ROLE OF POTASSIUM IN HUMAN AND ANIMAL NUTRITION

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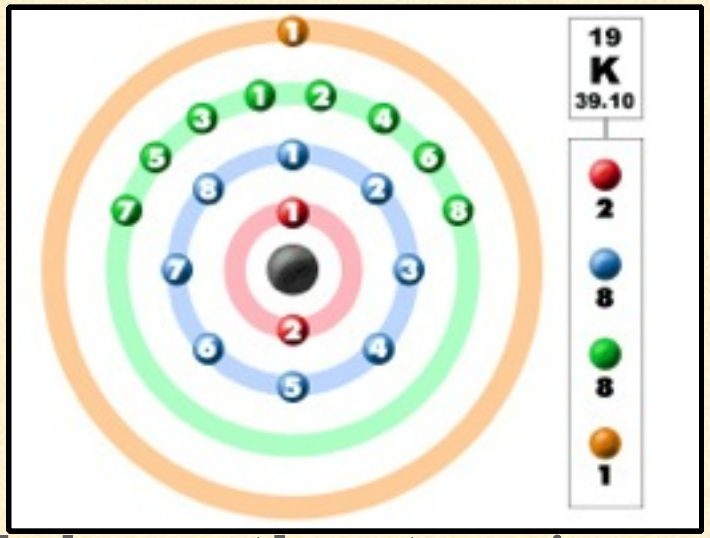
DAR ES SALAAM

OUTLINE

- Introduction
- Functions of potassium in the body
- Sources of potassium in the diet
- Potassium content of foods in Tanzania
- Recommended intake of potassium for optimal nutrition
- Effect of deficiency and excess intake of potassium
- Factors influencing availability of potassium in foods
- Factors influencing potassium availability in the body

INTRODUCTION

- **Potassium is a light soft silver-white metallic chemical element of the alkali metal group presented as symbol K**



- **Oxidises rapidly in air and reacts violently with water**
- **Atomic number 19; means it has 19 electrons (2:8:8:1)**
- **Atomic weight 39.098;**
- **Ability to loose an extra electron and acquire an over all +VE charge than to gain one and acquire a negative charge.**
- **Most of its functions are based on this overall +VE charge**

PERIODIC TABLE OF THE ELEMENTS

The Periodic Table is a systematic arrangement of the chemical elements according to their atomic structure. The elements are arranged so that their **atomic numbers**—the number of protons in each element's nucleus—increase as you read across each row from left to right. Thus hydrogen (atomic number 1) comes first in the Table, helium (atomic number 2) comes second, lithium (atomic number 3) comes third, and so on.

The first Periodic Table was designed by Dmitri Mendeleev in 1869. At that time only 63 of the elements were known. Today we know a total of 112. When Mendeleev made the first table he knew that other elements would eventually be discovered, and he left empty spaces so that the new elements could be added as they were found.

1	atomic number
H	symbol
Hydrogen	
1.00794	atomic weight (or mass number of most stable isotope if in parentheses)

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9	Group 10	Group 11	Group 12	Group 13	Group 14	Group 15	Group 16	Group 17	Group 18
Period 1	1 H Hydrogen 1.00794																	2 He Helium 4.0026
Period 2	3 Li Lithium 6.941	4 Be Beryllium 9.0122											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.0067	8 O Oxygen 15.9994	9 F Fluorine 18.9984	10 Ne Neon 20.183
Period 3	11 Na Sodium 22.9898	12 Mg Magnesium 24.305											13 Al Aluminum 26.9815	14 Si Silicon 28.086	15 P Phosphorus 30.9738	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948
Period 4	19 K Potassium 39.098	20 Ca Calcium 40.08	21 Sc Scandium 44.956	22 Ti Titanium 47.87	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.9380	26 Fe Iron 55.845	27 Co Cobalt 58.9332	28 Ni Nickel 58.69	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.72	32 Ge Germanium 72.61	33 As Arsenic 74.9216	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.80
Period 5	37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.22	41 Nb Niobium 92.906	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.905	46 Pd Palladium 106.4	47 Ag Silver 107.868	48 Cd Cadmium 112.41	49 In Indium 114.82	50 Sn Tin 118.71	51 Sb Antimony 121.76	52 Te Tellurium 127.60	53 I Iodine 126.9045	54 Xe Xenon 131.29
Period 6	55 Cs Cesium 132.905	56 Ba Barium 137.33	57–71* Lanthanides	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.84	75 Re Rhenium 186.2	76 Os Osmium 190.2	77 Ir Iridium 192.2	78 Pt Platinum 195.08	79 Au Gold 196.967	80 Hg Mercury 200.59	81 Tl Thallium 204.38	82 Pb Lead 207.2	83 Bi Bismuth 208.98	84 Po Polonium (210)	85 At Astatine (210)	86 Rn Radon (222)
Period 7	87 Fr Francium (223)	88 Ra Radium (226)	89–103** Actinides	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (265)	109 Mt Meitnerium (268)	110† (269)	111† (272)	112† (277)						

† Until official names are given to new elements, names based on a Latin translation of the atomic number are used; e.g. *ununbium* (Latin *unus* '1' + *unus* '1' + *bi-* '2') for element 112.

*LANTHANIDES	57 La Lanthanum 138.91	58 Ce Cerium 140.12	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.24	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.96	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.50	67 Ho Holmium 164.930	68 Er Erbium 167.26	69 Tm Thulium 168.934	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.97
**ACTINIDES	89 Ac Actinium (227)	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.03	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)

Periods

The elements are placed into seven rows, or **periods**, according to the number of electron shells in their atoms. Each atom consists of a nucleus of neutrons and protons surrounded by one or more energy levels, or shells, in which electrons are continuously orbiting. The smallest atoms have only one electron shell. Larger atoms have as many as seven shells, each one successively larger than the one inside it. Hydrogen and helium have only one electron shell and are therefore placed in Period 1, while sodium and chlorine have three shells and are placed in Period 3. By noting the period in which an element is located, you can immediately know how many electron shells it has.

Lanthanides and Actinides

The elements of the **lanthanide series** (elements 57–71) and the **actinide series** (elements 89–103) all behave in a manner similar to that of the elements in Group 3. But since they have different atomic numbers, they are separated from the main Periodic Table to make it easier to read.

Groups

The elements are organized into 18 separate columns, or **groups**, according primarily to the number of electrons occupying their outermost shell. This number is important because it strongly affects the way an element will behave in a chemical reaction. Since the elements in each group have the same number of electrons in their outer shell, they share certain chemical behaviors such as the ability to combine with other elements to form compounds. In the case of the larger elements in Periods 4 through 7, the number of electrons in some of the inner shells also affects their behavior and thus determines where their groups are placed in the Table.

Alkali metals	Actinide series	Transition elements	Nonmetals
Alkaline-earth metals	Other metals	Lanthanide series (rare-earth elements)	Noble gases

INTRODUCTION

- Potassium is a mineral found in foods
- It is also an electrolyte, which conducts electrical impulses throughout the body
- It is an essential nutrient because it is not produced naturally by the body
- Therefore it is important to consume the right balance of potassium-rich foods and beverages
- This nutrient has not been considered as an important nutrient in nutrition

BIOCHEMICAL FUNCTIONS OF POTASSIUM

- **Potassium is one of the high most common element/mineral (by mass) in the human body (0.2%) (70 kg == 140 g) after calcium and phosphorus**

- **Potassium assists in a range of essential body functions, including:**

  - **To maintain body fluid and electrolyte balance**

    A. **Body fluid: about 50-70% (42 litres) of an adult body weight is made up of fluid**

    B. **28 litres is within the cells - intracellular fluid and 14 litres is outside the cell - extracellular fluid.**

    - **There are two types of extracellular fluid:**

    1. **Tissue fluid or interstitial (flows between cells). Also includes cerebrospinal, mucus and synovial.**

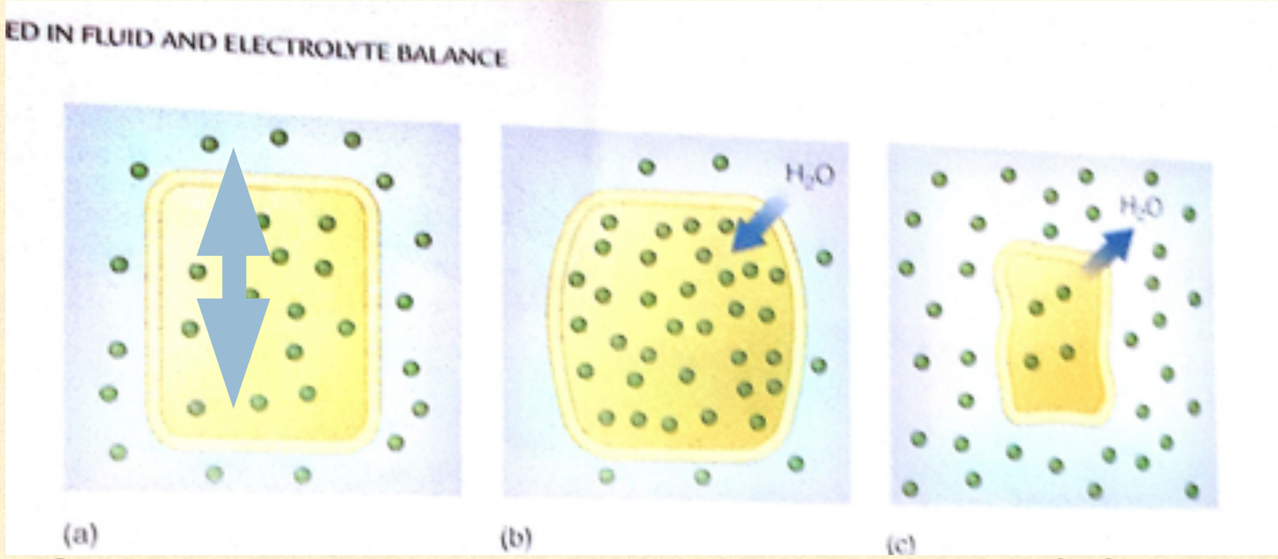
    2. **Intravascular fluid - plasma, which contains large proteins**

BIOCHEMICAL FUNCTIONS OF POTASSIUM….

- **Body fluid is composed of water and electrolytes**
- **Water: dissolves and transport substances, account for blood volume, maintain body temperature, protect and lubricate tissues**
- **Electrolytes (Potassium K^+, Sodium Na^+, Chloride Cl^- & Phosphorus HPO_4^{2-}), form ions when dissolve in water and are capable of carrying an electrical current. The electrical charge acts as a "spark" that stimulates nerves and causes muscles to contract.**
- **K^+ and HPO_4^{2-} are dominant in the intracellular fluid and Na^+ and Cl^- in the extracellular. The occurrence of these electrolytes on either side of the cell membrane creates a difference in electrical charge and this is needed in order for the cell to perform its normal functions.**

ELECTROLYTES- OSMOSIS

- Regulation of electrolyte balance: Water flows to an area where the level of electrolytes is high therefore controls movement of fluid into and out of the cells.

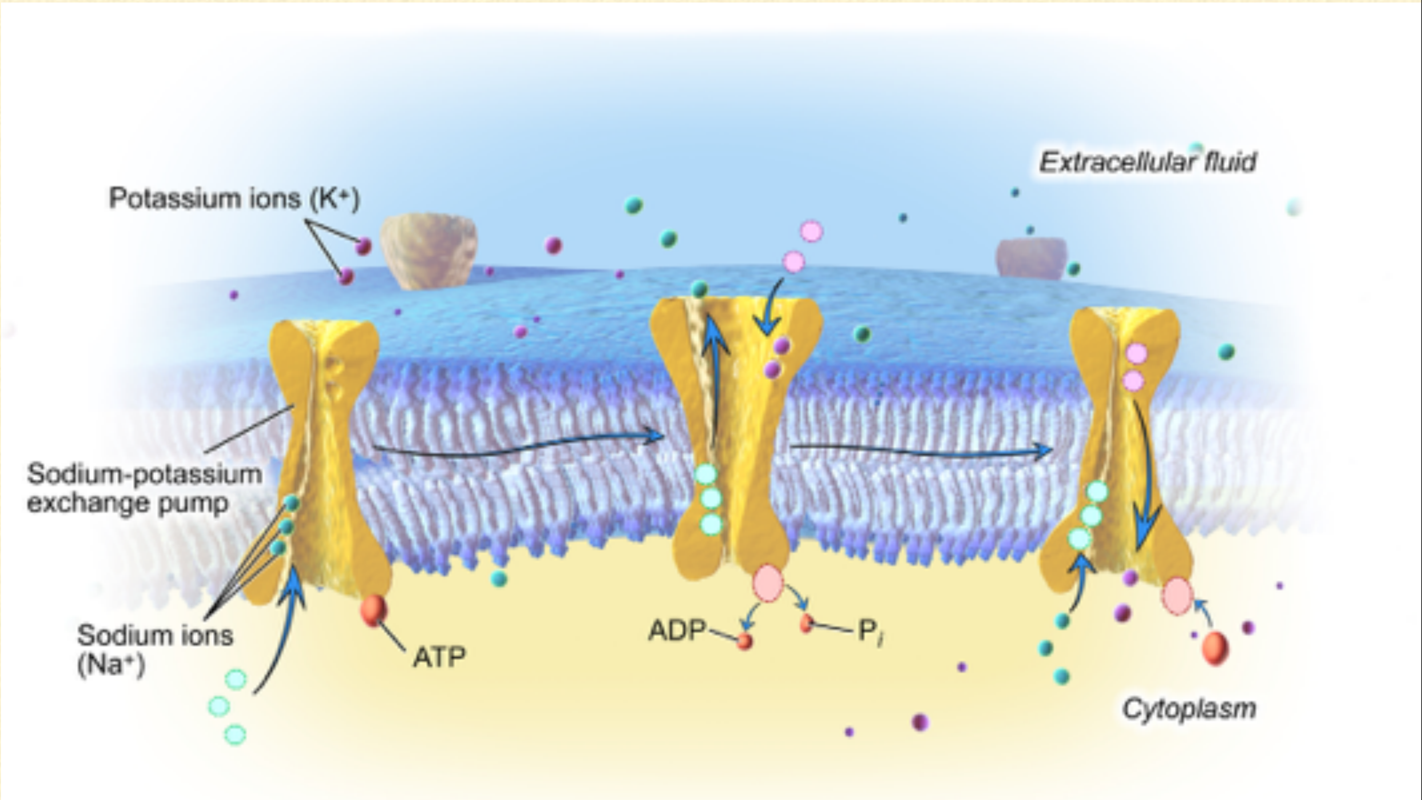


a. **Electrolyte concentration is the same in both sides of the cell membrane net movement of water is equal**
b. **Electrolyte concentration higher inside than outside**
c. **Electrolyte concentration higher outside than inside**

- Cells regulate the balance of fluids between internal and external environments by using special transport proteins that actively pump <u>**potassium**</u> and sodium across cell membranes

ELECTROLYTE REGULATION

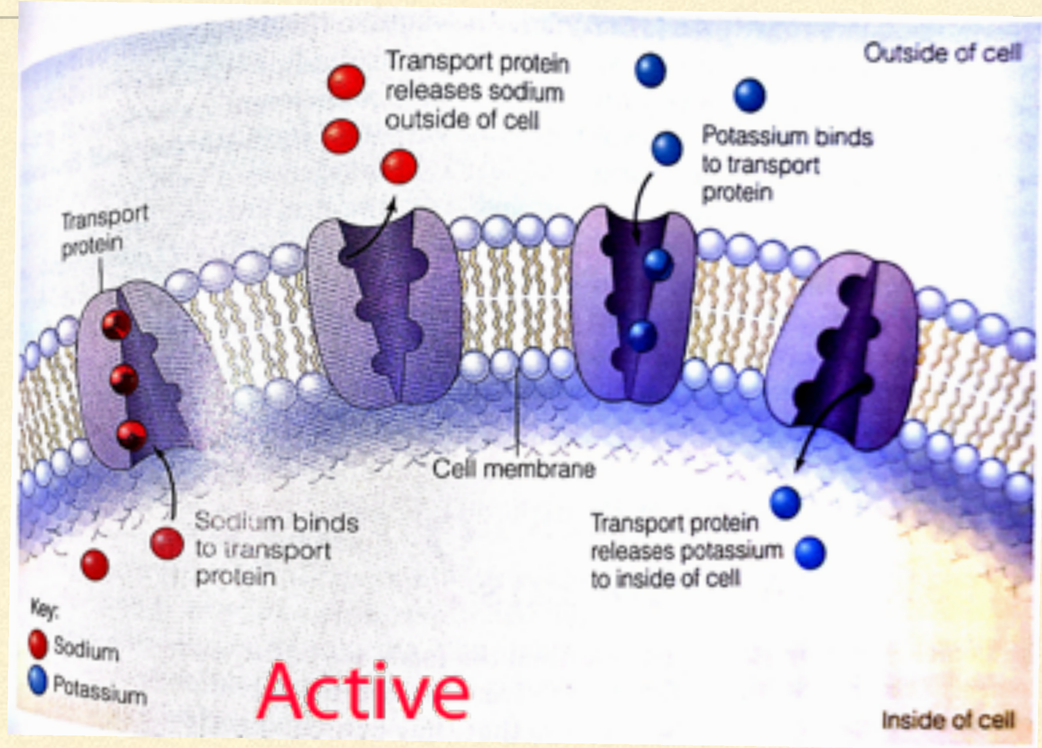
- Cells contain a relatively high concentrations of potassium ions but low concentrations of sodium ions.
- Most of the sodium ions are in the extracellular fluid compartment.
- The sodium-potassium pump moves two ions in opposite directions across the plasma membrane. The two sides of the membrane are interdependent
- The protein carrier ATP-ase transports both ions. The pump pumps three sodium ions out of the cell for every two potassium ions pumped into the cell.
- The balance between sodium and potassium creates an electrical and chemical gradient that functions to transport molecules in and out of the cell and transmit nerve signals that induce muscle contraction and induce functions related to muscles.

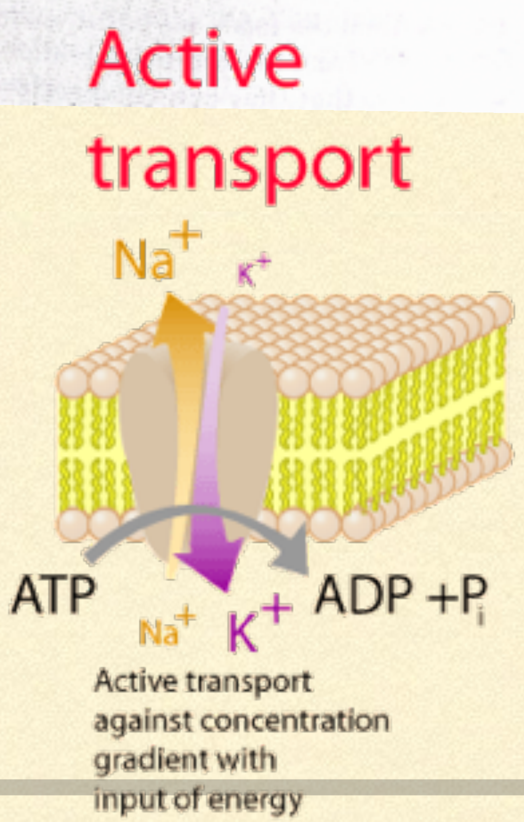


The Sodium-Potassium Exchange Pump

MAINTENANCE OF FLUID BALANCE

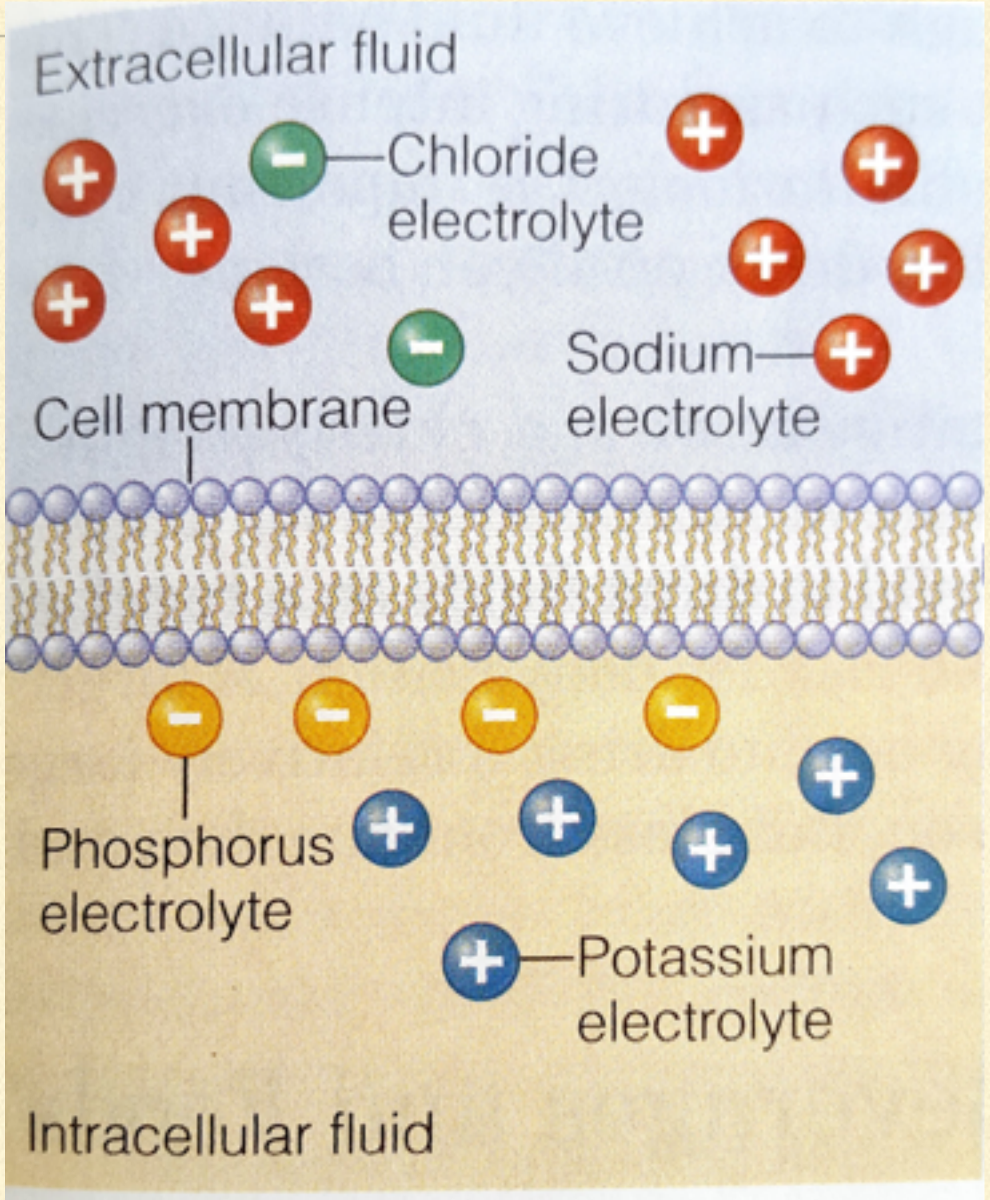
- Mechanisms:
  A. Thirst: A desire to drink fluids in response to an increase in the concentration of Na^+ in the blood or decrease in blood pressure and volume
- Increased salt concentration (Na^+) in the blood. Water moves from the cell into the ECF
- Reduction in blood volume and blood pressure (vomiting, sweating, blood loss, diarrhoea and low fluid intake
- dryness in tissues of the mouth and throat





NERVE IMPULSE TRANSMISSION

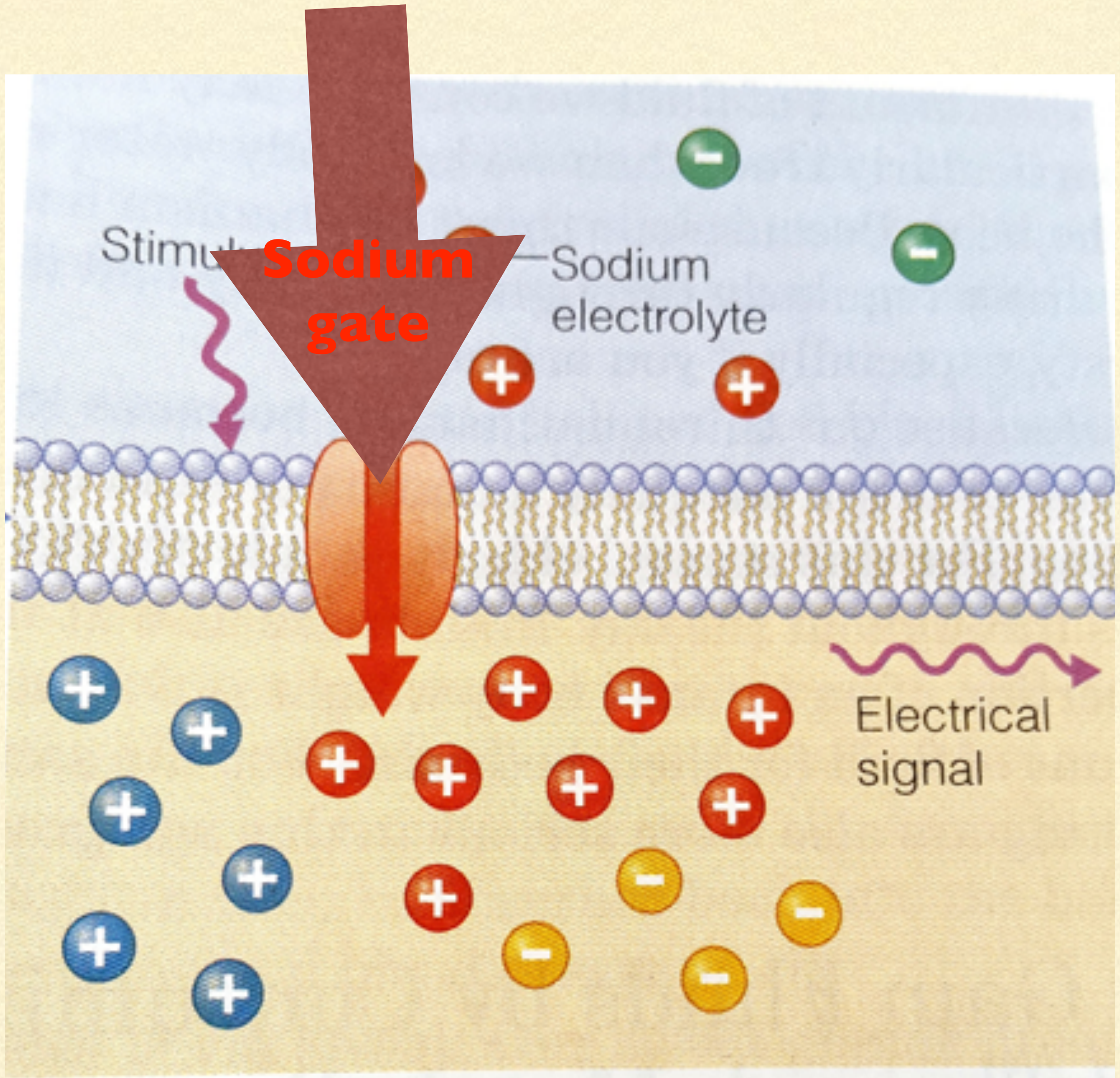
- In neural cells, electrical potentials are created by the separation of positive and negative electrical charges that are carried on ions (charged atoms) across the cell membrane.
- Resting state or potential: The intracellular fluid has slightly more electrolytes with a **<u>negative</u>** charge (K^+ and HPO_4^{2-}).
- The Nerve cell membrane is in the polarised state. There is a balance between charges on either side of the membrane.



(a) Resting state

NERVE IMPULSE TRANSMISSION

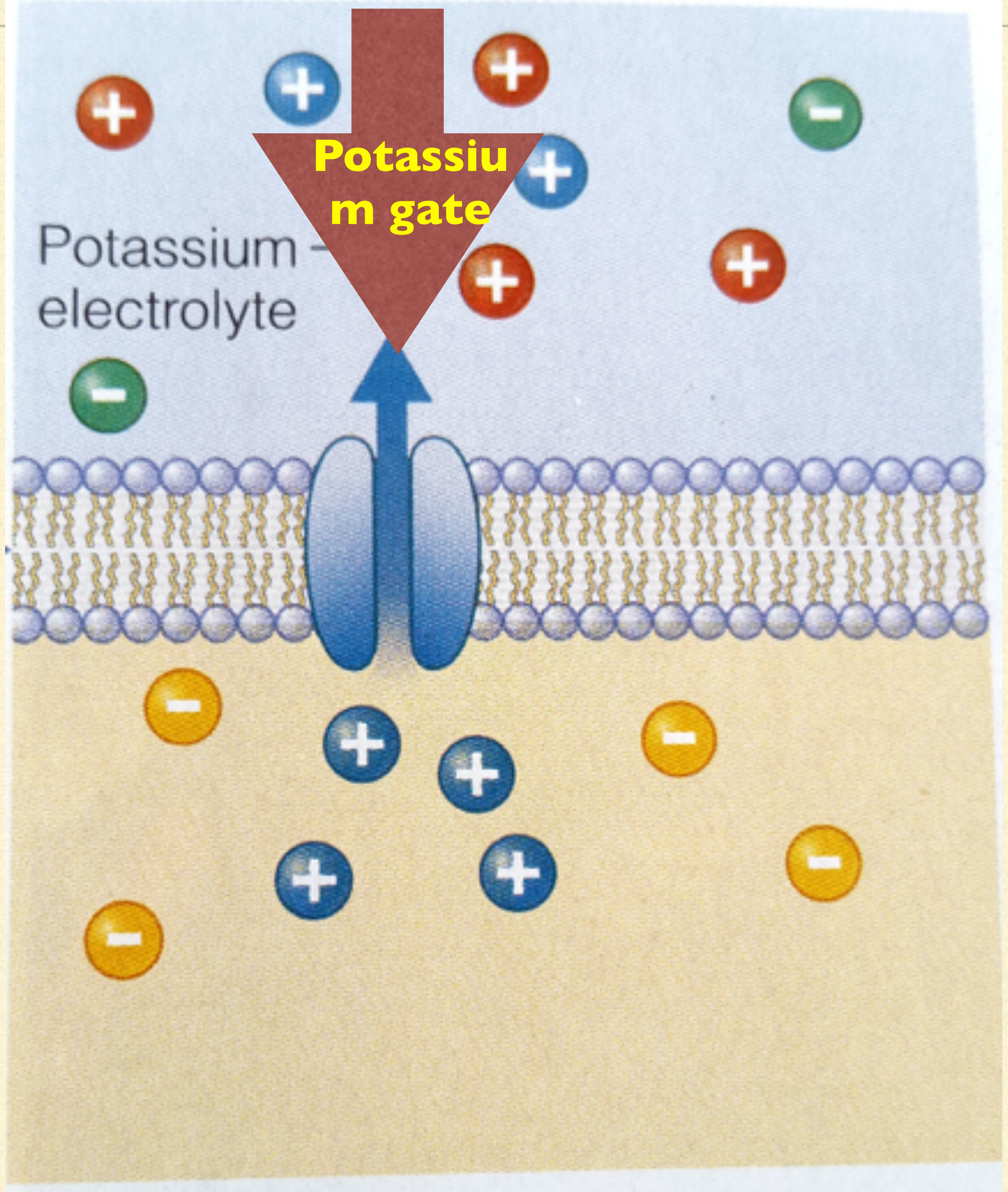
- Nerve Stimulation: A stimulus causes an influx of sodium into the interior of the cell through Na+ gates.
- The charge inside the cell becomes **positive and outside negative;** the cell membrane is depolarised.
- An action potential is transmitted to adjacent regions of the cell membrane
- This causes an imbalance in the concentration of ions, which prompts the movement of potassium ions to try to restore the balance



b) Depolarization

NERVE IMPULSE TRANSMISSION

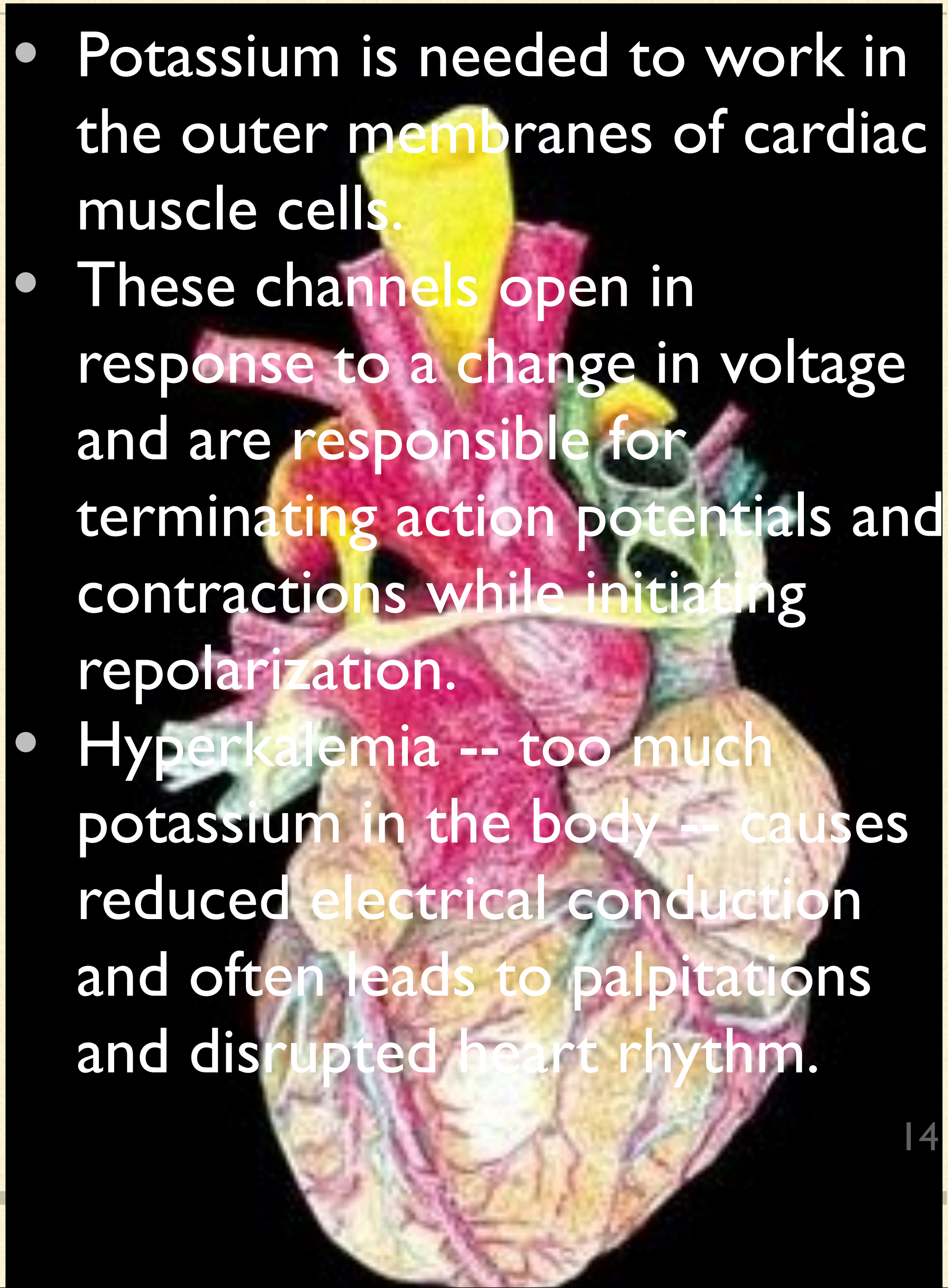
- **Repolarisation: Release of potassium to the exterior of the cell allows the first portion of the membrane to return to the resting state until next stimulation**
- **In the absence of potassium, this sequence of events will not take place and therefore no nervous impulse transmission can occur**



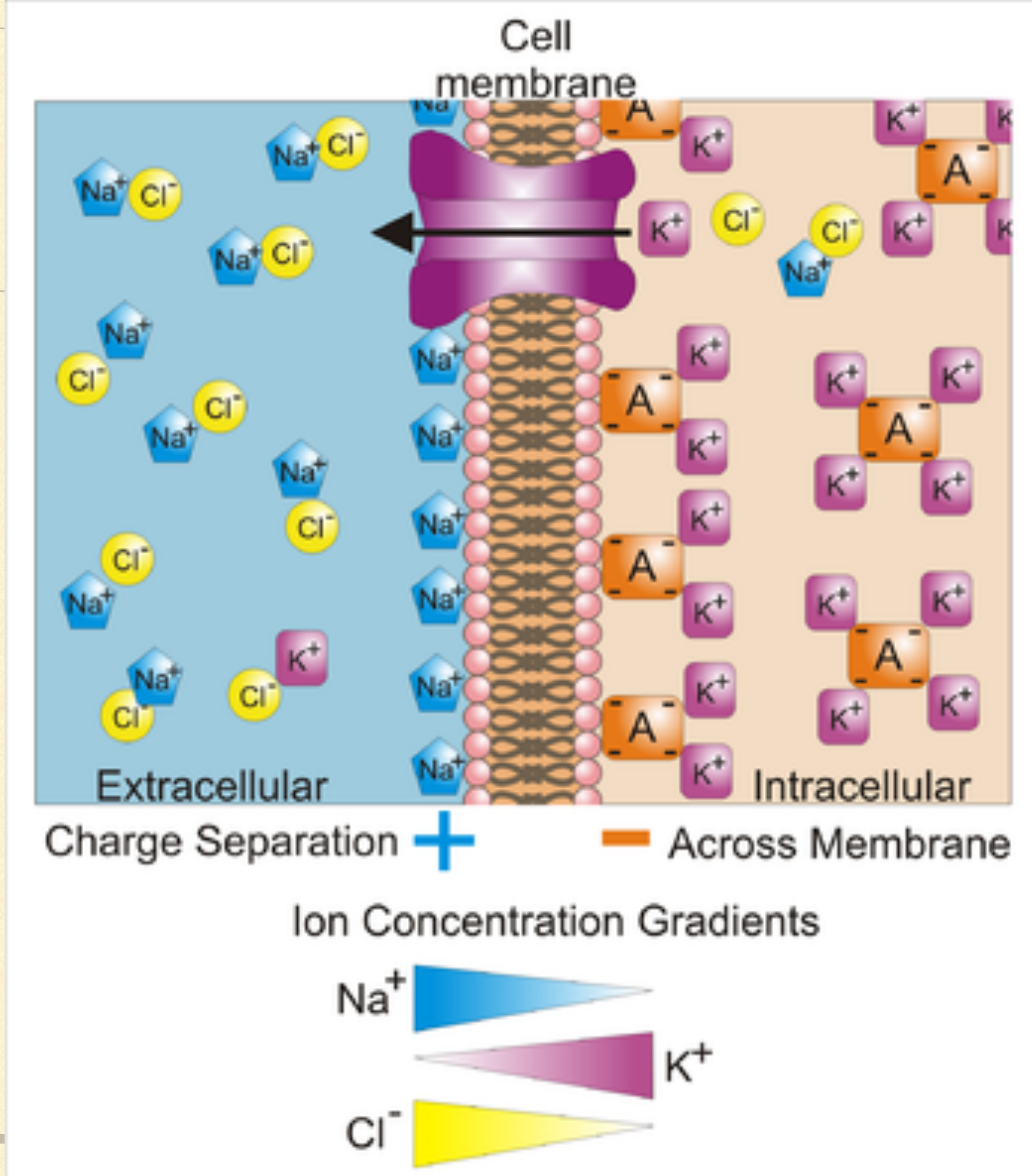
(c) Repolarization

MUSCLE CONTRACTIONS

- Electrolytes are especially important for normal contraction of skeletal and cardiac muscle fibres. Without the appropriate balance of electrolytes such as potassium and sodium, heart contractions become abnormal and the risk of heart attack increases.
- Potassium is crucial to heart function, and low levels in the body (hypokalemia) lead to irregular contractions and abnormal electrocardiograms



- Potassium is needed to work in the outer membranes of cardiac muscle cells.
- These channels open in response to a change in voltage and are responsible for terminating action potentials and contractions while initiating repolarization.
- Hyperkalemia -- too much potassium in the body -- causes reduced electrical conduction and often leads to palpitations and disrupted heart rhythm.


Cell membrane
Extracellular
Intracellular
Charge Separation
Across Membrane
Ion Concentration Gradients
Na+
K+
Cl-
A-

MUSCLE CONTRACTIONS…

- The electrical impulse generated by potassium stimulates calcium ions to move across the cell membrane to the fluid surrounding the cell. This movement of calcium ions triggers the muscle cells to contract and aids in movement.
- A low potassium level inhibits muscle relaxation, causing rigid muscles that lead to tension and impaired function.
- Common symptoms of potassium deficiency include muscle weakness and spasms

BLOOD PRESSURE

- Blood pressure is influenced by the dietary potassium intake, both in normal subjects and hypertensive subjects.
- The increased prevalence of high blood pressure in the population does not appear to be related to greater dietary intake of sodium chloride but rather due low potassium intake.
- Dietary potassium depletion raises blood pressure in normal humans

BLOOD PRESSURE….

- Potassium is a vasodilator and has a relaxation effect on the tiny blood vessels called arterioles and this results in increased local blood flow.
- Low level of potassium leads to vasoconstriction and increased blood pressure.
- Excessive sodium consumption results in urinary potassium loss and increased blood pressure
- Kidneys help to control blood pressure by controlling the amount of fluid stored in the body. The more fluid, the higher the blood pressure.
- Kidneys do this by filtering the blood to remove the extra fluid and stores it as urine in the bladder.
- This process requires a delicate balance of sodium and potassium in order to absorb water across a wall of cells from the bloodstream into a collecting channel that leads to the bladder.

GASTROINTESTINAL MOTILITY

- Digestion process is facilitated by rhythmic intestinal contractions called peristalsis responsible for propelling the food along the GIT.
- Peristalsis involves alternating contraction and relaxation of the smooth muscle tissue in the walls of the intestines and pushes the contents of the tract forward
- The muscles of the intestines rely on potassium and other minerals such as sodium, calcium and magnesium for normal tone to facilitate contraction.
- Hypokalemia (low potassium) negatively affect peristalsis and lead to stomach upset, abdominal cramps, constipation and even intestinal paralysis
- It is estimated that one in three persons has a GI functional or motility disorder (not sure about the prevalence in Tanzania since these cases are never diagnosed and reported)

OTHER FUNCTIONS

- Glucose and insulin metabolism
  - Potassium, (serum and extent dietary intake levels), has been associated with incident of diabetes.
  - Lower levels of potassium have been found to be associated with a higher risk of diabetes through interference on the functioning of beta cells
  - Hypokalemia lead to impaired glucose tolerance by reducing insulin secretion in response to glucose loads as well as interruption on glucose transportation at the cell membrane.
- Hormone secretion
- Control electrical activity of the heart
- Renal concentrating ability
- Mineral-corticoid action
- Body Growth and Development
- Activate enzymes
- Metabolism of carbohydrates and proteins

SOURCES OF POTASSIUM IN THE DIET

- Potassium occurs in all living cells. Therefore it is present in all plants (crops) and animals
  - Meat and meat products
  - Dairy and dairy products
  - Green leafy vegetables and non leafy vegetables, mushrooms
  - Legumes
  - Roots and tubers (potatoes and sweet potatoes)
  - Fruits - bananas, kiwi, citrus fruits, avocado
  - Nuts

RECOMMENDED INTAKE OF POTASSIUM FOR OPTIMAL NUTRITION

- The proper level of potassium is essential for normal cell function. An abnormal increase in potassium (hyperkalemia) or decrease in potassium (hypokalemia) can profoundly affect the nervous system and heart, and when extreme, can be fatal. The normal blood potassium level is 3.5 to 5.0 milliEquivalents/liter (mEq/L), or 3.5 international units (3.5 - 5.0 mmol per litre of plasma)

- Levels below or higher than these normal levels are associated with increased rate of death of any cause. Cardiac, kidney and lung diseases are accelerated if serum potassium levels are not maintained within the normal range

- A healthy diet should include **4,700 milligrams** of potassium each day

- In nutrition, we have no been paying attention either on this nutrient

- No recommended intake levels for Tanzania population or even prevalence of deficiency.

DIGESTION AND ABSORPTION

- The absorption of potassium takes place in the intestinal tract
- Potassium absorption occurs in the portions of the intestine called the ileum and the jejunum
- It is a passive process, therefore potassium diffuses into the blood on its own according to the concentration gradient

POTASSIUM CONTENT OF FOODS IN TANZANIA

Food Item	K (mg/
Maize flour	287
Bulrush millet	307
Finger millet	408
Rice	81
Sorghum	131
Wheat	107
Cowpea	278
Pigeon pea	777
Cassava	243
Sweet potatoes	303
Beans	1036

Food Item	K (mg/
Bambara	539
Chickpea	291
Cowpea	278
Lentil	303
Groundnuts	705
Cashewnute	732
Beef	230
Fish	122

POTASSIUM CONTENT OF FOODS IN TANZANIA…..

Baobab	1221
Banana	385
Bread fruit	490
Guava	417
Jackfruit	303
Orange	181
Tamarind	676
Papaya	257

Cassava leaves	550
Spinach	466
Carrot	320
Sweet potato	315
Mushroom	318
Okra	304
Cowpea	248
Chinese Cabbage	202

http://www.hsph.harvard.edu/nutritionsource/more/food-tables/index.html

DEFICIENCY OF POTASSIUM

- Hypokalemia: Cause GI loss due to vomiting and renal loss due to diuresis
  - Symptoms
    - muscle weakness,
    - paralytic ileum
    - ECG abnormalities
    - Decreased reflex response
    - Respiratory paralysis
    - Cardiac arrhythmia

- Hyperkalemia: is the medical term that describes a potassium level in the blood that's higher than normal.
- Symptoms:
  - malaise, palpitations and muscle weakness, mild hyperventilation may indicate a compensatory response to metabolic acidosis, which is one of the possible causes of hyperkalemia

FACTORS INFLUENCING POTASSIUM AVAILABILITY IN FOODS

- Soil test K: Higher soil test K increases the available K, by increasing the amount and balance of K relative to other cations.
- Cation Balance: Where there is a significant imbalance between available K and the other major cations (Primarily Calcium, Magnesium, and sometimes Hydrogen, Aluminum, or Sodium), it may affect the availability of K to the crop.
- Soil Moisture: K is transported within the soil and is absorbed by plant roots in the soil water. Therefore a water deficiency results in less K absorption.
- Soil pH: As the soil pH is reduced (increasing soil acidity) the availability of K is often reduced.
- Soil Temperature: Cold soils often reduce the availability of K.
- Soil compaction: Compacted soils often reduce the availability of K.
- Soil Drainage/Aeration: As soil drainage is improved, K uptake typically improves.
- Soil Salinity: Saline soils often have excess sodium (Na). One of the negative effects of excess Na is that it reduces the availability of K.
- Interactions
- K/Mg ratio: Each of K or Mg can reduce the uptake of the other when the "normal" soil balance does not exist.
- Soil CEC

FACTORS INFLUENCING POTASSIUM AVAILABILITY IN THE BODY

- Presence of substances that inhibit absorption, transportation and utilisation of potassium
- Deficiency of protein that may interfere with movement of potassium into and outside the cell

CONCLUSION

- Potassium is the chief intracellular cation
- Relative intracellular-extracellular potassium concentrations directly affects a cell's resting membrane potential, therefore a slight change on either side of the membrane has profound effects (e.g. on neurones and muscle fibres)
- Potassium is part of the body's buffer system, which resists changes in pH of body fluids; ECF potassium levels rise with acidosis (decrease pH) as potassium leave cells and fall with alkalosis (increase pH) as potassium moves into cells
- Potassium balance is maintained primarily by renal mechanisms (i.e. influenced by Aldosterone)
- Potassium reabsorption from the filtrate is constant - 10-15% is lost in urine regardless of need; because potassium content of ECF is low (compared to sodium concentration), potassium balance os accomplished by changing amount of potassium secreted into the filtrate; therefore regulated by collecting tubules

CONCLUSION

- Potassium is crucial for human as well as animal nutrition and foods are the good sources of the mineral.
- The mineral is essential because the body has no ability of making potassium for its requirement
- Crops obtain potassium from the soil, it is crucial that the soils in which food crops are grown should have sufficient quantities of the mineral
- As we strive to improve crop productivity we also need to consider nutritional quality of crops.
- Efforts to improve soil fertility should be seen as efforts to improve human health since this is our overall goal. Soil scientists are urged to consider nutritional quality of crops in soil programmes

THANK YOU