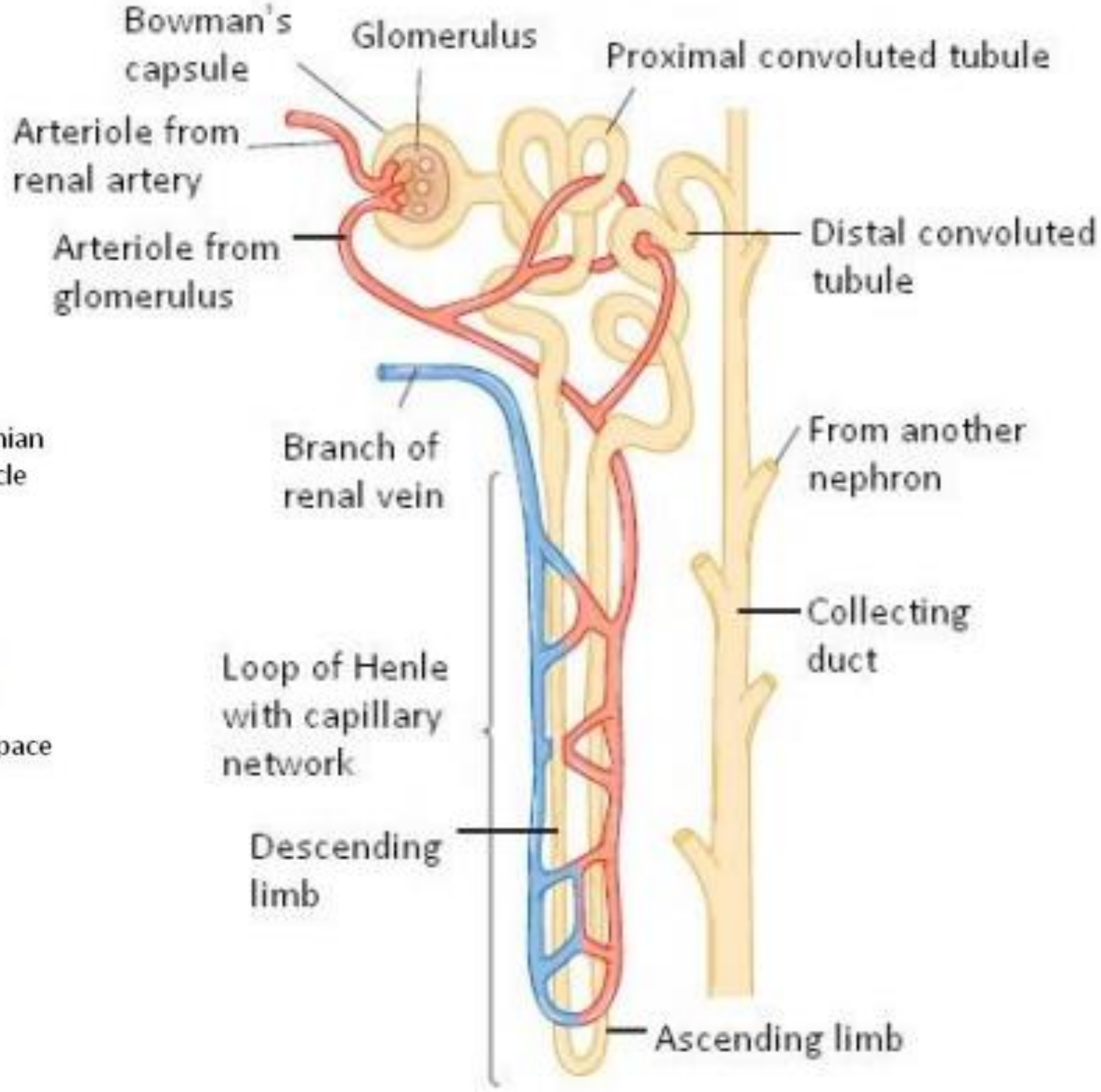
It is formed in the body from creatine phosphate.



The urea cycle converts ammonia to urea.


Cortex
Fibrous capsule
Major calyces
Renal artery
Renal vein
Renal pelvis
Ureter
Renal papilla
Minor calyces
Medulla (Renal pyramids)
Arcuate vein
Arcuate artery
Interlobular artery
Interlobular vein


Bowman's capsule
Malpighian corpuscle
Afferent vessel
Glomerulus
Tubule
Capsular space
Efferent vessel


Bowman's capsule
Glomerulus
Proximal convoluted tubule
Arteriole from renal artery
Arteriole from glomerulus
Distal convoluted tubule
Branch of renal vein
From another nephron
Collecting duct
Loop of Henle with capillary network
Descending limb
Ascending limb

Physiology of Urine Formation

Blood plasma is filtered across the endotheliocapsular membrane

↓

capsular space (glomerular filtrate –GF) **1° urine**

it passes through the rest of the nephron

(its composition is altered)

↓

essential substances are reabsorbed

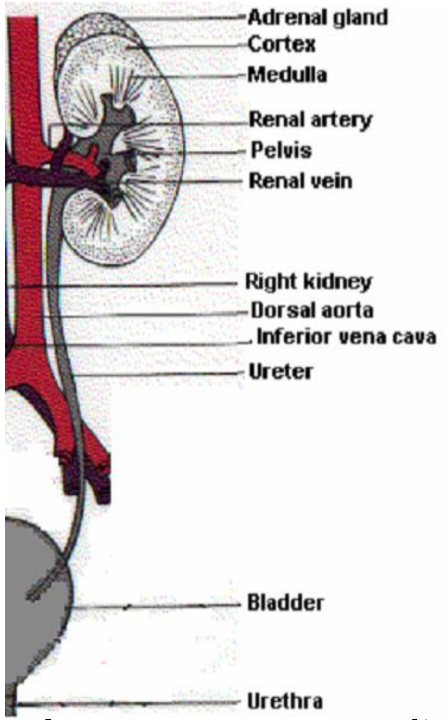
nonessential substances are added

↓

fluid enters the **pelvis (urine)**

into the bladder (through the ureters)

expelled (through the urethra)



three stages of Urine formation: **ultrafiltration, reabsorption and tubular secretion**.

Ultrafiltration (Glomerular Filtration).

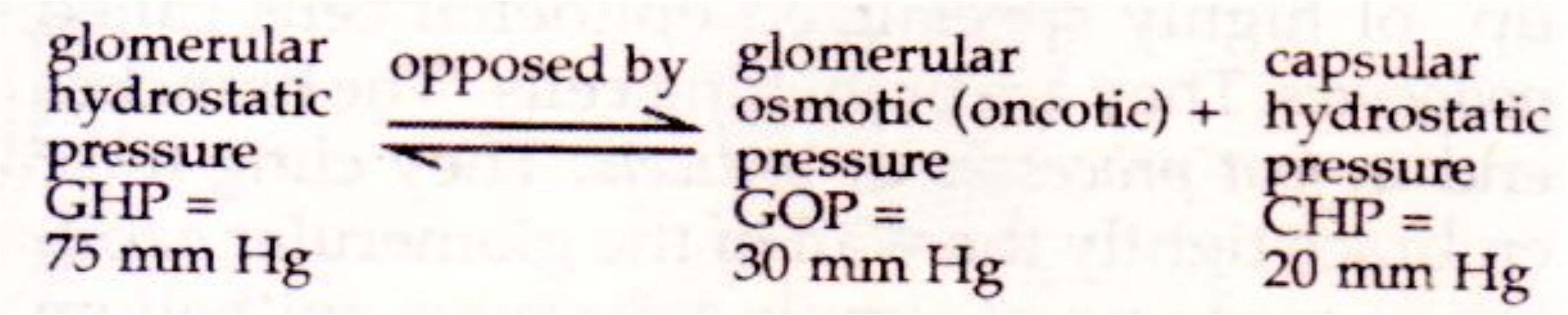
Three pressures are relevant to the process

(a) glomerular hydrostatic pressure (GHP or HPg)
Blood pressure in the capillaries of the glomerulus
lt is very high as the efferent arteriole has a smaller lumen than the afferent.
It is about 75 mm Hg.
This favours filtration

(b) The **glomerular osmotic pressure** (GOP or OPg)
is exerted by the plasma proteins in the blood
30mm Hg.

(c) **capsular hydrostatic pressure** (CHP or HPc)
pressure exerted by the fluid in the **capsular space** and **renal tubule**
it is about 20mm Hg.

Of the three pressures – GHP **favours filtration** and the other two **oppose filtration**



the pressure available for filtration of fluid or

net filtration pressure (NFP) or

the effective filtration pressure (Peff) is

75 - (30 + 20) = 25mmHg.

10-20 % plasma flow from capillaries into the capsular space as glomerular filtrate (GF) - **primary urine**.

The filtration is a **nonselective process**

All dissolved materials in the plasma such as glucose, amino acids, sodium, potassium, bicarbonate, other salts and urea, pass through and **become a part of the glomerular filtrate**.

About **125 mL.** of glomerular filtrate enters the tubules of the nephrons of the two kidneys **each minute (**glomerular filtration rate - GFR).

GFR directly proportional to Peff

Tubular Reabsorption (Resorption)

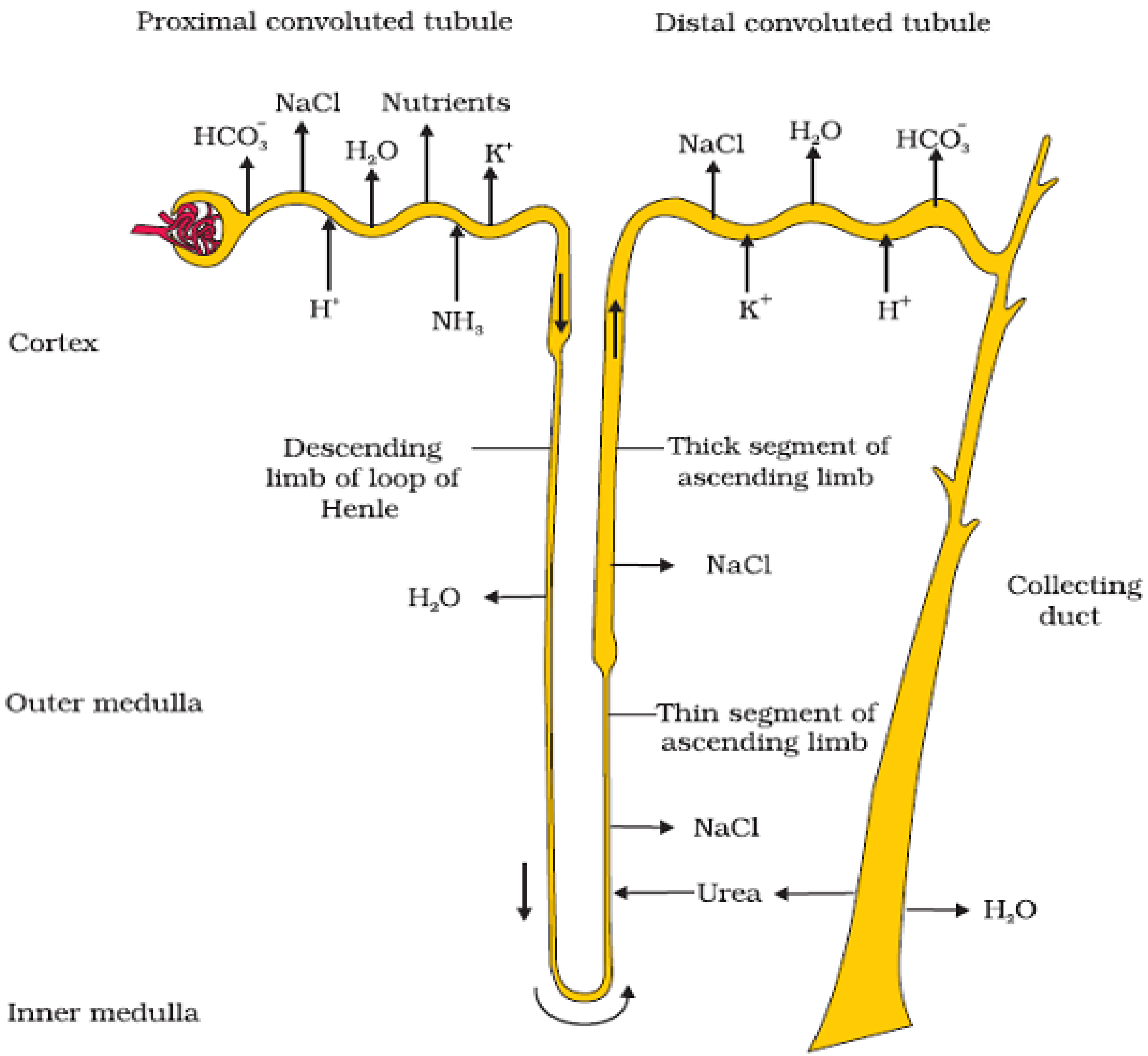
essential substances are reclaimed or returned to the blood flowing in the peritubular capillaries.

- Tubular reabsorption is a selective process.

- both passive (no ATP use) and active transport (ATP used) mechanisms.

- About 99 % of the filtrate (i.e., nearly 124 mL) consisting mostly of water, glucose, amino acids, vitamins, ions (Na^+, K^+, Cl^- HCO_3^-) and other useful substances are reabsorbed.

- about 65% (**proximal convoluted tubule**) and rest (in Henle's 1oop, distal convoluted tubule & collecting duct).



Proximal convoluted tubule
Distal convoluted tubule
HCO_3^-
NaCl
H_2O
Nutrients
K^+
H^+
NH_3
NaCl
H_2O
HCO_3^-
K^+
H^+
Cortex
Descending limb of loop of Henle
Thick segment of ascending limb
NaCl
H_2O
Collecting duct
Outer medulla
Thin segment of ascending limb
NaCl
Urea
H_2O
Inner medulla

Tubular Secretion or Augmentation

- reverse of reabsorption

- In this process cells of the tubule extract substances not required by the body from the blood (flowing in the peritubular capillaries) and add or secrete them into the forming urine.

Tubular secretion is necessary for

(a) getting rid of substances not filtered but are found in the blood ; e.g. certain drugs and foreign chemicals.

(b) getting rid of undesirable substances which have been reabsorbed (as if by error !) ; e.g.; urea, uric acid.

(c) getting rid of excessive K^+, creatinine, para-amino hippuric acid (PAHA).

(d) controlling pH of blood by eliminating H^+.

The Mechanism of Urine Concentration