PRINCIPALS OF RECOMMENDED NUTRITION

- Quantitative aspect
- Qualitative aspect
- **Special components of diet**
- Aesthetic aspect
- Socio-economic aspect

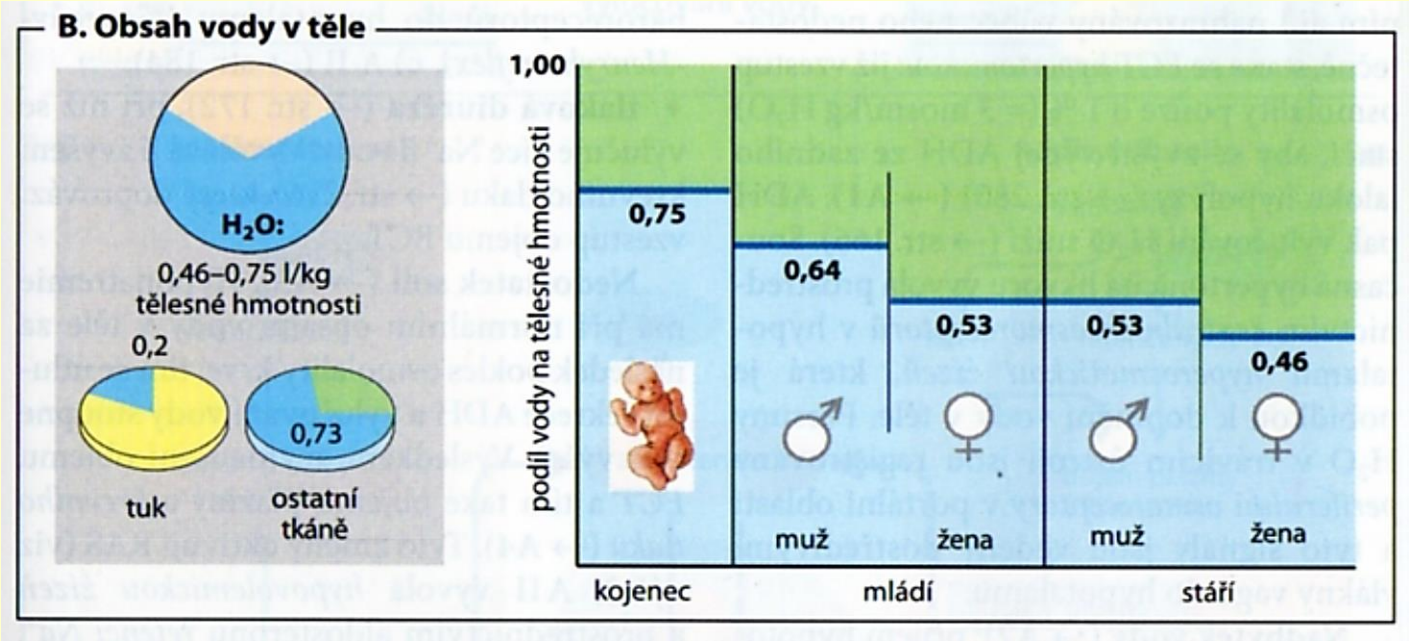
WATER, VITAMINS, MINERALS IN NUTRITION

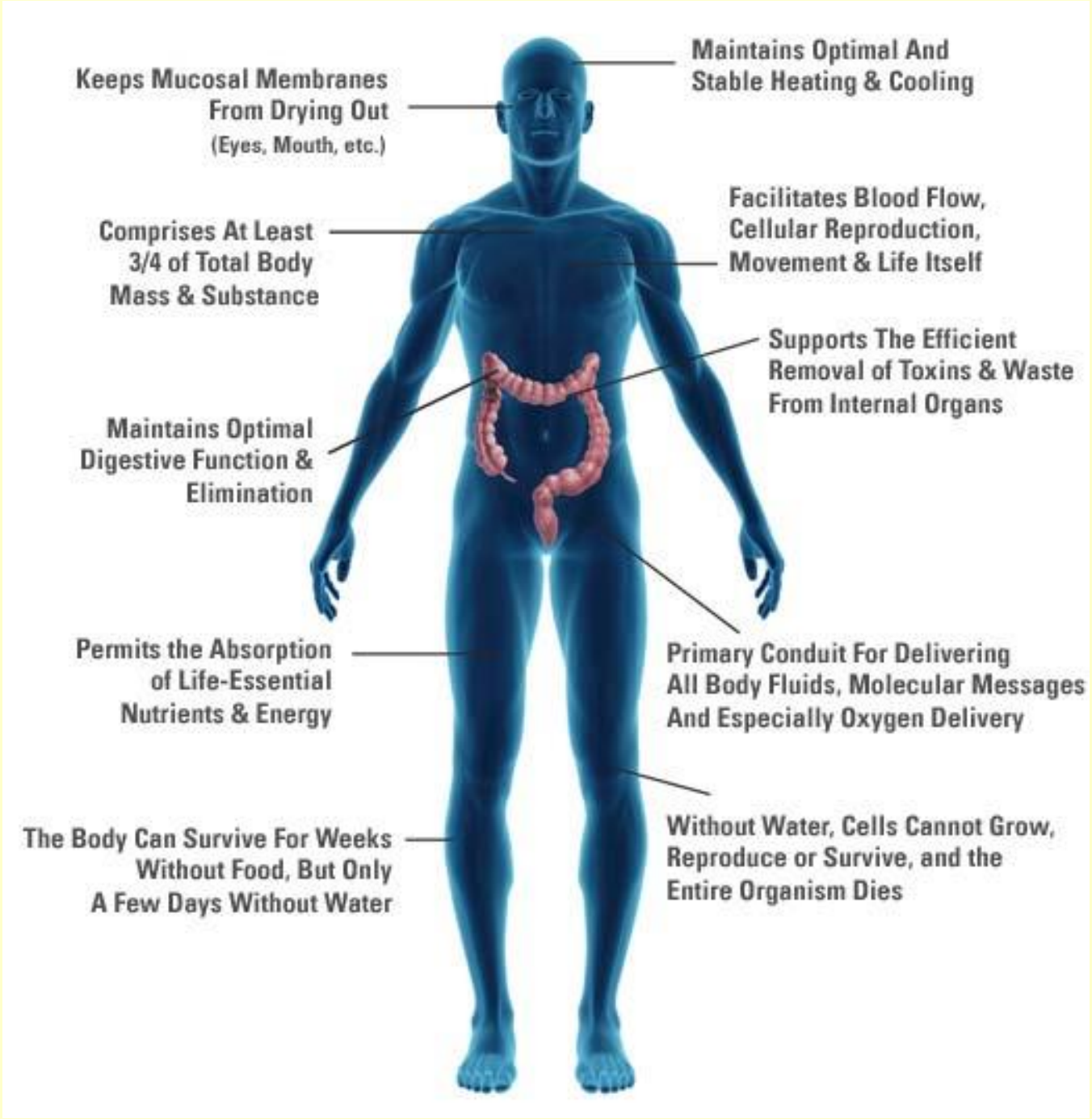
WATER

- 50-70% of body mass, newborns
- 2/3 intracellularly, 1/3 extracellularly
- metabolism
- compartmentalisation
- phylogenetic view

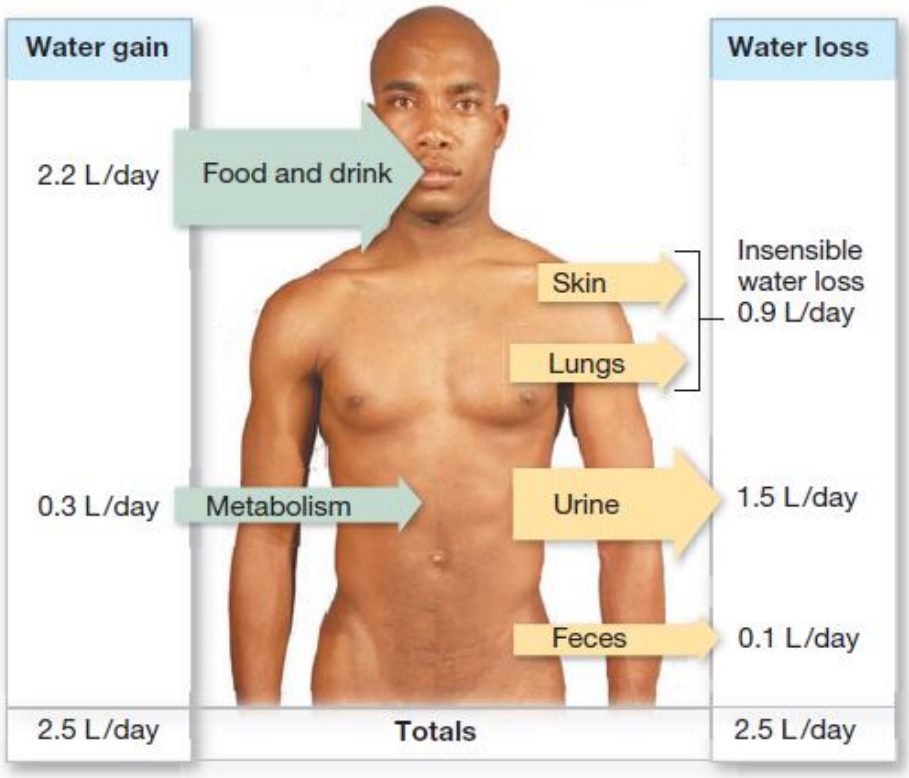
Water and its functions in the human body

- The transport medium, solvent, wetting and protection of the mucous membranes
- Age, sex, weight




Maintains Optimal And Stable Heating & Cooling
Keeps Mucosal Membranes From Drying Out (Eyes, Mouth, etc.)
Facilitates Blood Flow, Cellular Reproduction, Movement & Life Itself
Comprises At Least 3/4 of Total Body Mass & Substance
Supports The Efficient Removal of Toxins & Waste From Internal Organs
Maintains Optimal Digestive Function & Elimination
Permits the Absorption of Life-Essential Nutrients & Energy
Primary Conduit For Delivering All Body Fluids, Molecular Messages And Especially Oxygen Delivery
The Body Can Survive For Weeks Without Food, But Only A Few Days Without Water
Without Water, Cells Cannot Grow, Reproduce or Survive, and the Entire Organism Dies

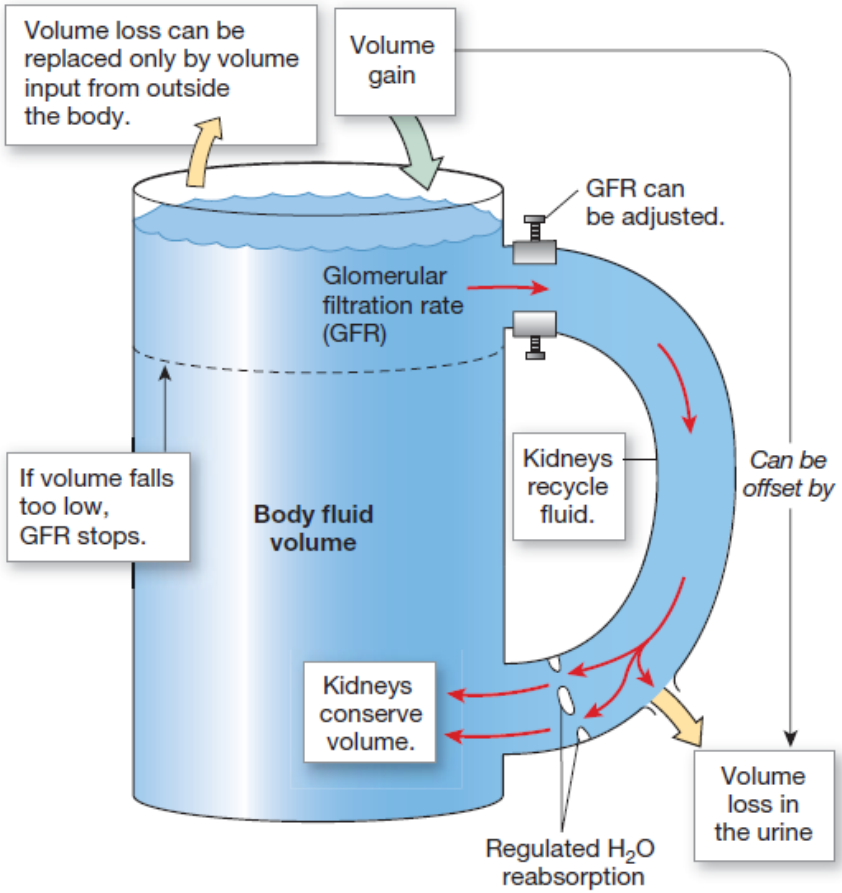
WATER BALANCE IN THE BODY

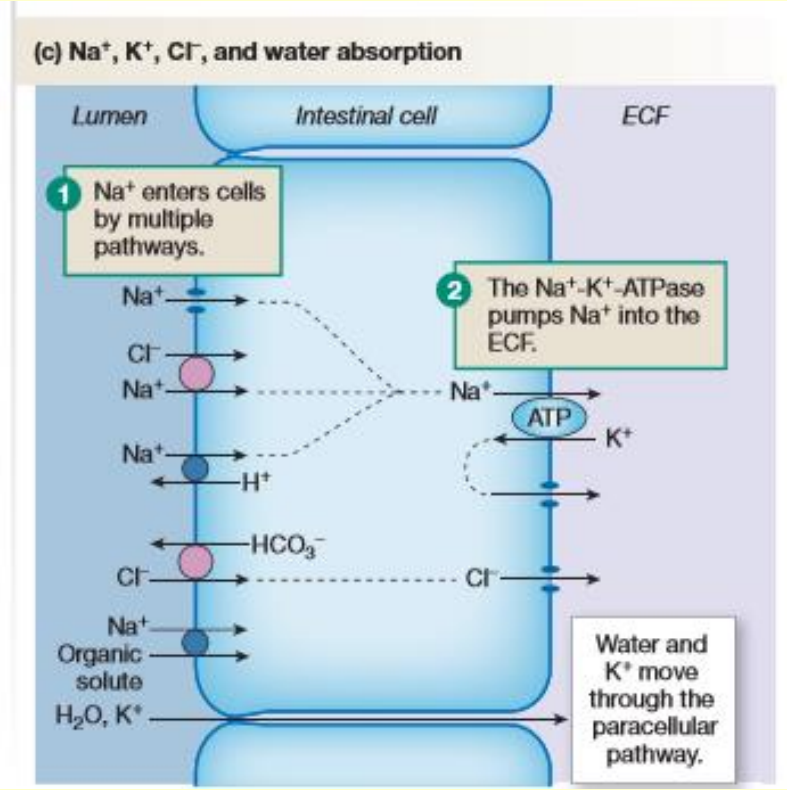


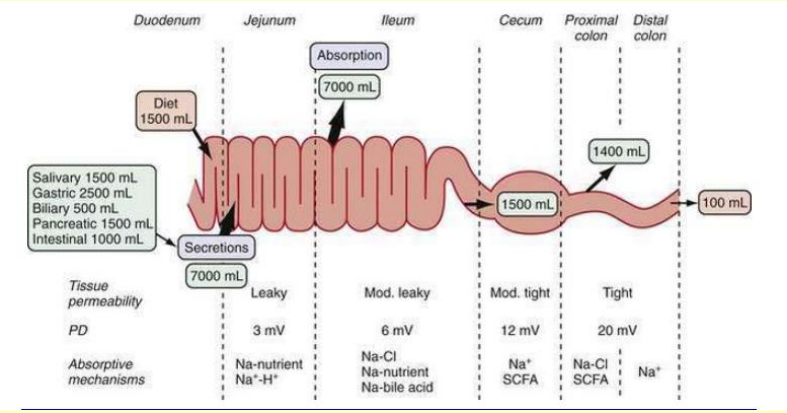
Intake 2.2 L/day + Metabolic production 0.3 L/day − Output 2.5 L/day = 0

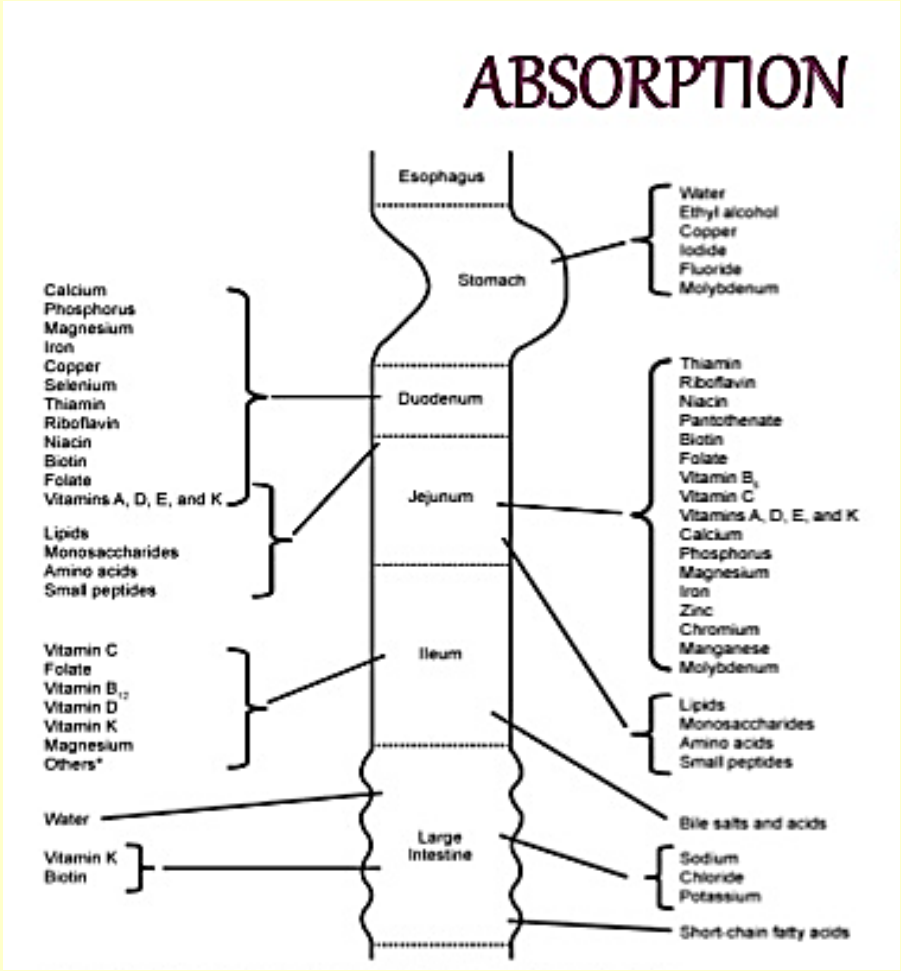
THE KIDNEYS CONSERVE VOLUME

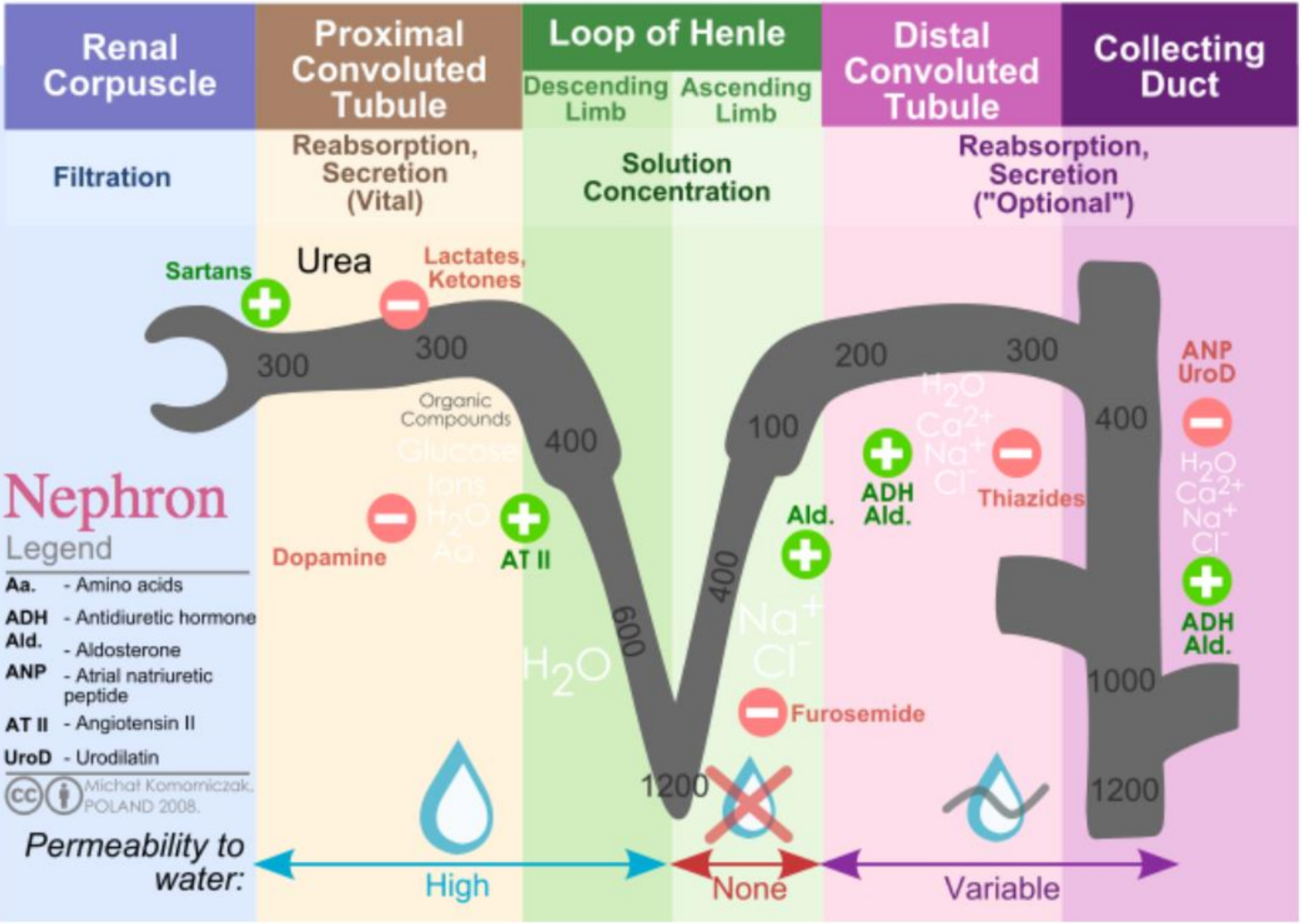
Kidneys cannot restore lost volume. They only conserve fluid.




(c) Na+, K+, Cl−, and water absorption
Lumen
Intestinal cell
ECF
1 Na+ enters cells by multiple pathways.
2 The Na+-K+-ATPase pumps Na+ into the ECF.
Na+
Cl−
Na+
Na+
H+
HCO3−
Cl−
Na+
Organic solute
H2O, K+
Na+
ATP
K+
Cl−
Water and K+ move through the paracellular pathway.

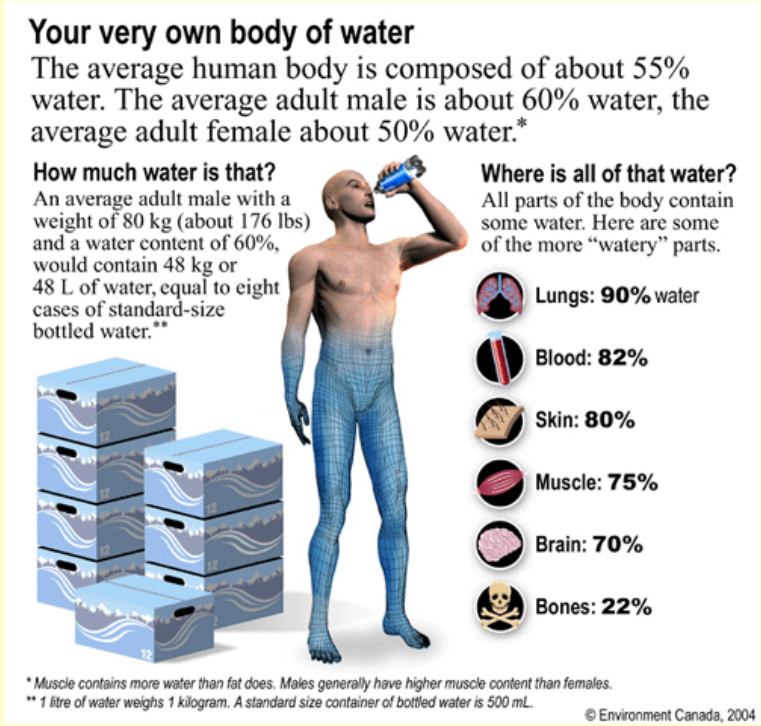

Duodenum
Jejunum
Ileum
Cecum
Proximal colon
Distal colon
Absorption
7000 mL
Diet 1500 mL
Salivary 1500 mL
Gastric 2500 mL
Biliary 500 mL
Pancreatic 1500 mL
Intestinal 1000 mL
Secretions
7000 mL
1500 mL
1400 mL
100 mL
Tissue permeability
Leaky
Mod. leaky
Mod. tight
Tight
PD
3 mV
6 mV
12 mV
20 mV
Absorptive mechanisms
Na-nutrient Na+-H+
Na-Cl Na-nutrient Na-bile acid
Na+ SCFA
Na-Cl SCFA
Na+

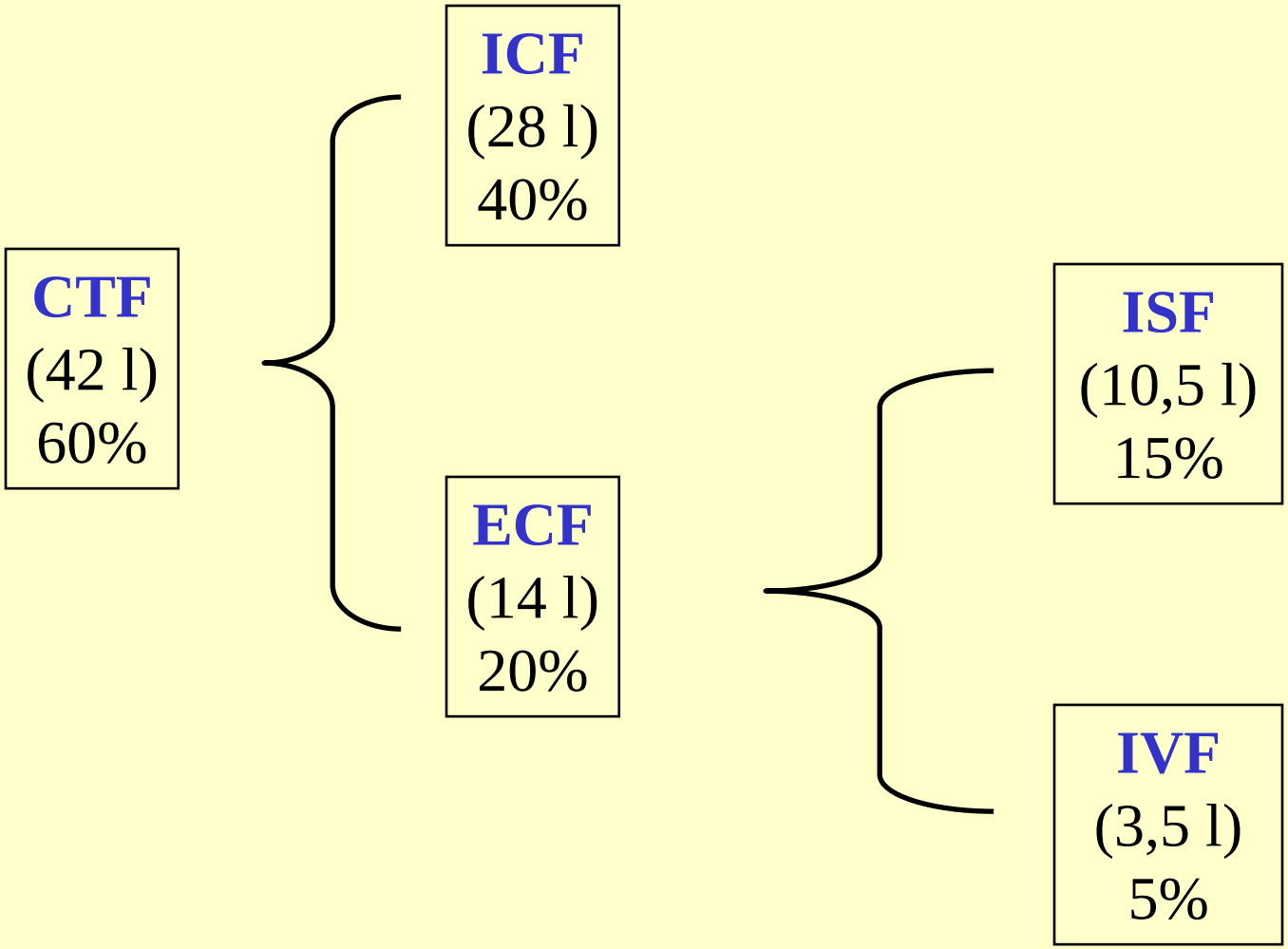

ABSORPTION
Esophagus
Stomach
Duodenum
Jejunum
Ileum
Large Intestine
Water
Ethyl alcohol
Copper
Iodide
Fluoride
Molybdenum
Calcium
Phosphorus
Magnesium
Iron
Copper
Selenium
Thiamin
Riboflavin
Niacin
Biotin
Folate
Vitamins A, D, E, and K
Lipids
Monosaccharides
Amino acids
Small peptides
Thiamin
Riboflavin
Niacin
Pantothenate
Biotin
Folate
Vitamin B6
Vitamin C
Vitamins A, D, E, and K
Calcium
Phosphorus
Magnesium
Iron
Zinc
Chromium
Manganese
Molybdenum
Vitamin C
Folate
Vitamin B12
Vitamin D
Vitamin K
Magnesium
Others*
Lipids
Monosaccharides
Amino acids
Small peptides
Water
Vitamin K
Biotin
Bile salts and acids
Sodium
Chloride
Potassium
Short-chain fatty acids


Renal Corpuscle
Proximal Convoluted Tubule
Loop of Henle
Descending Limb
Ascending Limb
Distal Convoluted Tubule
Collecting Duct
Filtration
Reabsorption, Secretion (Vital)
Solution Concentration
Reabsorption, Secretion ("Optional")
Sartans
Urea
Lactates, Ketones
300
300
200
300
100
400
400
600
400
1000
1200
1200
Organic Compounds
Glucose
Ions
H_2O
Aa
Dopamine
AT II
Ald.
ADH
Ald.
Thiazides
Furosemide
ANP
UroD
ADH
Ald.
Nephron
Legend
Aa. - Amino acids
ADH - Antidiuretic hormone
Ald. - Aldosterone
ANP - Atrial natriuretic peptide
AT II - Angiotensin II
UroD - Urodilatin
Michał Komorniczak, POLAND 2008.
Permeability to water:
High
None
Variable

The water content in different tissues (male, 70 kg)

	% of water
blood	83%
muscle tissue	76%
skin	72%
bones	22%
fats	10%
tooth enamel	2%





Clinical examination: evaluation of extracellular (plasmatic) levels of electrolytes (Na, K)

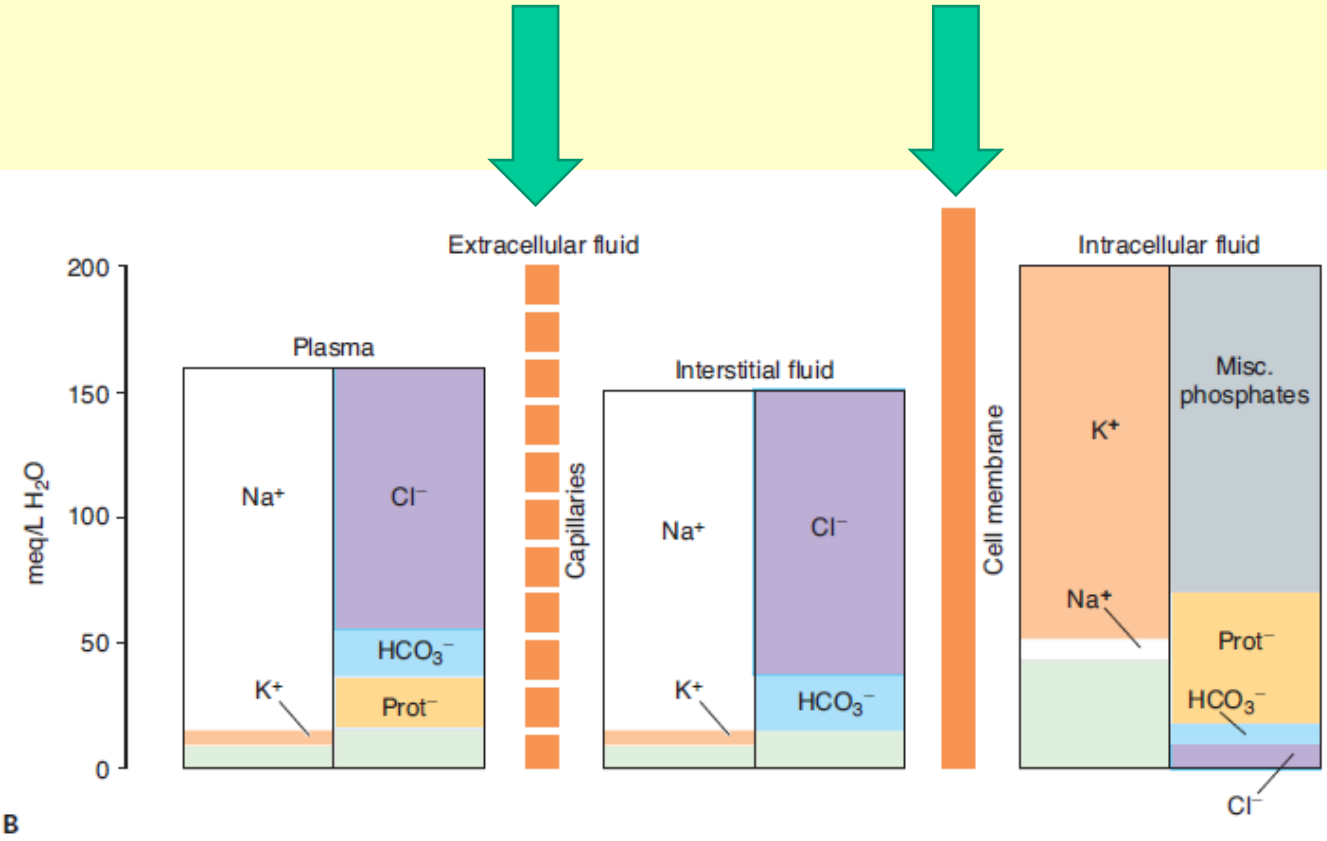
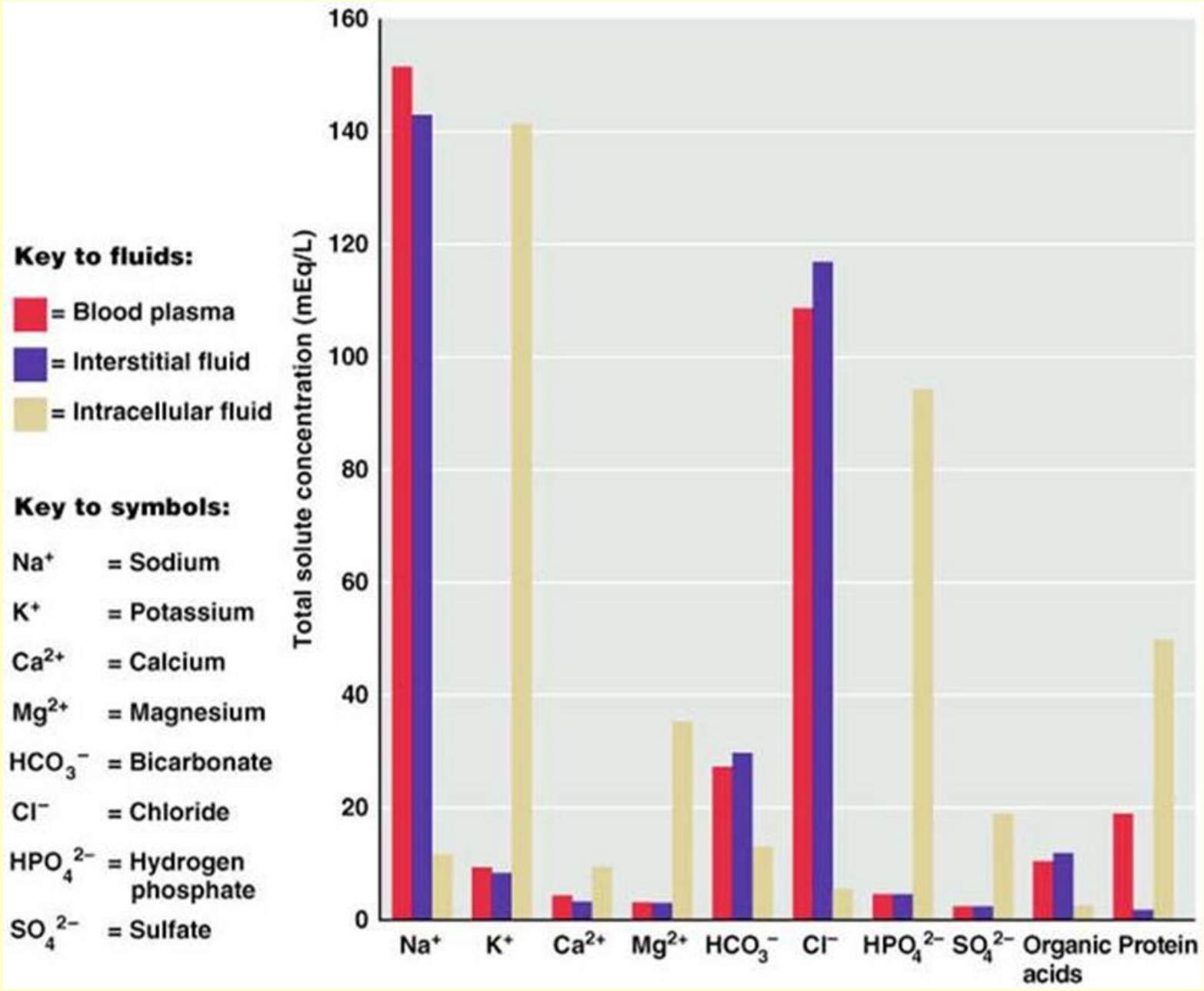
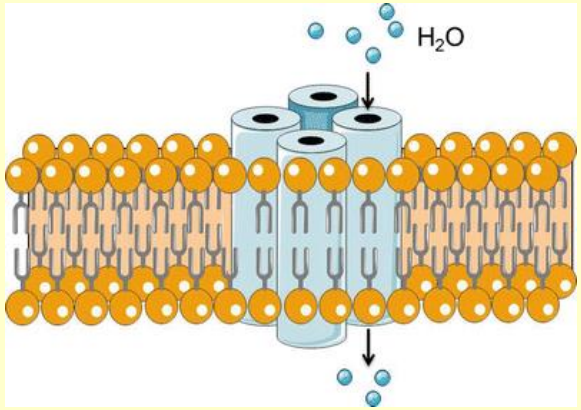
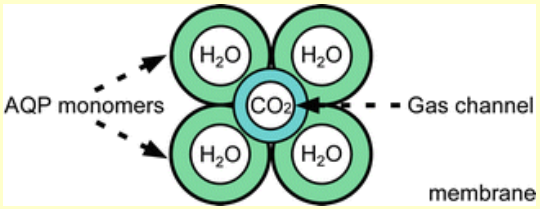


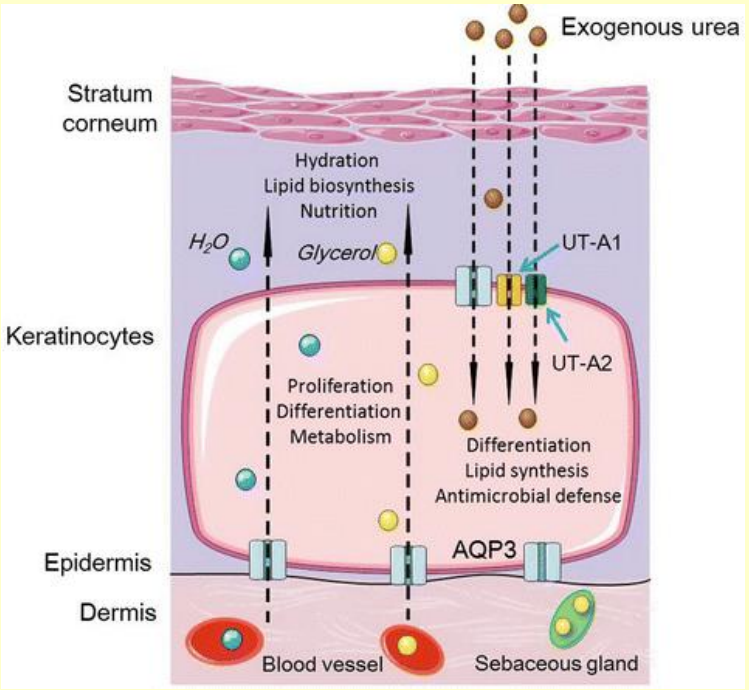
FIGURE 1–1 **Organization of body fluids and electrolytes into compartments. A)** Body fluids are divided into Intracellular and extracellular fluid compartments (ICF and ECF, respectively). Their contribution to percentage body weight (based on a healthy young adult male; slight variations exist with age and gender) emphasizes the dominance of fluid makeup of the body. Transcellular fluids, which constitute a very small percentage of total body fluids, are not shown. Arrows represent fluid movement between compartments. **B)** Electrolytes and proteins are unequally distributed among the body fluids. This uneven distribution is crucial to physiology. $Prot^-$, protein, which tends to have a negative charge at physiologic pH.

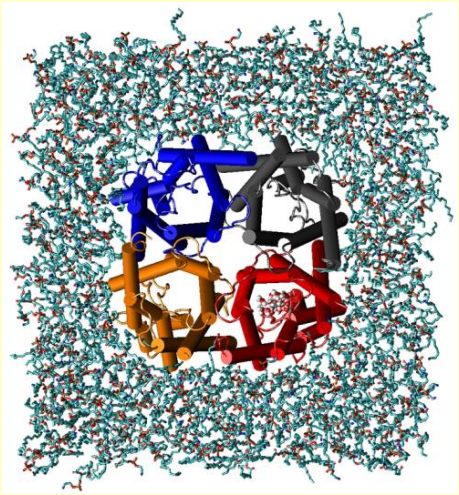

Key to fluids:
= Blood plasma
= Interstitial fluid
= Intracellular fluid
Key to symbols:
Na+ = Sodium
K+ = Potassium
Ca2+ = Calcium
Mg2+ = Magnesium
HCO3− = Bicarbonate
Cl− = Chloride
HPO4 2− = Hydrogen phosphate
SO4 2− = Sulfate
Total solute concentration (mEq/L)
160
140
120
100
80
60
40
20
0
Na+
K+
Ca2+
Mg2+
HCO3−
Cl−
HPO4 2−
SO4 2−
Organic acids
Protein

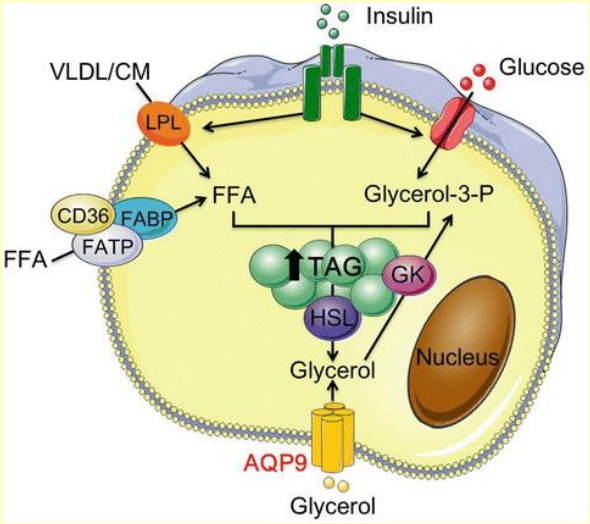
Aquaporins

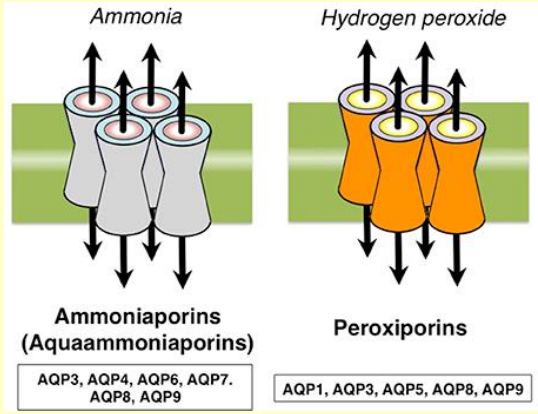

H_2O

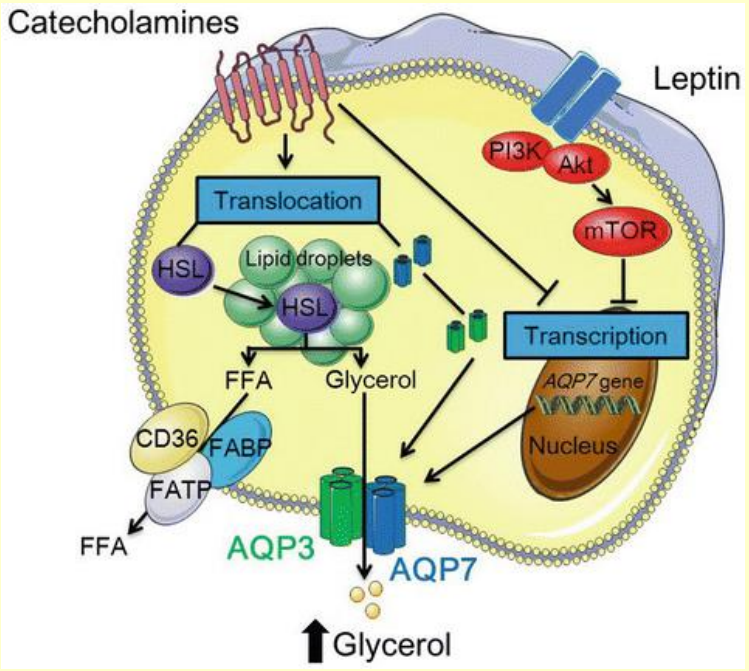

H_2O
H_2O
CO_2
H_2O
H_2O
AQP monomers
Gas channel
membrane

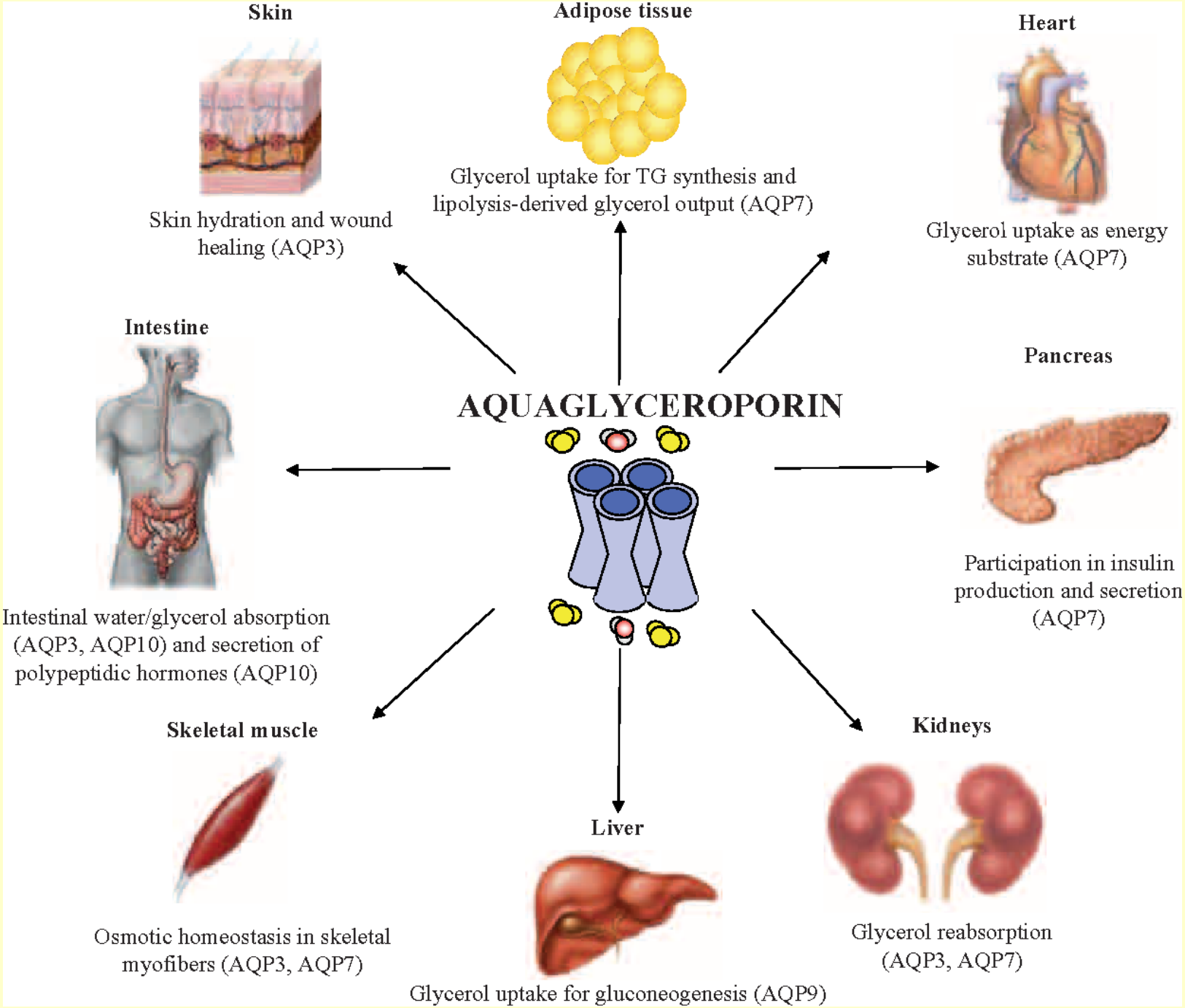

Exogenous urea
Stratum corneum
Hydration
Lipid biosynthesis
Nutrition
H_2O
Glycerol
UT-A1
Keratinocytes
UT-A2
Proliferation
Differentiation
Metabolism
Differentiation
Lipid synthesis
Antimicrobial defense
Epidermis
AQP3
Dermis
Blood vessel
Sebaceous gland

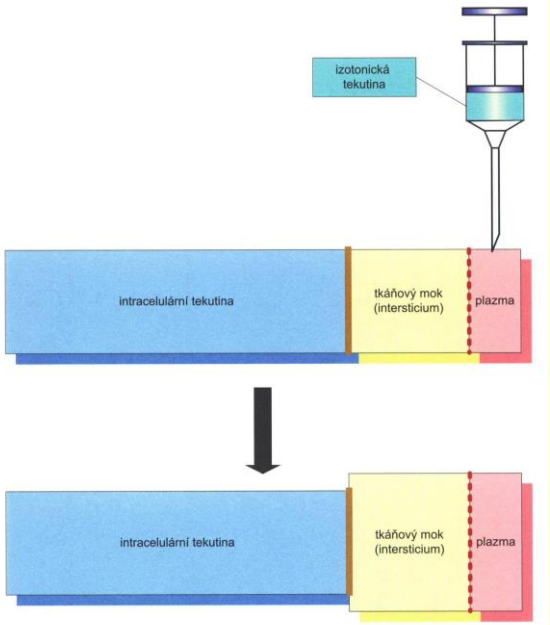



Insulin
VLDL/CM
Glucose
LPL
FFA
Glycerol-3-P
CD36
FABP
FATP
FFA
TAG
GK
HSL
Glycerol
Nucleus
AQP9
Glycerol

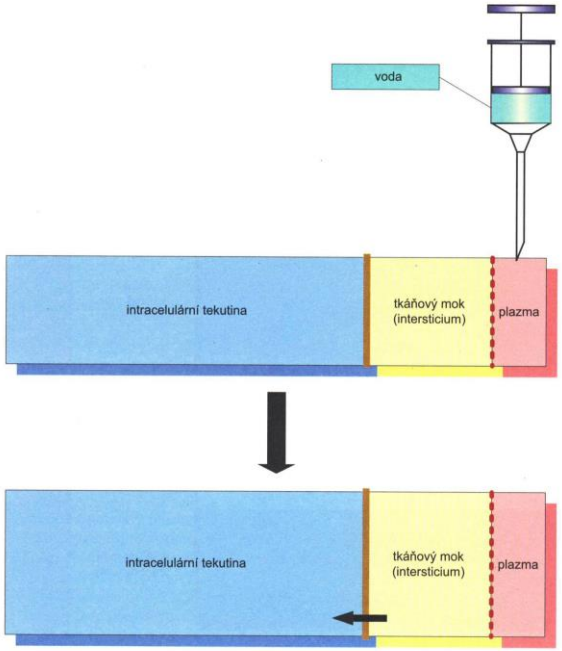

Ammonia
Hydrogen peroxide
Ammoniaporins
(Aquaammoniaporins)
AQP3, AQP4, AQP6, AQP7.
AQP8, AQP9
Peroxiporins
AQP1, AQP3, AQP5, AQP8, AQP9


Catecholamines
Leptin
PI3K
Akt
Translocation
mTOR
HSL
Lipid droplets
HSL
Transcription
FFA
Glycerol
AQP7 gene
Nucleus
CD36
FABP
FATP
FFA
AQP3
AQP7
Glycerol

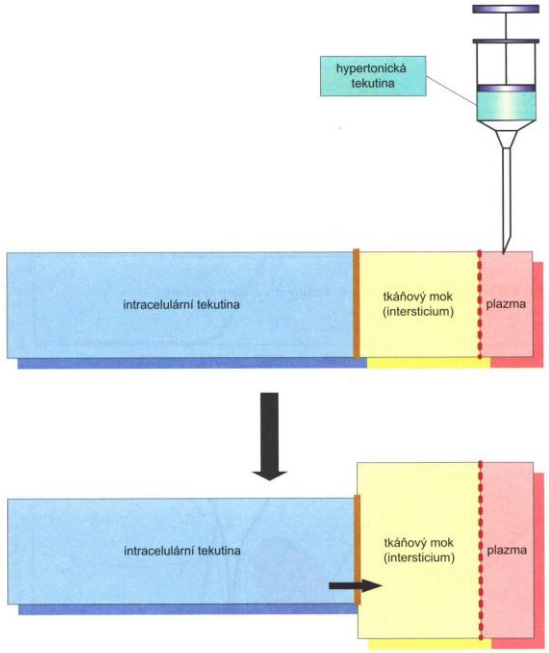

Skin
Skin hydration and wound healing (AQP3)
Adipose tissue
Glycerol uptake for TG synthesis and lipolysis-derived glycerol output (AQP7)
Heart
Glycerol uptake as energy substrate (AQP7)
Intestine
Intestinal water/glycerol absorption (AQP3, AQP10) and secretion of polypeptidic hormones (AQP10)
AQUAGLYCEROPORIN
Pancreas
Participation in insulin production and secretion (AQP7)
Skeletal muscle
Osmotic homeostasis in skeletal myofibers (AQP3, AQP7)
Liver
Glycerol uptake for gluconeogenesis (AQP9)
Kidneys
Glycerol reabsorption (AQP3, AQP7)



Obr. 8.42 *Při příjmu izotonické tekutiny se tekutina rozprostře mezi intravaskulární a extravaskulární část extracelulárního kompartmentu, do intravaskulárního kompartmentu tekutina nepřechází, protože bariéra je pro ionty nepropustná, a voda nepřechází, protože obě strany bariéry jsou izotonické*



Obr. 8.43 *Při příjmu čisté vody se voda rozprostře do všech kompartmentů, aby vyrovnala jejich osmolaritu*



Obr. 8.44 *Při příjmu hypertonické tekutiny přechází voda do extracelulárního prostoru z prostoru intracelulárního, aby vyrovnala osmolaritu obou kompartmentů*

table 5-1 Body Water and Body Fluid Compartments

Body Fluid Compartment	Fraction of TBW*	Markers Used to Measure Volume	Major Cations	Major Anions
TBW	1.0	Tritiated H_2O D_2O Antipyrene		
ECF	1/3	Sulfate Inulin Mannitol	Na^+	Cl^- HCO_3^-
Plasma	1/12 (1/4 of ECF)	RISA Evans blue	Na^+	Cl^- HCO_3^- Plasma protein
Interstitial	1/4 (3/4 of ECF)	ECF–plasma volume (indirect)	Na^+	Cl^- HCO_3^-
ICF	2/3	TBW–ECF (indirect)	K^+	Organic phosphates Protein

*Total body water (TBW) is approximately 60% of total body weight, or 42 L in a 70-kg man. ECF = extracellular fluid; ICF = intracellular fluid; RISA = radioiodinated serum albumin.

HOMEOSTASIS

- **Izoionia** – concentration of ions
- **Izotonia** – osmotic concentration
- **Izohydria** – ratio between acids and bases
- **Izovolemia** –ECL volume (volumoreceptors or baroreceptors, RAS, ADH)

- Izovolemia
- **Hypovolemia (dehydratation)**
- Hypervolemia (hyperhydratation)

Cause – result

Complex disorders!

EXAMINATIONS AT HYDRATATION DISORDERS

1. **Anamnesis** – diseases of kidneys, GIT, DM, DI, drugs, intake and output=balance, body mass changes, etc.

2. **Laboratory examinations**: electrolytes, blood osmolality, RBCC, total plasmatic proteins; Astrup examination

OBJECTIVE EXAMINATIONS

1. Skin changes
2. Body mass changes
3. Diuresis changes (oliguria, anuria, polyuria)
4. Respiration disorders (respiratory acidosis, alkalosis; secondary changes – Kussmaul breathing)
5. CNS disorders (changes of reflexes, muscle tonus, paresthesias, changes of consciousness, coma)
6. Central venous pressure changes (filling of neck veins)
7. Circulation changes: dehydratation – tachycardia, hypotonia

CAUSES OF HYDRATATION DISORDERS

1. Disturbance of normal intake of water and ions
2. Disturbance of normal circulation of water and ionts between ECL and GIT
3. Disturbance of cell metabolism
4. Disturbance of loss of water and ions
5. Excessive loss of water (and ions) by skin

DEHYDRATATION

= decreased volume of body fluids accompanied by lack of sodium

HYPERTONIC DEHYDRATATION = loss of (only) water

Bigger lack of water than sodium. Disorders of intake and big losses.
Cell dehydratation.
Thirst. Decreased skin turgor. CNS symptoms.
Hydratation.

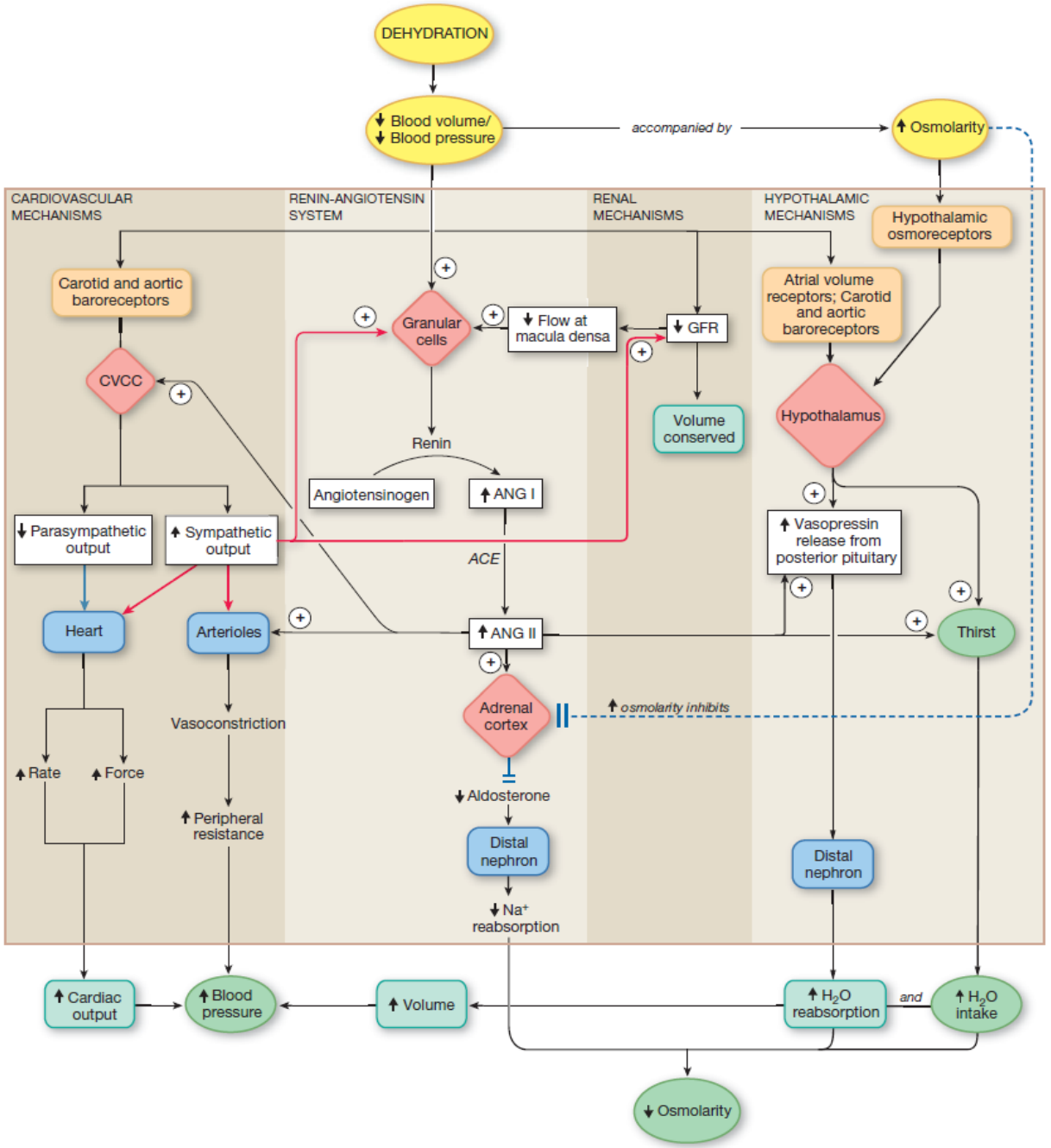
IZOTONIC DEHYDRATATION = isonatremic

Causes – bleeding, diuretics, „blind spaces“
Hypovolemic syndrome: decreased diuresis, symptoms of dehydratation.

HYPOTONIC DEHYDRATATION

Always bigger deficiency of sodium than water.
Cell hyperhydratation.
Losses by GIT, kidneys.
Hypovolemic syndrome, CNS symptoms.

HOMEOSTATIC COMPENSATION FOR SEVERE DEHYDRATION



HYPERHYDRATATION

= increased volume of extracellular fluid

HYPOTONIC HYPERHYDRATATION – **water intoxication**

Cell hyperhydratation. Decreased osmolality.
Excessive intake of liquids (dialysed patient, patient with kidney disorders), hyperproduction of ADH

IZOTONIC HYPERHYDRATATION

Increased volume of ECF. Osmolality stabile.
Heart failure, nefrotic syndrome, liver cirrhosis.
Oedemas and water withholding in serose cavities.

HYPERTONIC HYPERHYDRATATION = hypernatremic

Rare. Increase of ECF caused by sodium abundance. Osmolality increases.
Primary hyperaldosteronism.

table 5-2 Changes in Volume and Osmolarity of Body Fluids

Type	Key Examples	ECF Volume	ICF Volume	ECF Osmolarity	Hct and Serum [Na^+]
Isosmotic volume expansion	Isotonic NaCl infusion	↑	No change	No change	↓ Hct –[Na^+]
Isosmotic volume contraction	Diarrhea	↓	No change	No change	↑ Hct –[Na^+]
Hyperosmotic volume expansion	High NaCl intake	↑	↓	↑	↓ Hct ↑ [Na^+]
Hyperosmotic volume contraction	Sweating Fever Diabetes insipidus	↓	↓	↑	–Hct ↑ [Na^+]
Hyposmotic volume expansion	SIADH	↑	↑	↓	–Hct ↓[Na^+]
Hyposmotic volume contraction	Adrenal insufficiency	↓	↑	↓	↑ Hct ↓[Na^+]

– = no change; ECF = extracellular fluid; Hct = hematocrit; ICF = intracellular fluid; SIADH = syndrome of inappropriate antidiuretic hormone.

SIADH = syndrome of inappropriate antidiuretic hormone secretion)

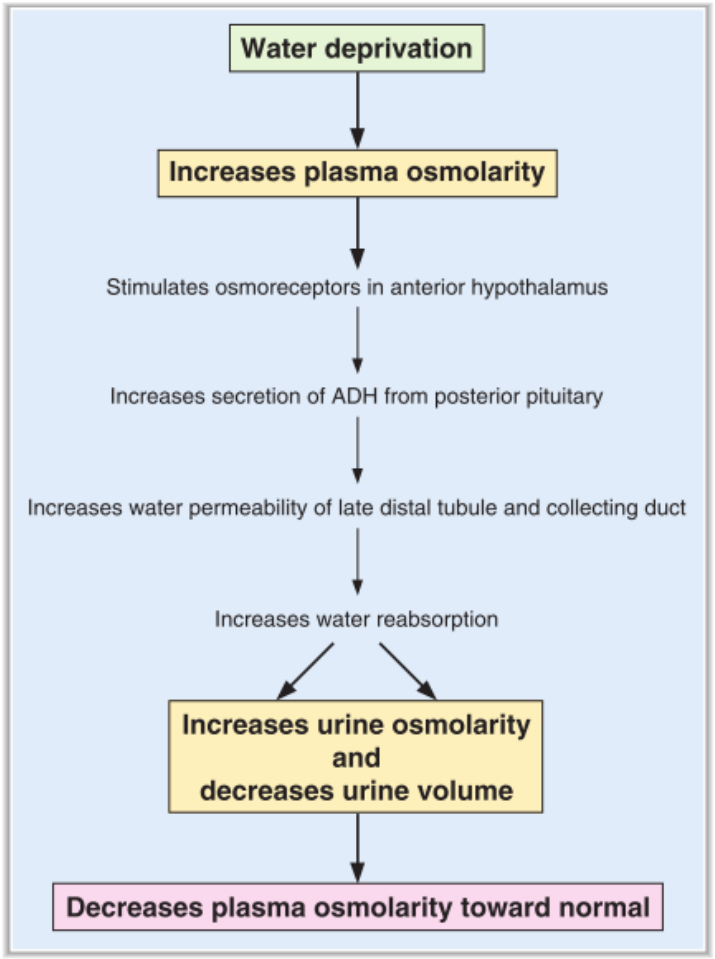


FIGURE 5-14 Responses to water deprivation. ADH = antidiuretic hormone.

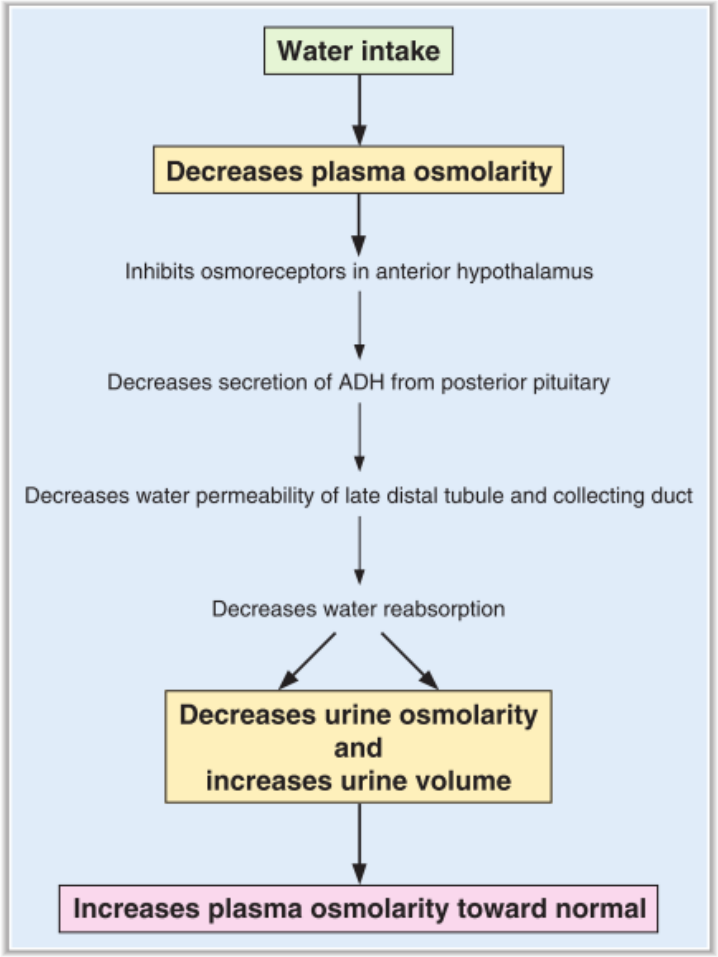


FIGURE 5-15 Responses to water intake. ADH = antidiuretic hormone.

VITAMINS

= all organic compounds of diet, necessary for life, health and growth; NO source of energy

HYPOVITAMINOSIS (AVITAMINOSIS)
HYPERVITAMINOSIS

1. Decrease supply in diet
2. Food intake disorders
3. Absorption disorders
4. Increased consumption
5. Store organ diseases

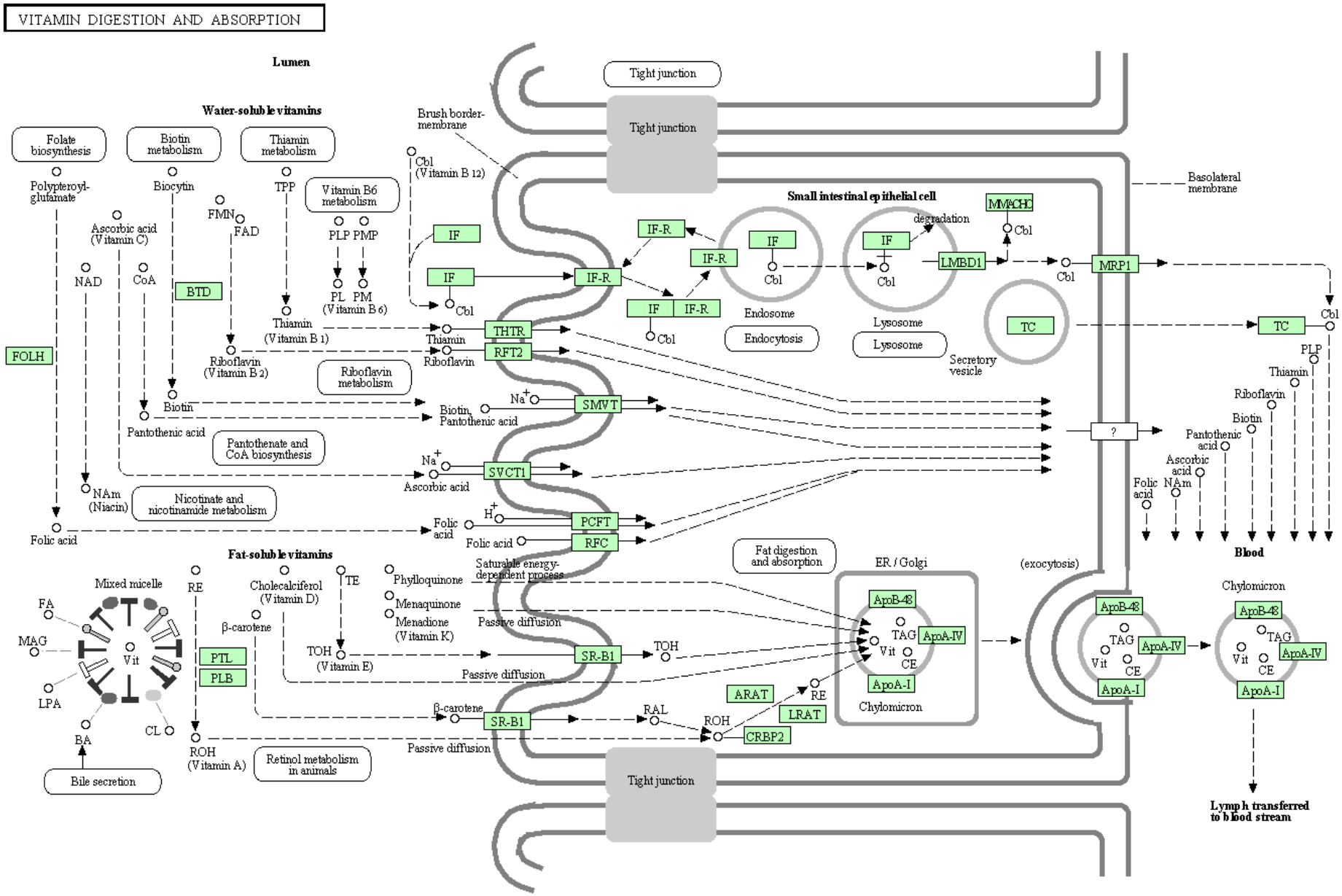
1. Increased supply in diet – usually **iatrogenic**

SOLUBLE

in water: diffusion, D, J; **vit.B_{12}** - I

in lipids: deficient absorption in disorders of lipids absorption (pancreatic enzymes or bile missing)

Vitamin	Species	Place of absorption	Transport mechanism	Maximal absorption capacity in humans / day	Daily dose
C	Humans, guinea pig	Ileum	Active	>5000mg	<50mg
Biotin	Hamster	Small intestine	Active	?	?
Cholin	Guinea pig, hamster	Small intestine	Facilitated diffusion	?	?
Folic acid (pteroylglutamate)	Rat	Jejunum	Facilitated diffusion	> 1000µg (dose)	100-200µg
Folic acid (5-methyltetrahydrofolate)	Rat	Jejunum	Diffusion	> 1000µg (dose)	100-200µg
Nicotinic acid	Rat	Jejunum	Facilitated diffusion	?	10-20mg
Pantothenic acid		Small intestine	?	?	(?)10mg
B_6 (pyridoxine)	Rat, hamster	Small intestine	Diffusion	> 50mg (dose)	1-2mg
B_2 (riboflavin)	Humans, rat	Jejunum	Facilitated diffusion	10-12mg (dose)	1-2mg
B_1 (thiamine)	Rat	Jejunum	Active	8-14mg	Approx. 1mg
B_{12}	**Humans, rat, hamster**	**Distal ileum**	**Active**	**6-9µg**	**3-7µg**


VITAMIN DIGESTION AND ABSORPTION
Lumen
Water-soluble vitamins
Folate biosynthesis
Biotin metabolism
Thiamin metabolism
Vitamin B6 metabolism
Polypteroyl-glutamate
Biocytin
TPP
FMN
FAD
PLP PMP
Ascorbic acid (Vitamin C)
NAD
CoA
BTD
PL PM (Vitamin B 6)
Thiamin (Vitamin B 1)
Riboflavin (Vitamin B 2)
FOLH
Riboflavin metabolism
Biotin
Pantothenic acid
Pantothenate and CoA biosynthesis
NAm (Niacin)
Nicotinate and nicotinamide metabolism
Folic acid
Fat-soluble vitamins
Mixed micelle
FA
MAG
LPA
BA
Vit
CL
Bile secretion
RE
Cholecalciferol (Vitamin D)
TE
β-carotene
PTL
PLB
TOH (Vitamin E)
ROH (Vitamin A)
Retinol metabolism in animals
Phylloquinone
Menaquinone
Menadione (Vitamin K)
Brush border-membrane
Cbl (Vitamin B 12)
IF
IF-R
Cbl
THTR
RFT2
Thiamin
Riboflavin
SMVT
Biotin, Pantothenic acid
SVCT1
Ascorbic acid
PCFT
RFC
Folic acid
Tight junction
Tight junction
Saturable energy-dependent process
Passive diffusion
SR-B1
TOH
Passive diffusion
β-carotene
SR-B1
RAL
ROH
ARAT
LRAT
RE
CRBP2
Passive diffusion
Small intestinal epithelial cell
Endosome
Endocytosis
Lysosome
Secretory vesicle
degradation
MMACHC
LMBD1
MRP1
TC
?
Basolateral membrane
Fat digestion and absorption
ER / Golgi
(exocytosis)
ApoB-48
ApoA-IV
ApoA-I
TAG
Vit
CE
Chylomicron
Blood
Lymph transferred to blood stream
04977 7/30/15
(c) Kanehisa Laboratories

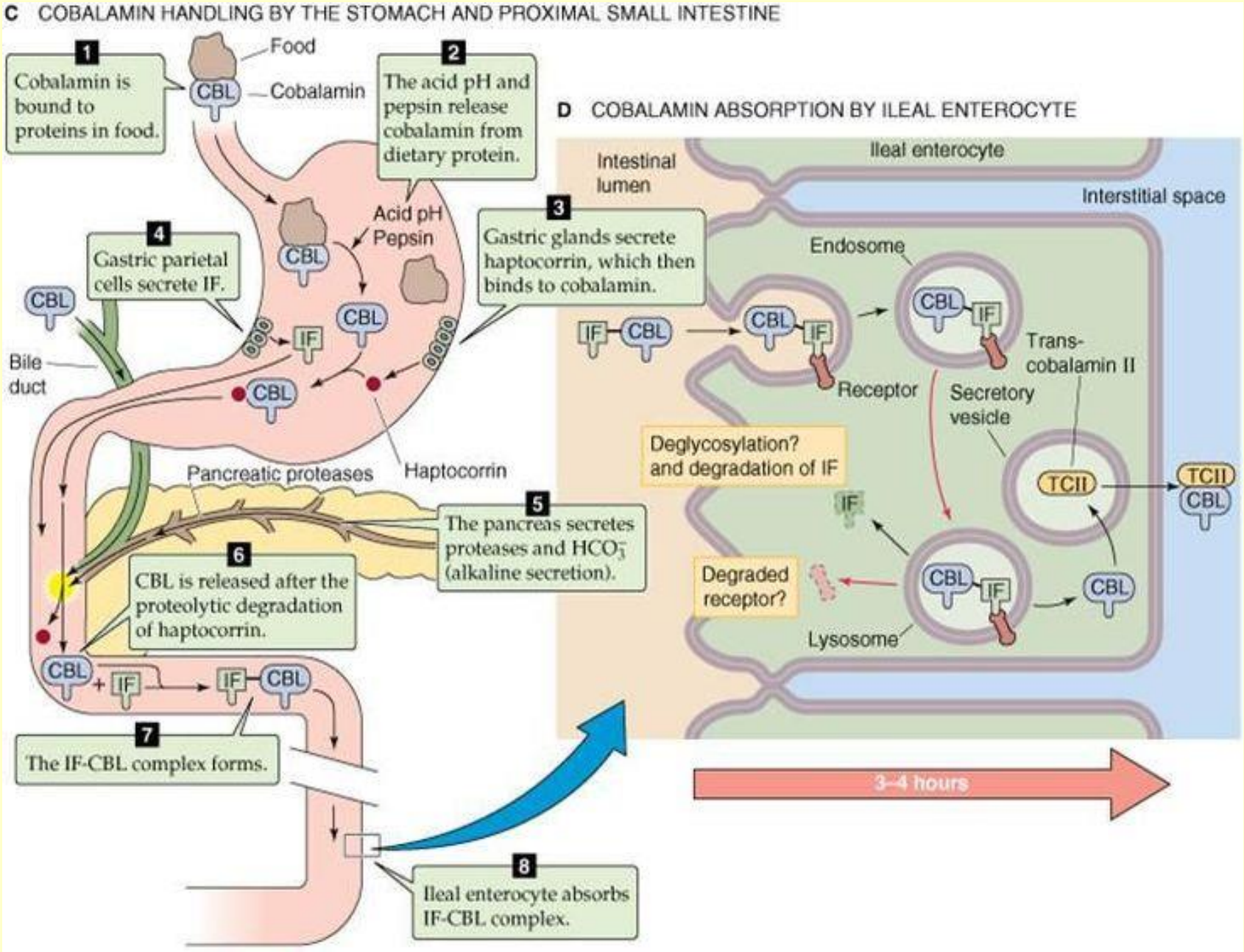
Vitamin	Name	Active Form (co-factor)	Biochemical Function	Physiological/cellular Role
B_5	Pantothenic Acid	Coenzyme A	Acyl Transfer	• Energy production from foodstuff • Fatty acid synthesis
B_6	Pyridoxine	Pyridoxal Phosphate (PLP)	• Transamination • Racemization • Decarboxylation • β/γ-Elimination	• Amino acid breakdown • Glycogen breakdown
B_7	Biotin	Biotin	Carboxylation	• Glucose & fatty acid synthesis • Leucine synthesis
B_9	Folic Acid	Tetrahydrofolate (THF)	One-Carbon Group Transfer	Amino Acid & nucleotide synthesis
B_{12}	Cobalamin	Coenzyme B_{12}	• Intramolecular Rearrangements • Methyl transfer	• Nucleotide synthesis • Amino acid metabolism • Fatty acids breakdown • Folic acid regeneration
C	Ascorbic Acid	Ascorbic Acid	Proline Hydroxylation	Collagen synthesis
			Reduction	Antioxidation
D	Calciferol	Calcitriol	Gene expression	Bone growth

VITAMIN B_{12}

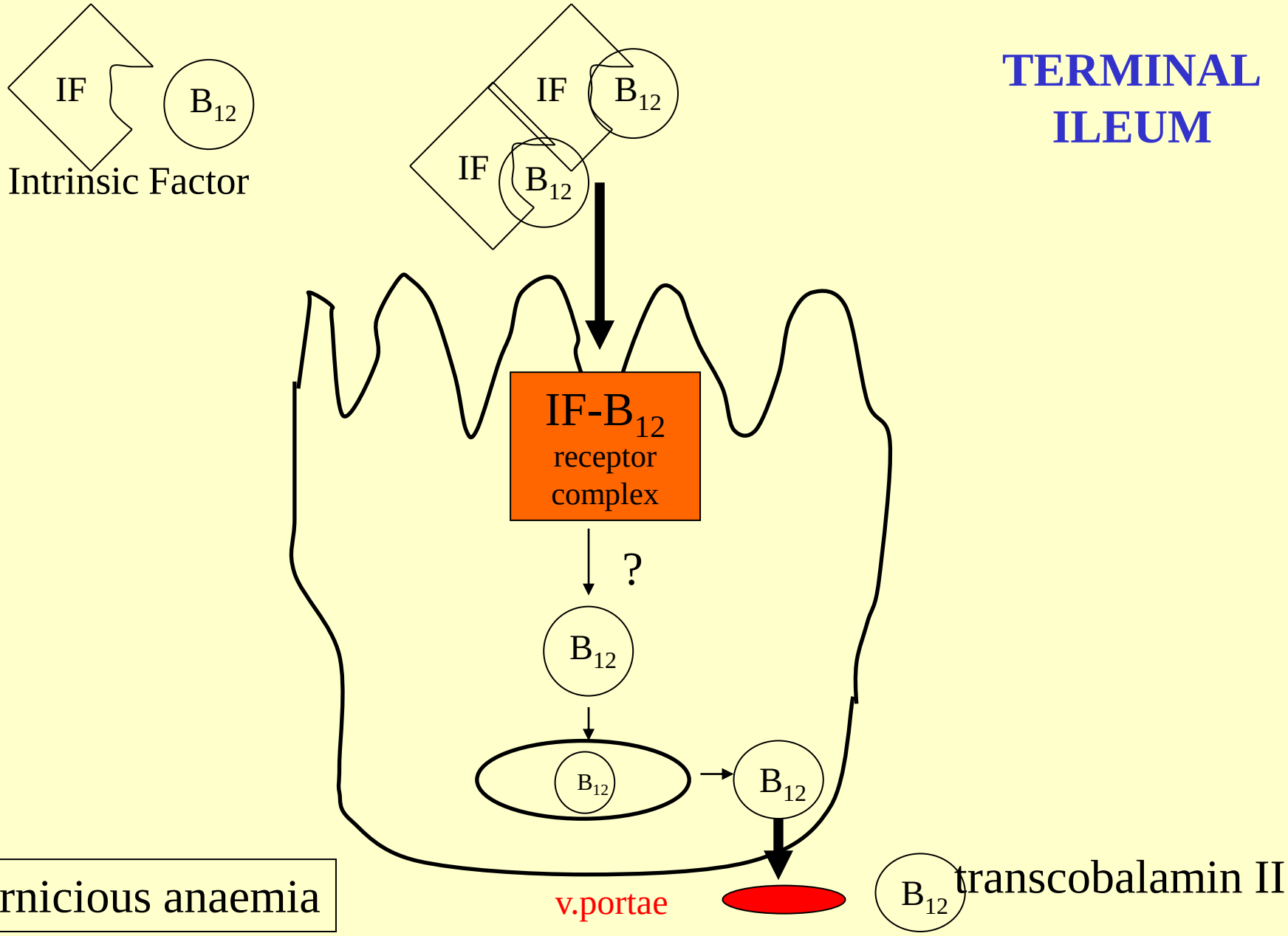
- Daily dose is close to absorption capacity
- Synthesised by bacteria in colon – BUT there is not absorption mechanism
- Store in liver (2-5mg)
- In bile 0,5-5μg / day, reabsorbed
- Daily loss – 0,1% of stores → stores will last for 3-6 years

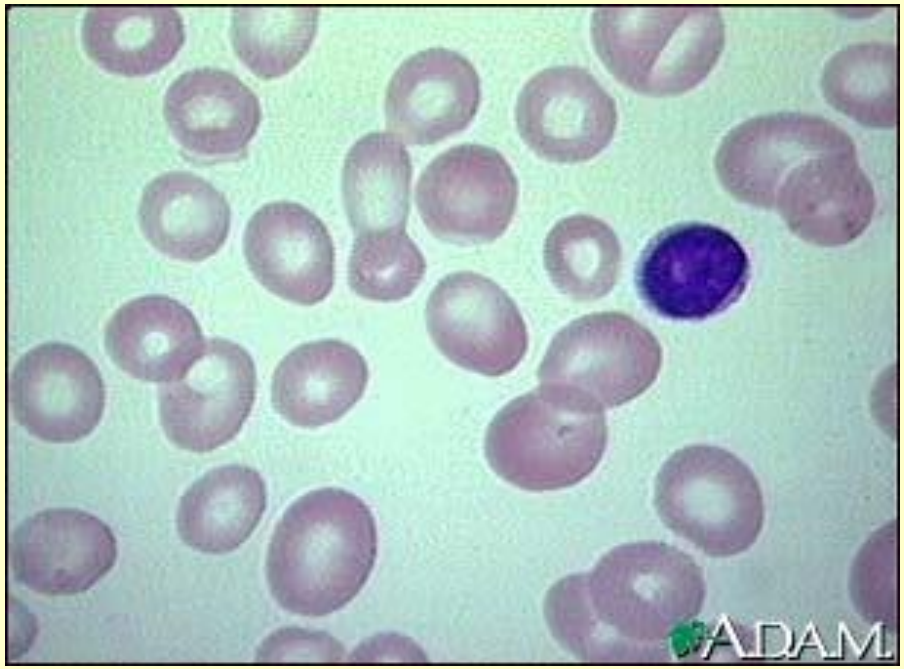
ABSORPTION

1. **Gastric phase**: B_{12} is bound to proteins, low pH and pepsin release it; bound to glycoproteins – **R-proteins** (saliva, gastric juice), almost pH-undependable; intrinsic factor (**IF**) – parietal cells of gastric mucosa; most of vitamin bound to R-proteins
2. **Intestinal phase:** pancreatic proteases, cleavage of R-B_{12}, bound to IF (resistant to pancreatic proteases)


C COBALAMIN HANDLING BY THE STOMACH AND PROXIMAL SMALL INTESTINE
1
Cobalamin is bound to proteins in food.
Food
CBL
Cobalamin
2
The acid pH and pepsin release cobalamin from dietary protein.
Acid pH
Pepsin
3
Gastric glands secrete haptocorrin, which then binds to cobalamin.
4
Gastric parietal cells secrete IF.
IF
Bile duct
Haptocorrin
Pancreatic proteases
5
The pancreas secretes proteases and HCO_3^- (alkaline secretion).
6
CBL is released after the proteolytic degradation of haptocorrin.
7
The IF-CBL complex forms.
8
Ileal enterocyte absorbs IF-CBL complex.
D COBALAMIN ABSORPTION BY ILEAL ENTEROCYTE
Intestinal lumen
Ileal enterocyte
Interstitial space
Endosome
Receptor
Trans-cobalamin II
Secretory vesicle
Deglycosylation? and degradation of IF
TCII
Degraded receptor?
Lysosome
3–4 hours

ABSORPTION OF B_{12} VITAMIN

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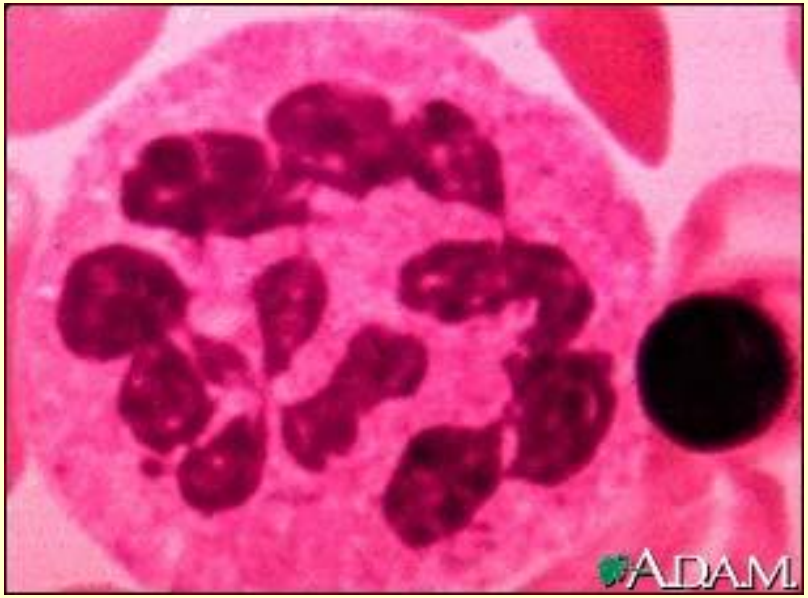
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HYPOVITAMINOSES

Folic acid – disorders of embryo development (clefts)
B_{12} – pernicious anaemia
C – scurvy (scorbutus)
D – rickets (rhachitis, English disease, English sickness)
E – fertility problems
K - haemorrhage

HYPERVITAMINOSES

A – teratogenic effects
D – kidney failure
K – anaemia, GIT disorders
B_6 – peripheral polyneuropathy

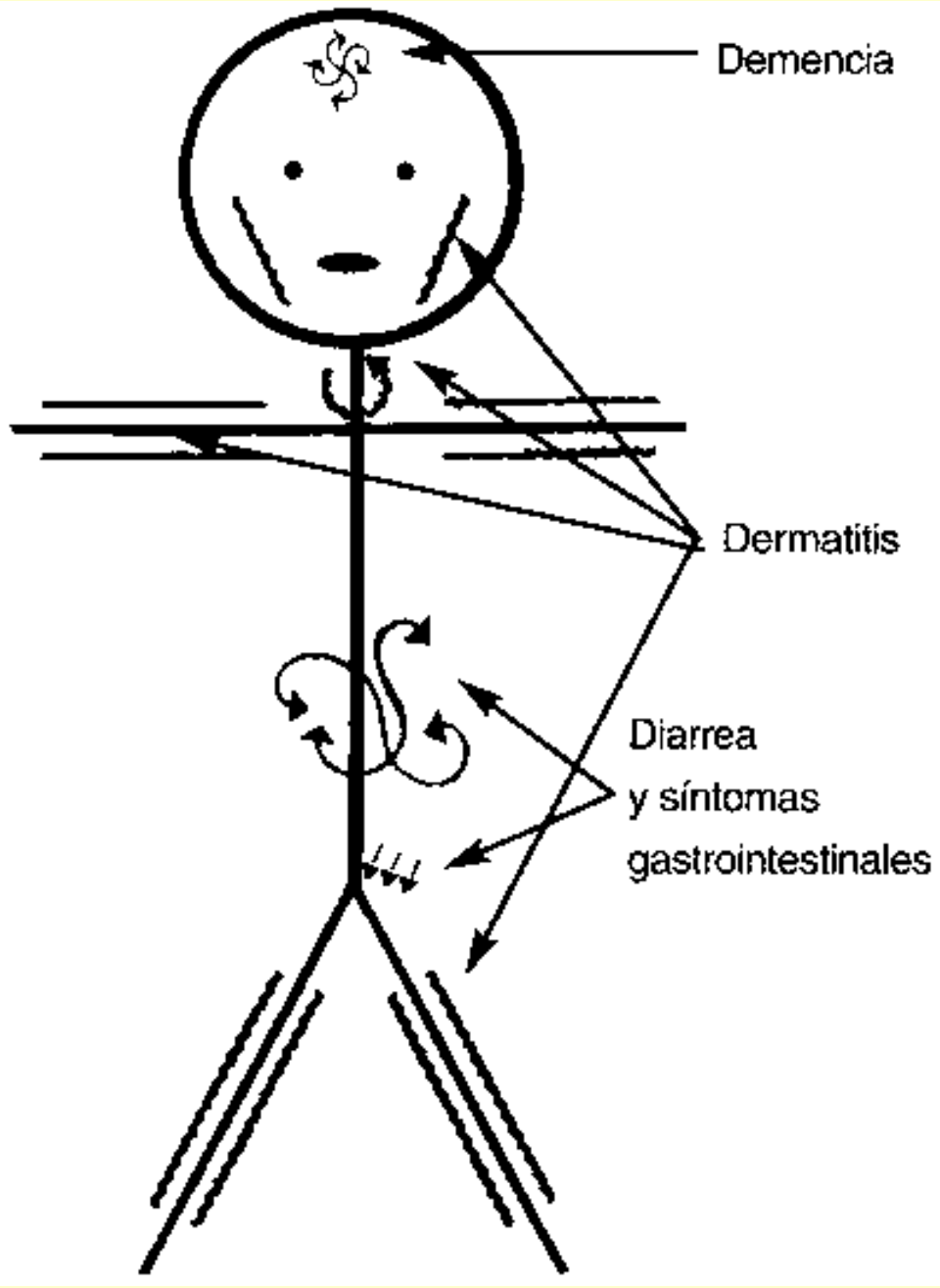
BERI-BERI (B_1)

"The first clinical descriptions of beriberi were by Dutch physicians, Bontius (1642) and Nicolaas Tulp (1652). Tulp treated a young Dutchman who was brought back to Holland from the East Indies suffering from what the natives of the Indies called beriberi or "the lameness." Tulp's description of beriberi was a detailed one, but he had no clues that it was a dietary deficiency disease. This discovery came more than two hundred years later. Nicholaas Tulp (1593-1674) is best remembered as the central figure in Rembrandt's famous painting, "The Anatomy Lesson" (1632).

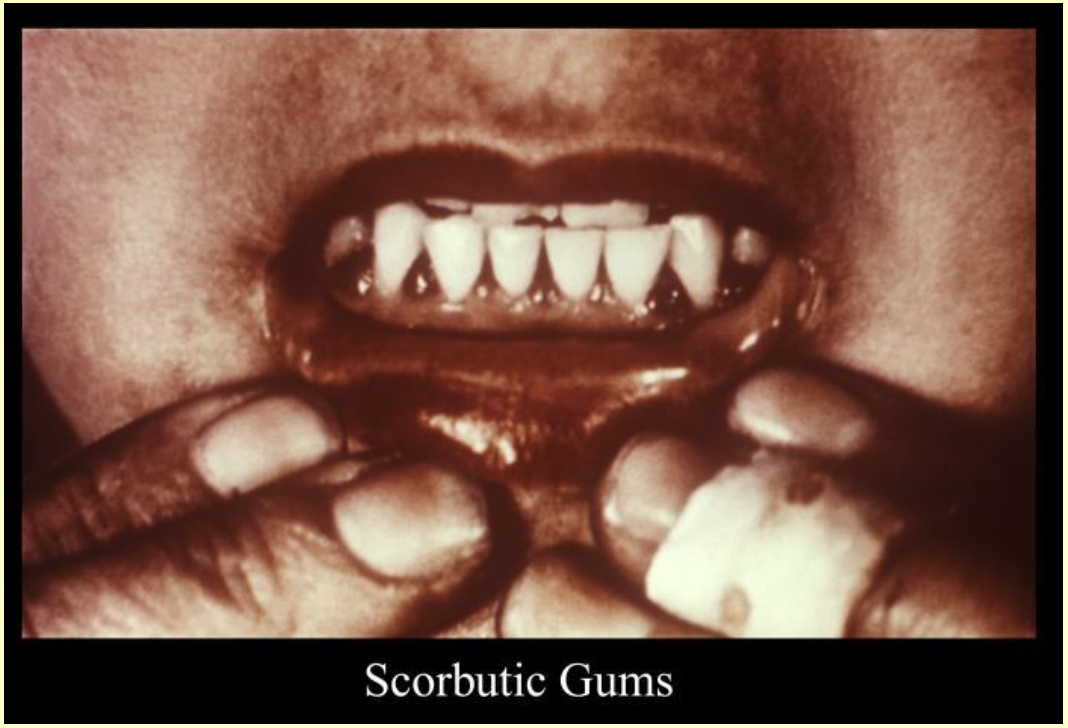
PELAGRA

(3 D disease)

(niacin)

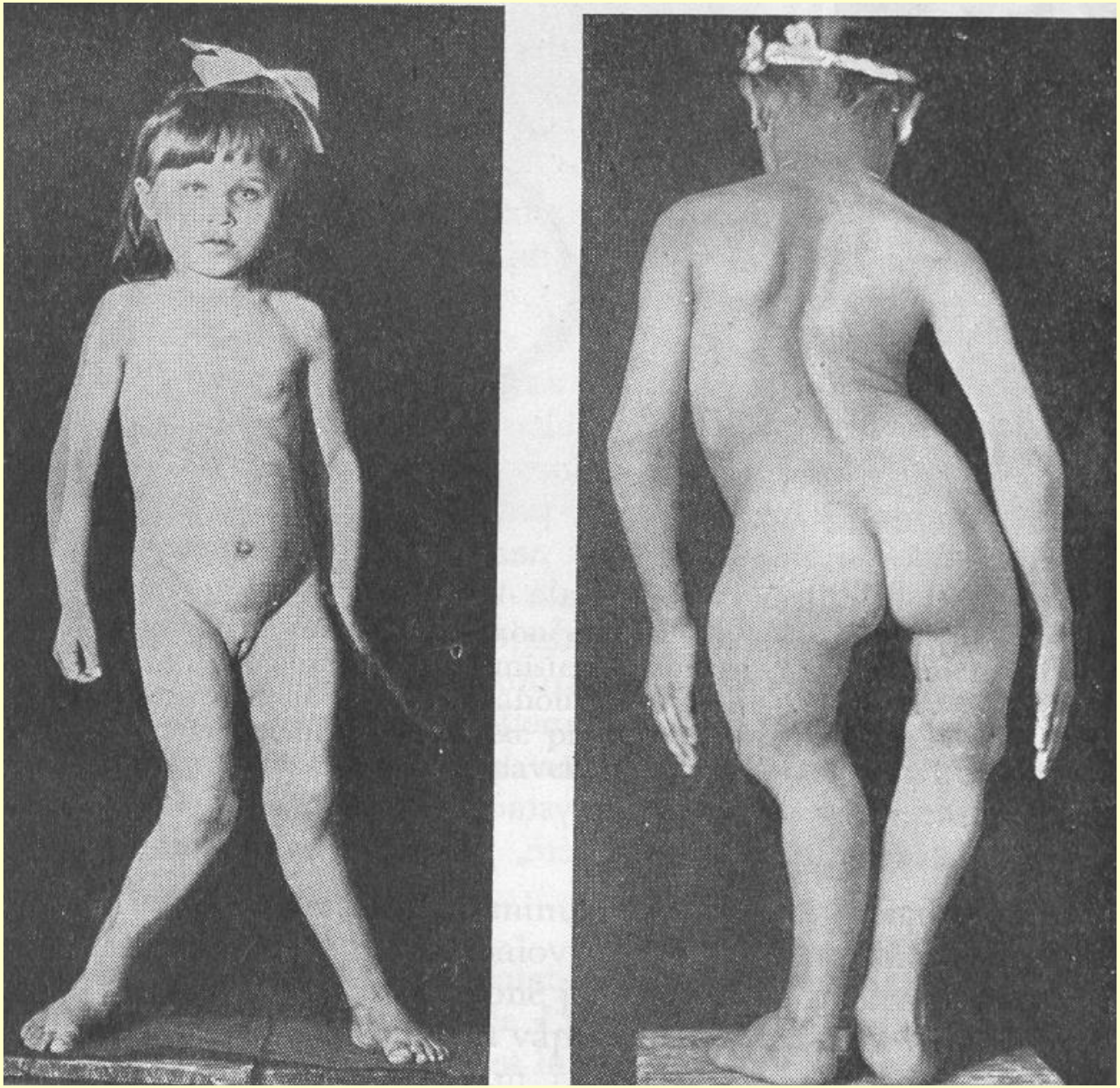


SCURVY



Scorbutic Gums

RICKETS



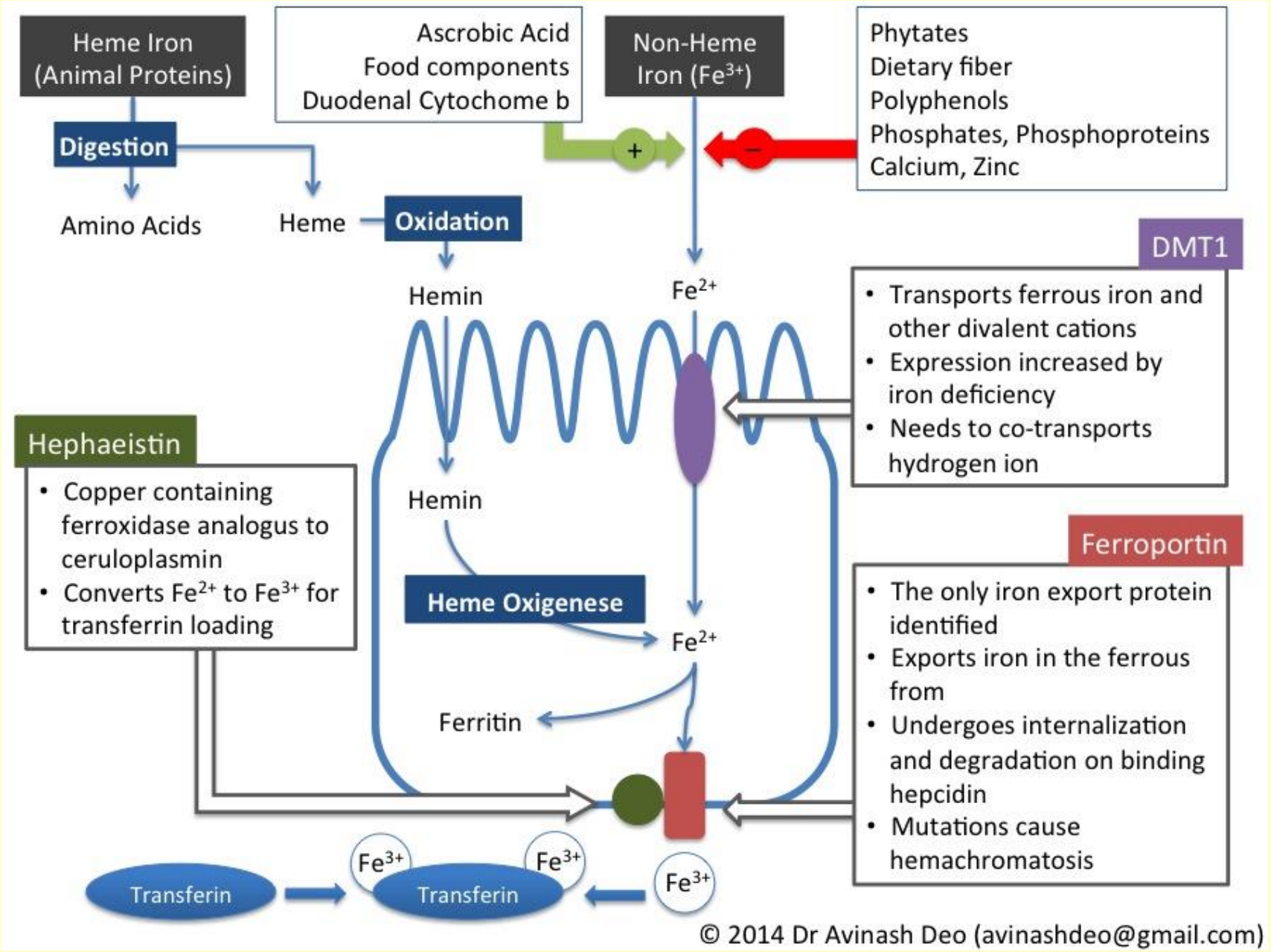
Mineral	Daily need (dose)
Na	3,0 g
K	1,0 g
Cl	3,5 g
Ca	1,2 g
P	1,2 g
Fe	18,0 mg
J	150,0 µg
Mg	0,4 g
Co	?
Cu	?
Mn	?
Zn	15 mg

Coenzyme of metabolic reactions of saccharides; deficiency – increased irritability of CNS, peripheral vasodilatation, arrhythmias; excess – suppresses electrical activity of CNS and skeletal muscle

Part of enzymes (carboanhydrase in erythrocytes, lactatedehydrogenase, peptidases)

MINERALS AND TRACE ELEMENTS

1. Arsenic
2. Chrome – experimental deficiency, glucose oral test is of diabetic character
3. Cobalt – part of enzymes, vit.B_{12}; poisoning by cobalt (beer), cobalt cardiomyopathy
4. Copper – impairment of cytochromoxidase (experiment), melanoma – increase of radiosensitivity when copper is depleted; vessel wall damage
5. Fluorine
6. Iodine
7. Iron
8. Manganese – catalyses similar reactions as Mg, stored in mitochondria, β1-globulintransmanganin
9. Molybdenum – in xantinoxidase and flavoproteins, defficiency in humans???
10. Nickell
11. Selenium – antioxidant, in diet bound to proteins (alcoholism, liver cirrhosis)
12. Silicon
13. Vanadium
14. Zinc – part of metalloenzymes, proteosynthesis (ribosomes);deficiency-Middle East (parasites, fytates in diet); testes atrophy, immune disorders; in DM 50% of stores Zn (insulin stored in pancreas together with Zn)



Iron: Factors Affecting Absorption

Physical State (bioavailability)	**heme > Fe^{2+} > Fe^{3+}**
Inhibitors	phytates, tannins, soil/clay (pica), laundry starch, iron overload, antacids
Competitors	lead, cobalt, strontium, manganese, zinc
Facilitators	ascorbate, citrate, amino acids, iron deficiency, stomach acid, high altitude, exercise, pregnancy