

Module 9: Water and Minerals

**Electrolytes, Mg, Zn I-
Chap.8**

+ Minerals

- Bioavailability
 - Inorganic, highly variable
 - Absorption varies with need
 - Interactions with other nutrients
 - Potential toxicity from excess intakes
 - Metabolic interactions
 - General function in metalloenzymes
 - Regulators of body processes
 - Structural components
- Food contents
- Minerals: micrograms (μg) to grams (g)

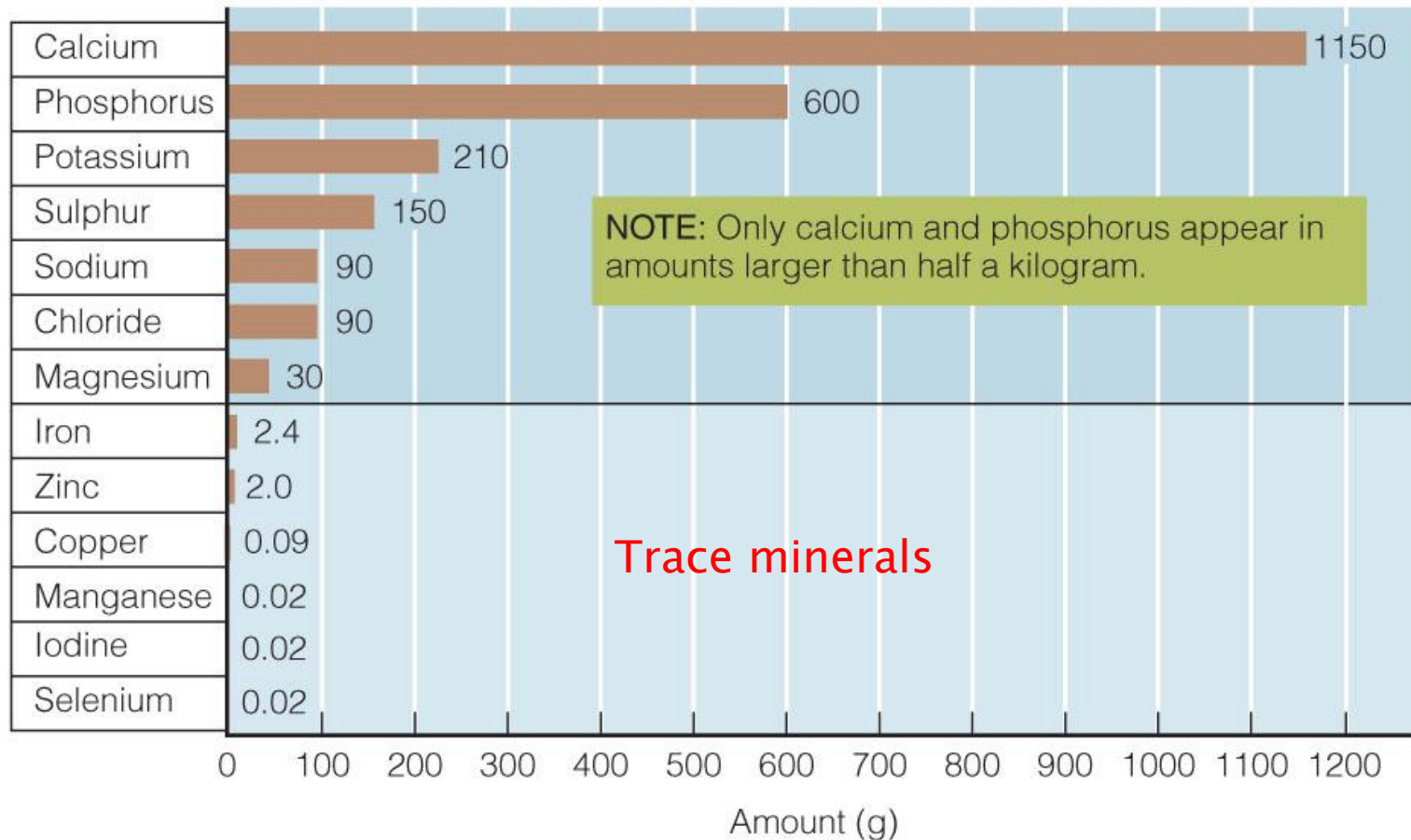




Minerals – in a 60 kg person

FIGURE 10-2 Minerals in a 60-kilogram (132-pound) Human Body

Not only are the major minerals needed by the body in larger amounts, but they are also present in the body in larger amounts than the trace minerals.





Water, Electrolytes, Mg

Blood pressure



Water and Body Fluids



- About 60% of body weight (higher in children)
- Dependent on body composition
 - 3/4 of weight in lean tissue is water
 - < 1/4 of weight in fat tissue
- Proportion of water is smallest in:
 - Females
 - Individuals with higher % body fat
 - Elderly



An extra drink of water benefits both young and old.

+ Water and Body Fluids



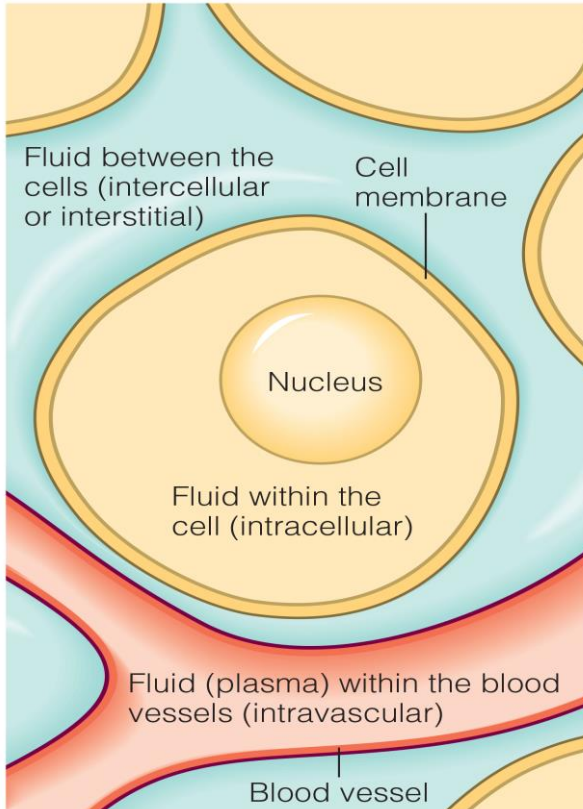
■ Functions:

- Nutrient absorption and transport
- Waste product
- Maintains the structure of large molecules
- Participates in metabolic reactions
- Serves as a solvent
- Acts as a lubricant
- Shock absorber

Aids in body temperature regulation

- Maintains blood volume

+ Water Balance



- Every cell contains fluid and is surrounded by fluid
 - Intracellular
 - Extracellular (interstitial)
- Continual turnover
- Rapid adjustments to maintain homeostasis

+ Water Intake



- Controlled by hypothalamus
 - ↓ water = concentrated blood = ↑ thirst
 - ↑ water = distension of stomach = ↓ thirst
- Dehydration
 - Thirst
 - Weakness, exhaustion, delirium
- Water intoxication
 - Confusion, convulsions, death
 - Hyponatremia

+ How Much Water Do I Need to Drink in a Day?

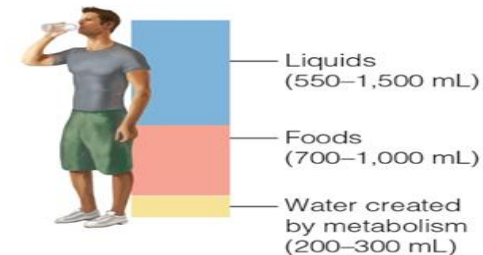
- Water needs vary
- ~1 to 1.5 mL/kcal
- DRI recommendations:
 - Men need about 15.6 cups (3.7 L) of fluid
 - Women need about 11.4 cups (2.7 L)

Figure 8-2

Water Balance—A Typical Example

Each day, water enters the body in liquids and foods, and some water is created in the body as a by-product of metabolic processes. Water leaves the body through the evaporation of sweat, in the moisture of exhaled breath, in the urine, and in the feces.

Water input (Total = 1,450–2,800 mL)



Water output (Total = 1,450–2,800 mL)





Water Balance

Water Sources	Amount (mL)
Beverages	550 to 1500
Foods	700 to 1000
Metabolism	200 to 300
Total	1450 to 2800

Water Losses	Amount (mL)
Kidneys (urine)	500 to 1400
Skin (sweat)	450 to 900
Lungs (breath)	350
GI tract (feces)	150
Total	1450 to 2800

Obligatory urine excretion = 500 ml

~2/3 fluid intracellular and 1/3 extracellular



Water Intake



- Increased intakes for:
 - Pregnant and lactating women
 - Diarrhea, vomiting and/ or Fever
 - Alcohol
 - Heavy exercise
 - Very young or Elderly
 - Disease conditions, surgery
 - Medications
 - Diet: fiber, high protein, salt and sugar intakes
 - Air travel
 - Hot or cold environment, High altitude

- Thirst
 - Mouth sensations, stomach, hypothalamus
 - Slow - can lag behind need
 - Must notice thirst signal then drink

+ Dehydration



- Water lost > water consumed
 - Negative water balance
- Many causes:
 - Diarrhea
 - Vomiting
 - Fever or excessive sweating
 - Unmanaged diabetes
 - Laxative or diuretic use

+ Water Balance and Recommended Intakes

	Transparent Possible over-hydration
	Pale straw Normal, well hydrated
	Transparent yellow Normal
	Dark yellow Normal, possible mild dehydration
	Deep amber or honey Normal, possible moderate dehydration
	Orange Possible severe dehydration



Signs of Dehydration

Body Weight Lost %	Symptoms
1-2	Thirst, fatigue, weakness , vague discomfort, loss of appetite
3-4	Impaired physical performance, dry mouth, reduction in urine, flushed skin, impatience, apathy
5-6	Difficulty concentrating, headache, irritability, sleepiness, impaired temperature regulation, increased respiratory rate
7-10	Dizziness, spastic muscles, loss of balance, delirium, exhaustion, collapse

NOTE: The onset and severity of symptoms at various percentages of body weight lost depend on the activity, fitness level, degree of acclimation, temperature, and humidity.

If not corrected, dehydration can lead to death.

Cengage 2019



Which of these is correct about water sources?

- a) Water is the main source of water in the diet.
- b) Water, fruits, and vegetables are the only water sources.
- c) Water, other foods, metabolism, and beverages provide water.
- d) Water, beverages, and food are the only water sources.



Percentage of Water in Selected Foods

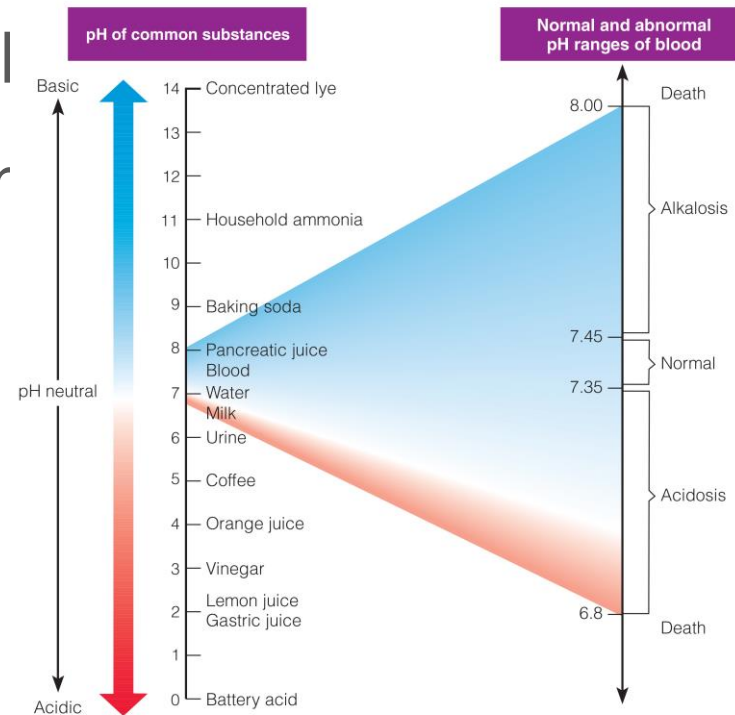
100%	Water
90-99%	Fat-free milk, strawberries, watermelon, lettuce, cabbage, celery, spinach, broccoli
80-89%	Fruit juice, yogurt, apples, grapes, oranges, carrots
70-79%	Shrimp, bananas, corn, potatoes, avocados, cottage cheese, ricotta cheese
60-69%	Pasta, legumes, salmon, ice cream, chicken breast
50-59%	Ground beef, hot dogs, feta cheese
40-49%	Pizza
30-39%	Cheddar cheese, bagels, bread
20-29%	Pepperoni sausage, cake, biscuits
10-19%	Butter, margarine, raisins
1-9%	Crackers, cereals, pretzels, taco shells, peanut butter, nuts
0%	Oils, sugars



Acid–Base

- Fluids and electrolytes help
- pH is maintained within a range
- Acidity = H^+ atoms
- Buffered by:
 - Blood
 - Kidneys
 - Lungs

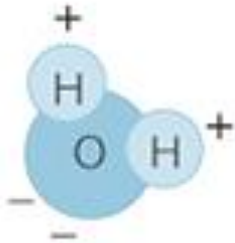
FIGURE 11-8 The pH Scale



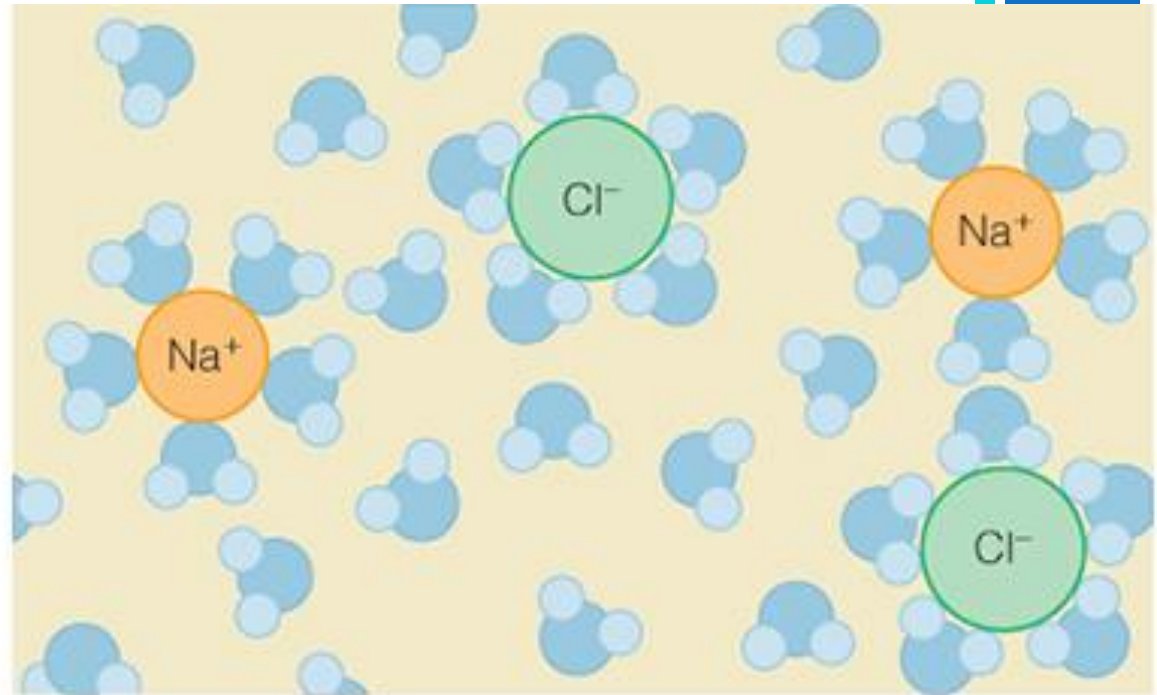
NOTE: Each step is ten times as concentrated in base ($1/10$ as much acid, or H^+) as the one below it.



Water Dissolves Salts and Follows Electrolytes



The negatively charged electrons that bond the hydrogens to the oxygen spend most of their time near the oxygen atom. As a result, the oxygen is slightly negative, and the hydrogens are slightly positive (see Appendix B).



In an electrolyte solution, water molecules are attracted to both anions and cations. Notice that the negative oxygen atoms of the water molecules are drawn to the sodium cation (Na^+), whereas the positive hydrogen atoms of the water molecules are drawn to the chloride ions (Cl^-).



Fluid and Electrolyte Balance



■ Balance of fluid:

- 2/3 inside cells and 1/3 outside cells

■ Dissociation of salt

- $\text{NaCl} \rightarrow \text{Na}^+ \text{ (cation)} + \text{Cl}^- \text{ (anion)}$
- Carry electrical currents (electrolytes)
- Muscle contractions & conduction of nerve impulses

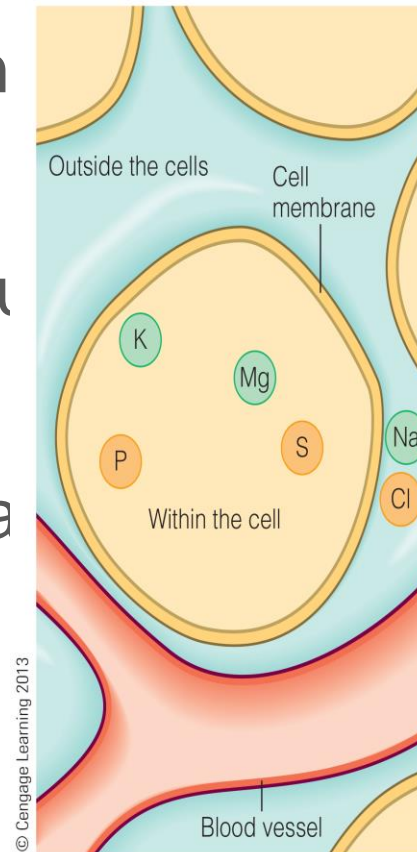
■ Balance of cations and anions

■ Electrolytes attract water

■ Acid/base balance

+ Water Follows Electrolytes

- Some electrolytes reside in
 - P, K, Mg, S
- Some electrolytes reside outside the cell
 - Na, Cl
- Water follows electrolytes across a cell membrane
 - Osmosis



Chemical symbols:

K = potassium
P = phosphorus
Mg = magnesium
S = sulfate
Na = sodium
Cl = chloride

Key:

- Cations
- Anions



Electrolytes

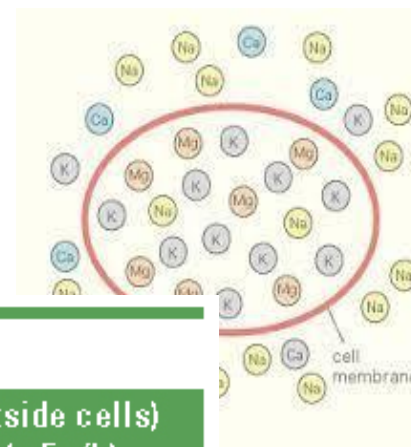


TABLE 12-1 Important Body Electrolytes

Electrolytes	Intracellular (inside cells) Concentration (mEq/L)	Extracellular (outside cells) Concentration (mEq/L)
Cations (positively charged ions)		
Sodium (Na^+)	10	142
Potassium (K^+)	150	5
Calcium (Ca^{++})	2	5
Magnesium (Mg^{++})	40	3
	202	155
Anions (negatively charged ions)		
Chloride (Cl^-)	2	103
Bicarbonate (HCO_3^-)	10	27
Phosphate ($\text{HPO}_4^{=}$)	103	2
Sulfate ($\text{SO}_4^{=}$)	20	1
Organic acids (lactate, pyruvate)	10	6
Proteins	57	16
	202	155

NOTE: The numbers of positive and negative charges in a given fluid are the same. For example, in extracellular fluid, the cations and anions both equal 155 milliequivalents per liter (mEq/L). Of the cations, sodium ions make up 142 mEq/L; and potassium, calcium, and magnesium ions make up the remainder. Of the anions, chloride ions number 103 mEq/L; bicarbonate ions number 27; and the rest are provided by phosphate ions, sulfate ions, organic acids, and protein.

+ Regulation of Fluid & Electrolyte Balance

- Fluids maintain blood volume and pressure
- GI Tract 8-10 L/day
 - Secretion and reabsorption
- Kidneys
 - Hormones regulate water and sodium excretion to adjust blood and urine volume and concentration and blood pressure
 - Antidiuretic hormone (ADH) – signal from hypothalamus to pituitary
 - Renin, Angiotensin, Aldosterone
- Losses
 - Sweating, bleeding, GI loss (vomiting, diarrhea)
 - Diabetes - lose glucose and water
 - Replacement - oral rehydration therapy

+ Oral rehydration therapy (ORT) Recipe



ORT solution

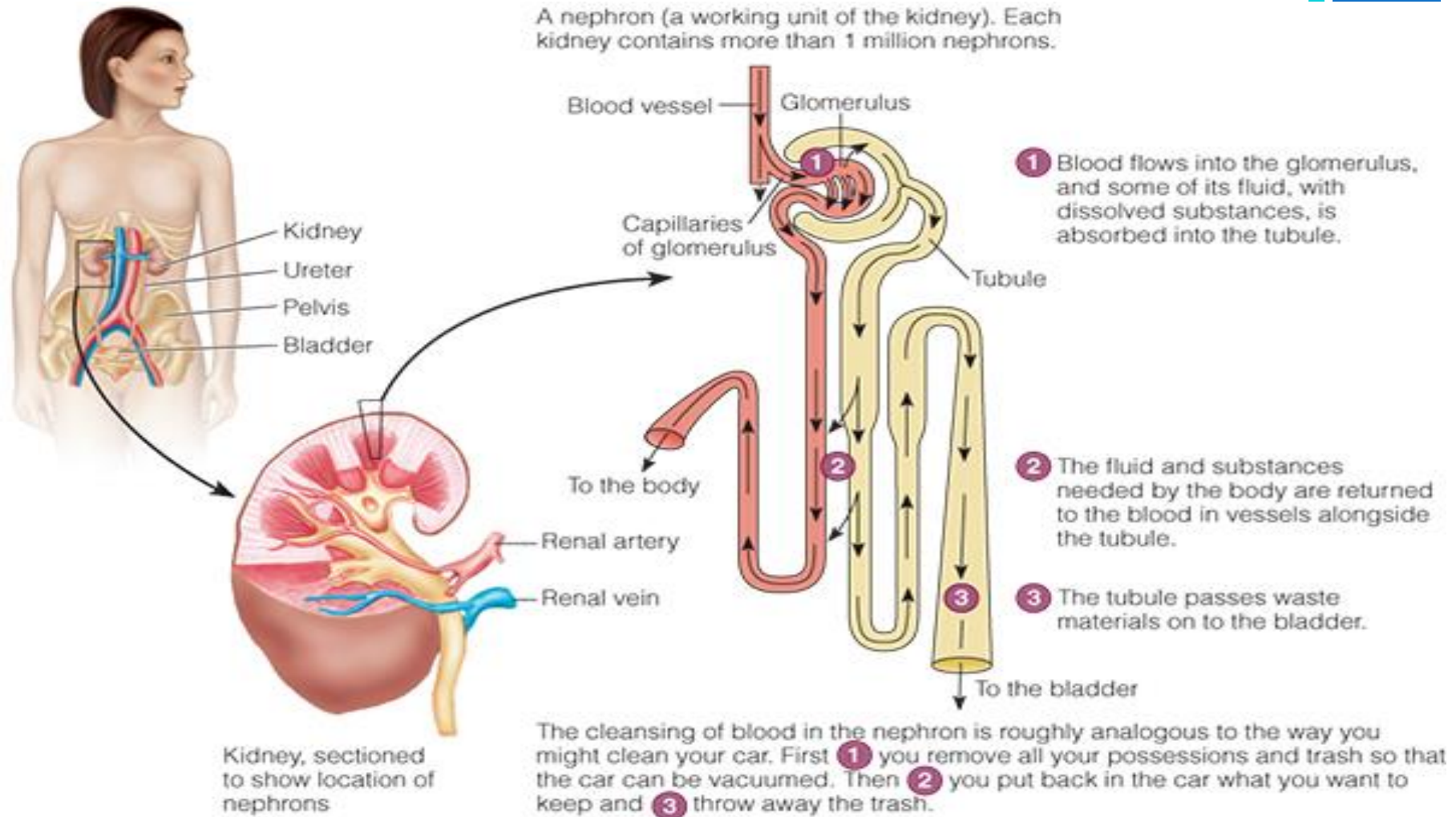
- Sugar (4tsp),
- Salt (1/2 tsp)
- Water (boiled and cooled ½ liter)

Water alone won't restore balance. Imbalances can result in a medical emergency.

- ORT intervention depends on the circumstances surrounding losses
- Ideally use *commercially-available oral rehydration salts
<https://travel.gc.ca/travelling/health-safety/rehydration> *

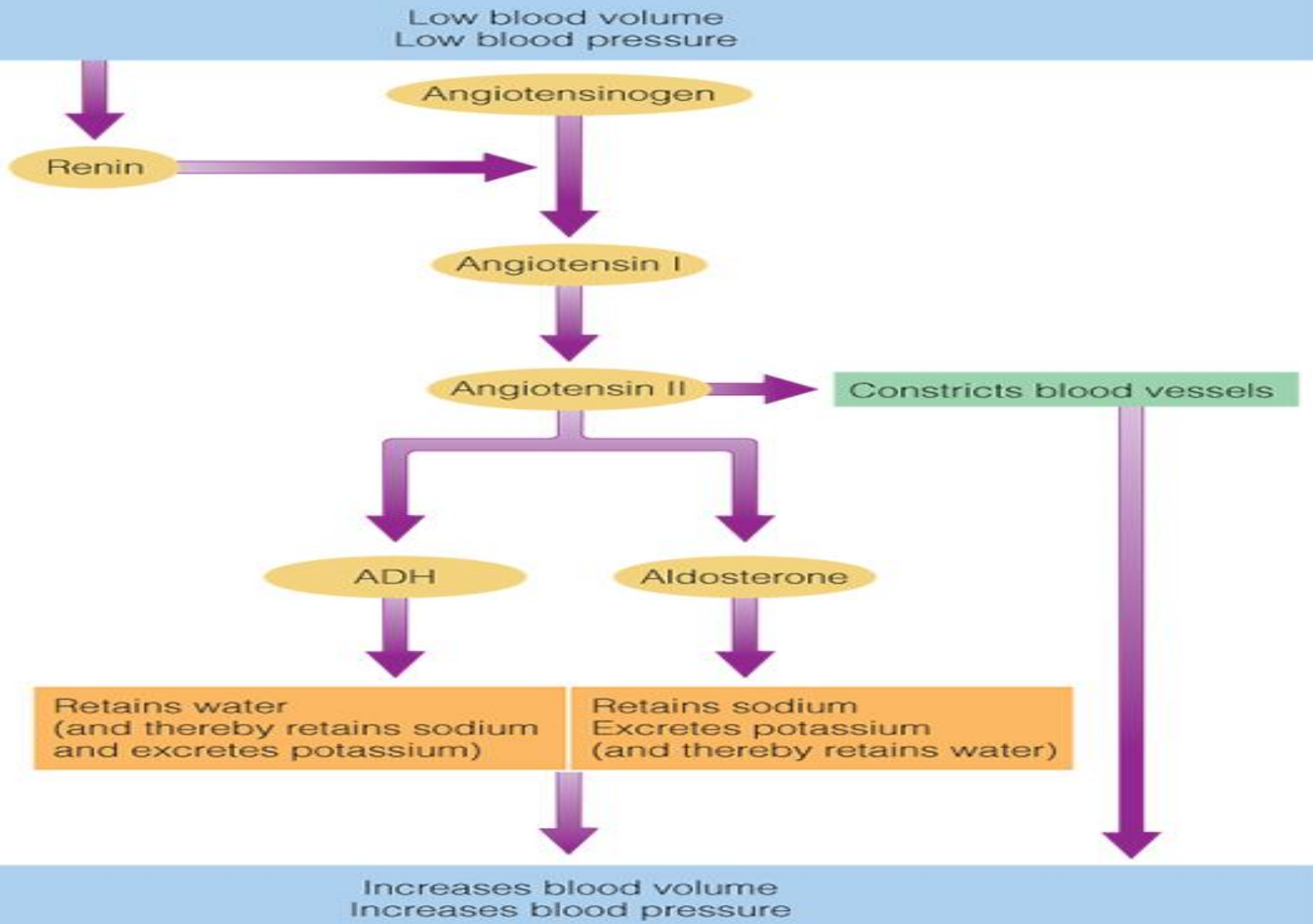


A Nephron, One of the Kidneys' Many Functioning Units

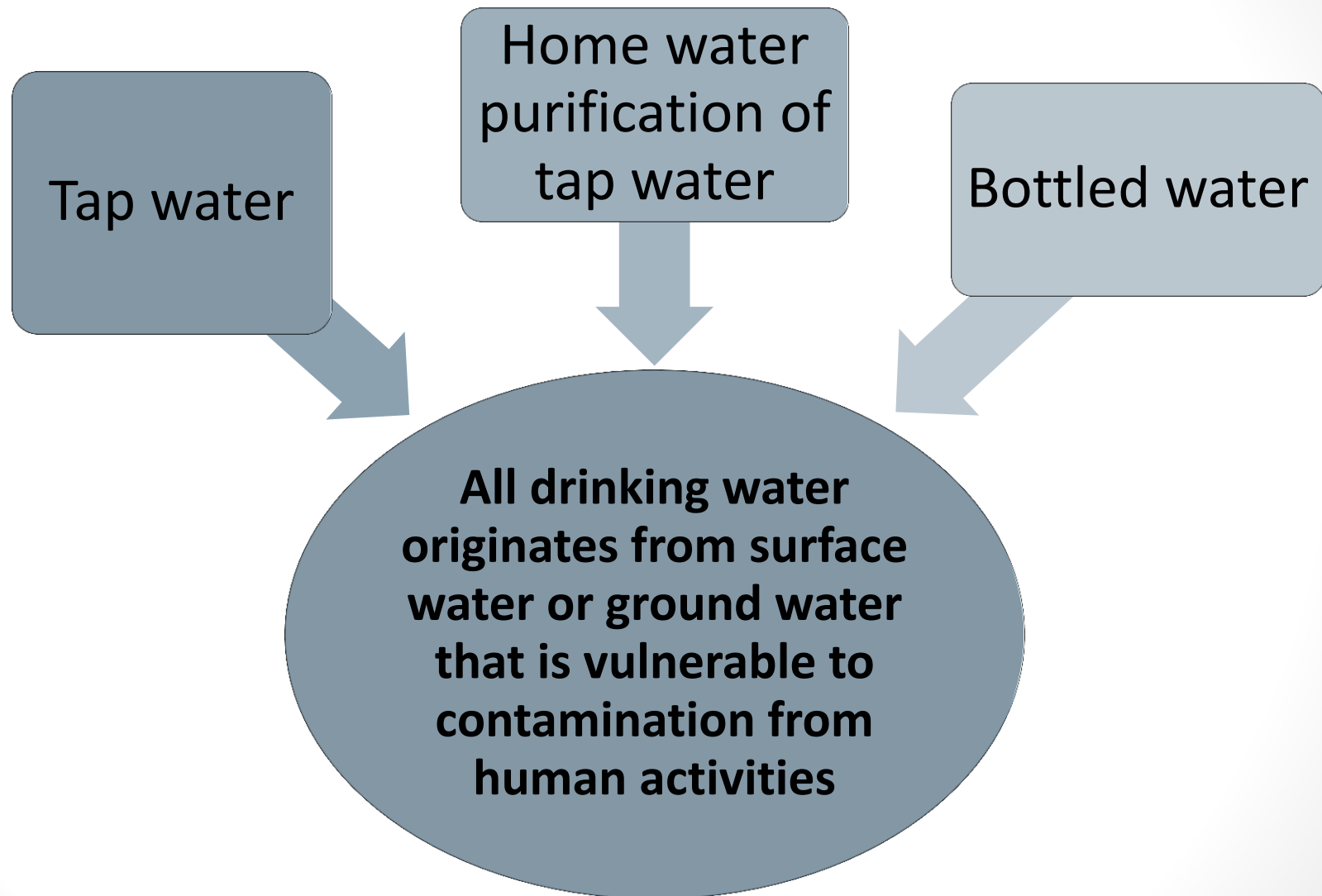


+

How the Body Regulates Blood Volume and Blood Pressure



Safety and sources of Drinking Water





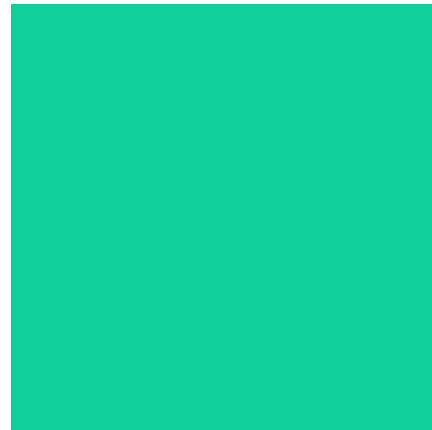
Water Recommendations



- Needs vary
 - Best beverages, foods
- Health effects
 - Physical and mental performance
 - Proper functioning of kidneys, heart, GI tract, and other systems



Sodium,
Potassium and
Magnesium





Electrolyte Balance



■ Sodium

- Extracellular cation
- Blood volume regulation
- Na K ATPase

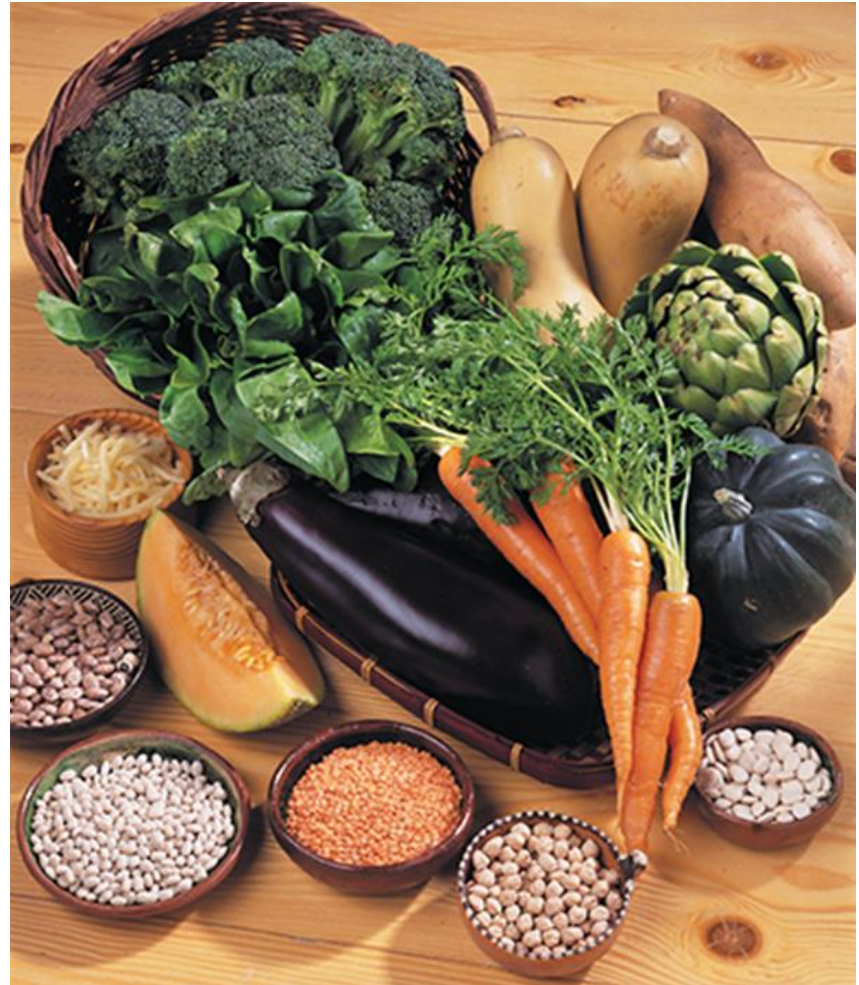
■ Potassium

- Intracellular cation
- High blood conc (cardiac arrest)
- Deficiency
 - Losses (vomiting and diarrhea)
 - Diuretics (for hypertension)



Potassium

- Principal intracellular cation
- Roles in the body
 - Helps maintain fluid and electrolyte balance
 - Helps maintain cell integrity
 - Aids in nerve impulse transmission and muscle contraction



Potassium

Adequate Intake:

Men (19–30 yr): 3,400 mg/d

Women (19–30 yr): 2,600 mg/d

CCHS 2.2 Mean Intake:^a

Men: ~2,985 mg/d

Women: ~2,411 mg/d

Chief Functions:

Maintains normal fluid and electrolyte balance; facilitates chemical reactions; supports cell integrity; assists in nerve functioning and muscle contractions

Deficiency:^b

Muscle weakness, paralysis, confusion

Toxicity:

Muscle weakness; vomiting; for an infant given supplements, or when injected into a vein in an adult, potassium can stop the heart

^aNote: Statistics Canada began releasing/rolling out the 2015 CCHS Nutrition data starting in the summer of 2017. Therefore, watch for possible changes to mean intakes of both the macro- and micro-nutrients by Canadians.

^bDeficiency accompanies dehydration.

Source: All nutrient and Caloric values for the food items shown are based on the 2015 version of the Canadian Nutrient File, available at <https://food-nutrition.canada.ca/cnf-fce/index-eng.jsp>.

+ Sodium (Na)



- Salt = sodium chloride (NaCl)
- Preserves food and enhances taste
- Roles in the body:
 - Fluid and electrolyte balance
 - Acid–base balance
 - Nerve transmission
 - Muscle contraction
- Readily absorbed and travels freely in the blood to the kidneys

+ Sodium



- Foods with sodium:
 - Processed foods (75%)
 - Also tend to have low potassium
 - Salt added
 - Natural sources
- Deficiency – rare
 - Vomiting, heavy sweating, diarrhea
 - Hyponatremia
- Toxicity

+ Sodium

Table 8–5

Sodium and Salt Intake Guidelines

2019 DRI Recommendations

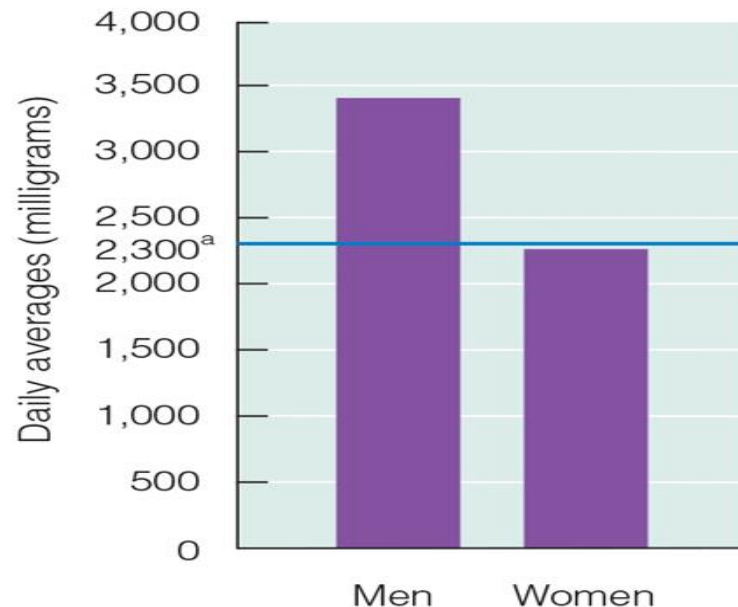
- Recommended intakes for sodium:
 - Adults (19–50 years): 1,500 mg/d
 - Adults (51–70 years): 1,500 mg/d
 - Adults (71 years and older): 1,500 mg/d
- Chronic Disease Risk Reduction (CDRR) level for sodium and salt:
 - Adults (19 years and older): 2,300 mg sodium, or 5.6 g salt (sodium chloride) per day (<http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=25353>).

Canada's Food Guide recommends

- Canada's Food Guide recommends that we make healthy choices by choosing “foods that have little to no added sodium...” and by taking care to “Compare the nutrition facts table on foods to choose products that are lower in sodium...” (go to the bottom of the page at <https://food-guide.canada.ca/en/healthy-eating-recommendations/make-it-a-habit-to-eat-vegetables-fruit-whole-grains-and-protein-foods/eat-vegetables-and-fruits/>).

Figure 8–7

Sodium Intakes of Canadian Adults (19–30 years)

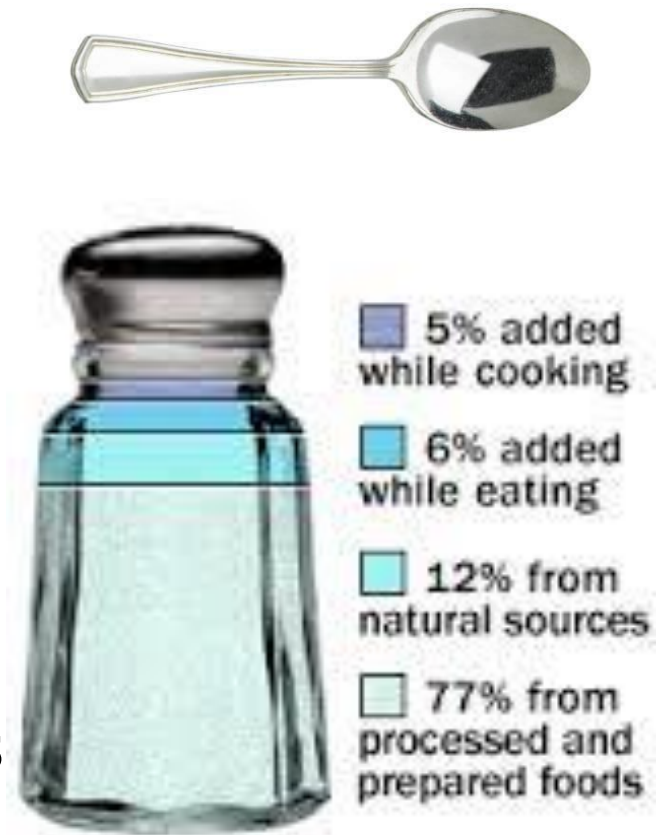


^aChronic Disease Risk Reduction (CDRR) level

Health Canada, Sodium Intake of Canadians in 2017, available at <https://www.canada.ca/en/health-canada/services/publications/food-nutrition/sodium-intake-canadians-2017.html#a2>.

Sodium

- Controlling daily salt intake
- 6 grams of salt (1 teaspoon) contains 2400 mg of sodium
 - Table salt contributes ~10%
 - Processed & fast foods contribute ~75%
 - 1/3 food budget on processed foods
 - Choose and prepare foods with less salt
 - Label reading is crucial



Functions of Salt and Sodium-Containing Additives in Food

- Microbial food preservation
- Texture, flavour, colour
- Control fermentation in bread and cheese





Magnesium



- Storage: More than half is in bones
 - Reservoir to ensure normal blood concentrations

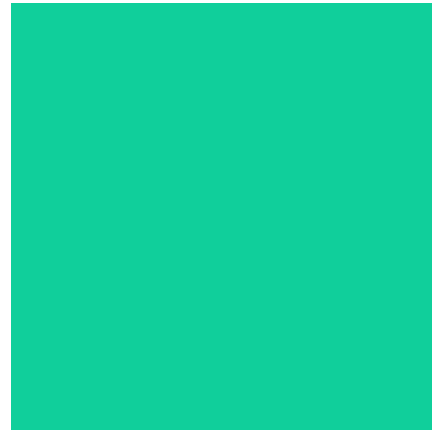
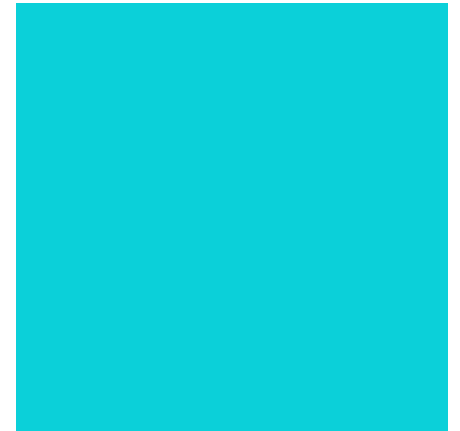
■ Roles

- Maintains bone health
- Energy metabolism and ATP production
- Inhibits muscle contraction and blood clotting
 - Blood pressure – dietary intake protective
- Supports normal function of immune system
- Deficiency rare – d/t inadequate intakes
 - Impairs central nervous system activity
- UL: 350 mgfor supplements not foods

+ Magnesium



- Half found in bones
 - Acts as a reservoir for blood
- Involved in energy metabolism
- Other functions:
 - Immune system, muscle contraction, blood clotting
- Deficiencies and toxicities rarely occur
- Critical to heart function
 - ↑ hard water = low rates of heart disease
 - Deficiency = vessel wall constriction



Trace minerals

Zinc and Iodine

+ Zinc

Works with proteins in every organ

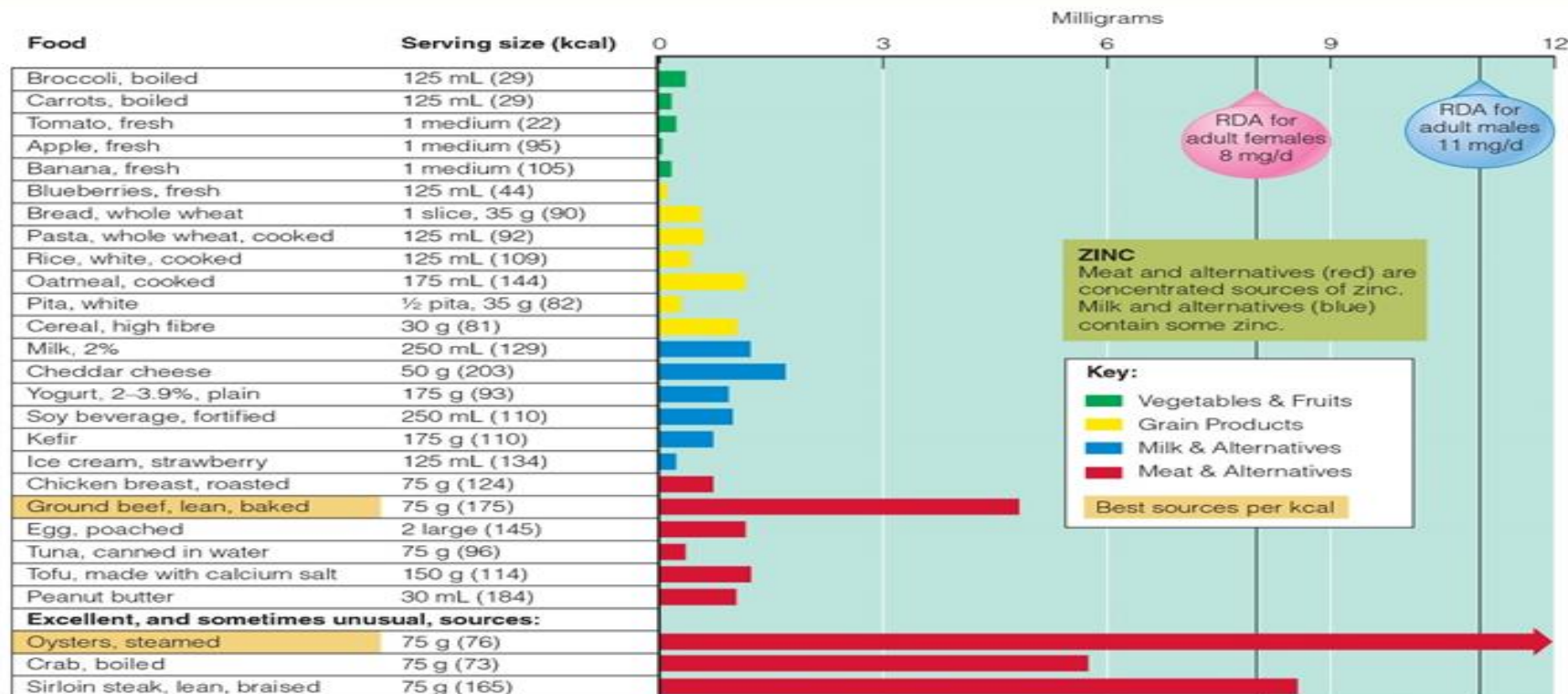
Metalloenzymes (>100)

- DNA and protein synthesis
- release of vitamin A from stores
- synthesis, storage, and release of insulin
- taste perception
- free radical protection
- RBC synthesis – heme, blood clotting
- immune function, wound healing
- growth and development, reproduction
- influences behavior and learning



Snapshot 8-6

Zinc



DRI Recommended Intakes:

Men: 11 mg/d
Women: 8 mg/d

CCHS 2.2 Mean Intake:^a

Men: ~14 mg/d
Women: ~9.5 mg/d

Tolerable Upper Intake Level:

Adults: 40 mg/d

Chief Functions:

Activates many enzymes; associated with hormones; synthesis of genetic material and proteins, transport of vitamin A, taste perception, wound healing, reproduction

Deficiency:^b

Growth retardation, delayed sexual maturation, impaired immune function, hair loss, eye and skin lesions, loss of appetite

Toxicity:

Loss of appetite, impaired immunity, reduced copper and iron absorption, low HDL cholesterol (a risk factor for heart disease)

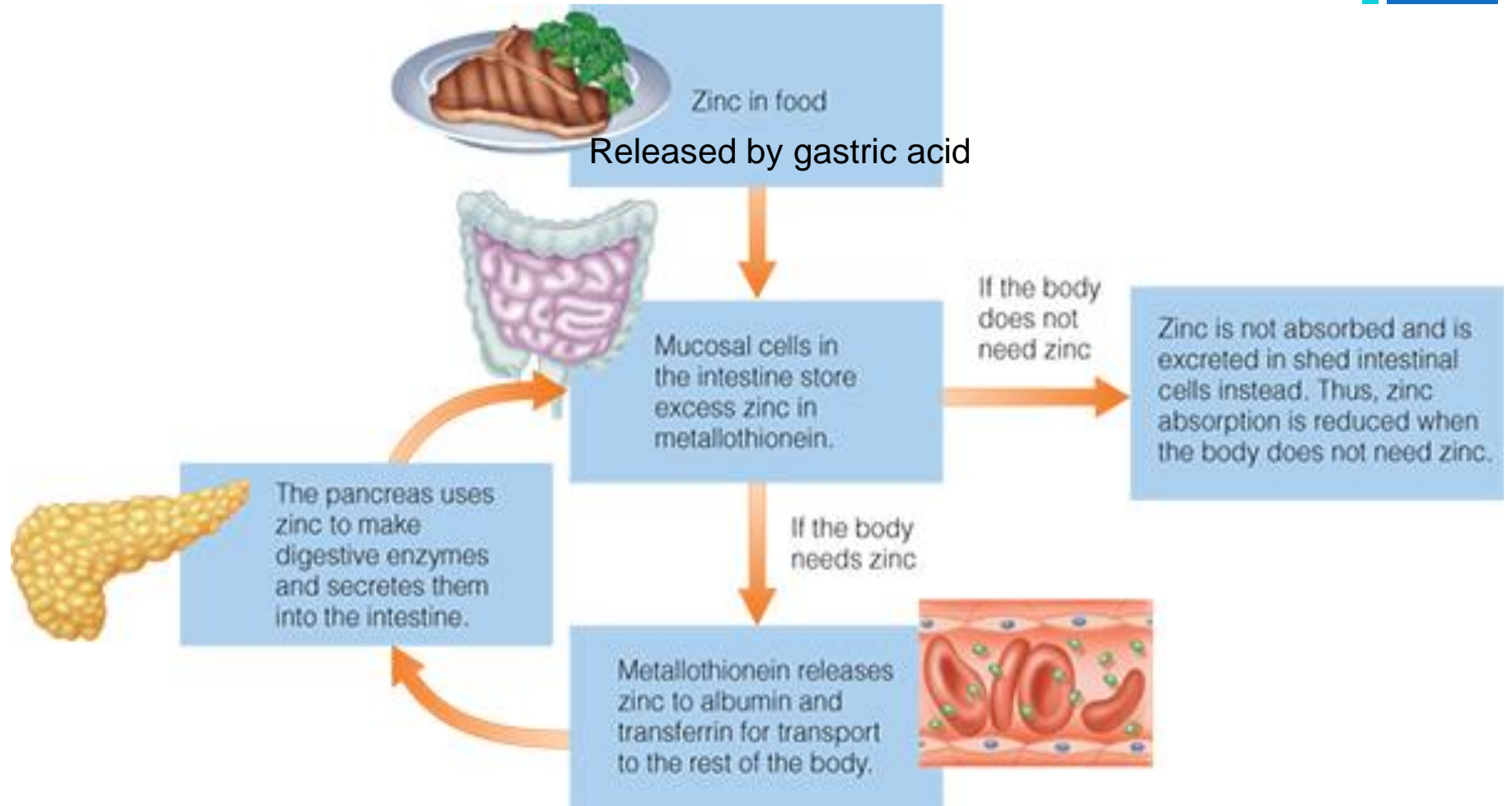
^aNote: Statistics Canada began releasing/rolling out the 2015 CCHS Nutrition data starting in the summer of 2017. Therefore, watch for possible changes to mean intakes of both the macro- and micronutrients by Canadians.

^bA rare inherited form of zinc malabsorption causes additional and more severe symptoms.

Source: All nutrient and Caloric values for the food items shown are based on the 2015 version of the Canadian Nutrient File, available at <https://food-nutrition.canada.ca/cnrf-fce/index-eng.jsp>.



Enteropancreatic Circulation of Zinc



+ Zinc: Homeostatic regulation



Total body zinc content is controlled between

- ◆ absorption efficiency of dietary zinc and
 - ◆ Absorption increases at low intakes
- ◆ endogenous circulation secretions in pancreatic fluid
 - ◆ Endogenous fecal losses increase several folds at high intakes
 - ◆ Recycling from pancreas to small intestine if low intake

+ Zinc Absorption



Enhancers

- Acids
- Amino acids

Inhibitors

- Phytate
- Oxalate
- Polyphenols
- Fibre – insoluble
- Other divalent cations
- Folate
- H₂ blockers

Absorption rate varies depending on amount consumed: 15-40%

<https://ods.od.nih.gov/factsheets/Zinc-HealthProfessional/>

+ Steps in dietary zinc deficiency

Increased absorption / decreased losses
(re-establishes homeostasis in mild deficiency)



Tissue zinc conservation



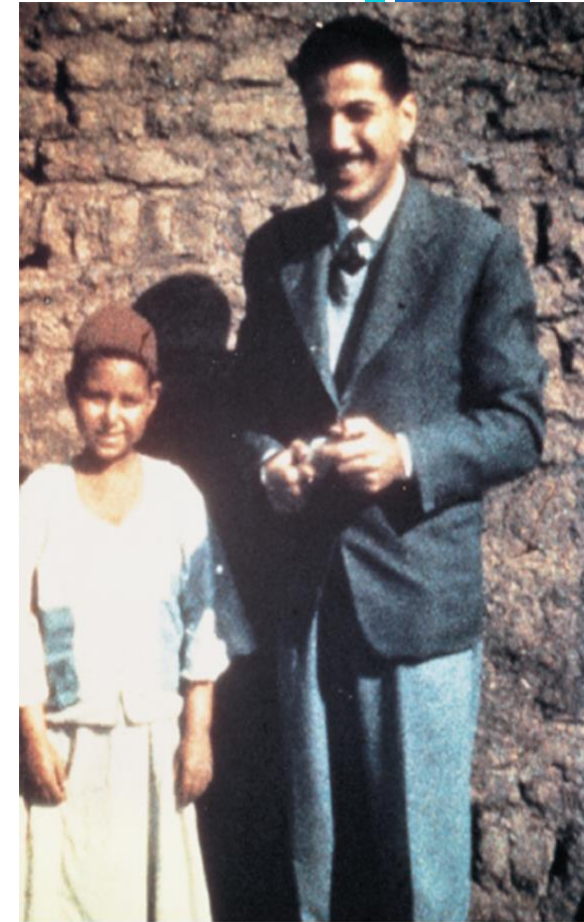
Mobilization of zinc
from exchangeable pool



General tissue dysfunction

+ Zinc Deficiency

- Difficult to diagnose
- Misdiagnosed as general PEM
 - No sensitive and specific test
 - Pancreatic function, GI function, infections
- Children most vulnerable
 - Compromised growth and development
 - Poor appetite, diarrhea
 - Immune system and CNS dysfunction
 - Widespread in developing world



The Egyptian man on the right is an adult of average height. The Egyptian boy on the left is 17 years old but is only 4 feet tall, like a 7-year-old in the United States. His genitalia are like those of a 6-year-old.

+ Zinc Toxicity



- UL= 40 mg Zn
- Zn excess interferes with copper(Cu) and Fe metabolism

Symptoms:

- **Acute toxicity:** Nausea, vomiting, diarrhea
- **Chronic Zn Toxicity:**
 - Cu deficiency, alter Fe function and conversion Fe^{2+} to Fe^{3+}
 - Increased intestinal metallothionein
 - Copper not released into blood, lost in shed mucosal cells
 - Reduced immunity, urinary problems
 - May decrease HDL (“good”) cholesterol in the blood

+ Chromium and Copper

■ Chromium

- Works with insulin to regulate and release energy from glucose
- Food sources:
 - Unrefined foods, whole grains, liver, nuts, cheese

■ Copper

- Helps form hemoglobin and collagen
- Food sources:
 - Organ meats, seafood, nuts, seeds

+ Mineral Interactions

■ ↑ Iron affects Zinc

- iron overload - Fe occupies all transferrin binding sites, ↓ Zn absorption, transport

■ ↑ Zinc affects Copper

- high diet Zn ↑ metallothionein - Cu bound more strongly - not released from mucosal cell

■ ↓ Protein affects Zinc

- ↓ albumin - ↓ Zn released from mucosal cell - more growth failure, immune dysfunction

■ Others...

+ Iodine



- Thyroxin - thyroid hormones (T3 and T4)
 - metabolic rate of every cell
 - body temperature
 - RBC synthesis
 - growth, reproduction
 - brain development
- Body's work is done by ionic form, iodide

+ Iodine Deficiency



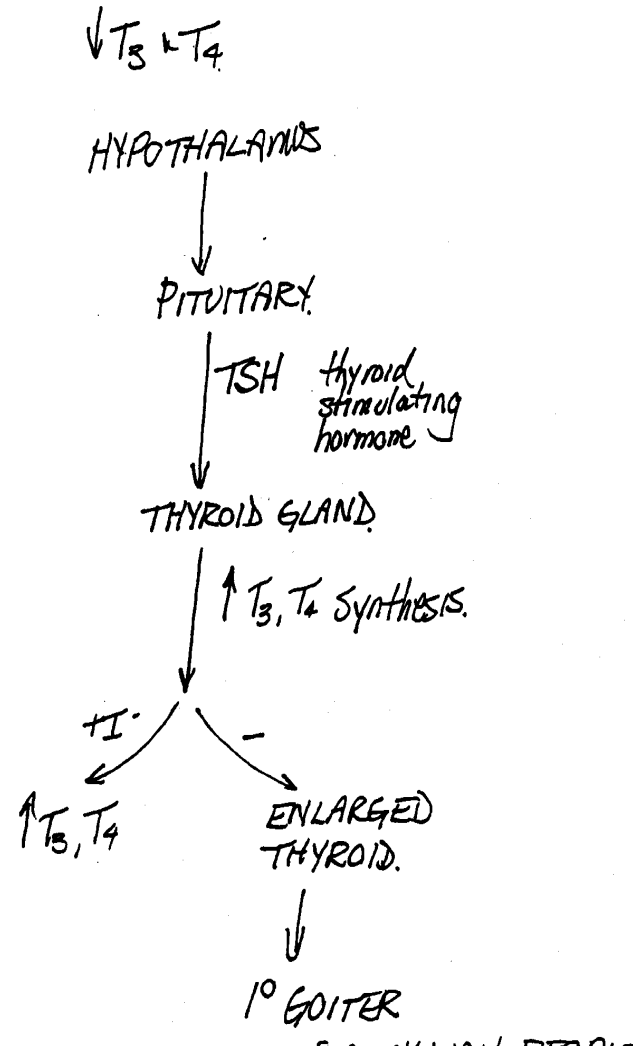
- Dietary Iodine
 - Iodized salt, seafood
 - Deliver RDA (150ug) in 2 g salt
 - (average intake: 8 g/d)
 - UL= 1100ug
- 200 Million people:
 - Goiter
 - Cretinism (pregnancy)



In iodine deficiency, the thyroid gland enlarges—a condition known as simple goiter.



Normal:



Iodine
Deficient:



In iodine deficiency, the thyroid gland enlarges—a condition known as goitre.