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Metabolism of sacharides, lipids and proteins. Energy metabolism.

Introduction

At steady state, the energy input must correspond to the energy output

- Energy expenditure = external work + energy reserves + heat
- Intermediate: various chemical, mechanical and thermal reactions

- Saccharides, lipids, proteins

- Conversion of proteins and sugars into fats - efficient energy storage

- Conversion of proteins into sugars - the need for fast energy

- BUT: there is no significant conversion of fats into sugars

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Nutrient pools and metabolism

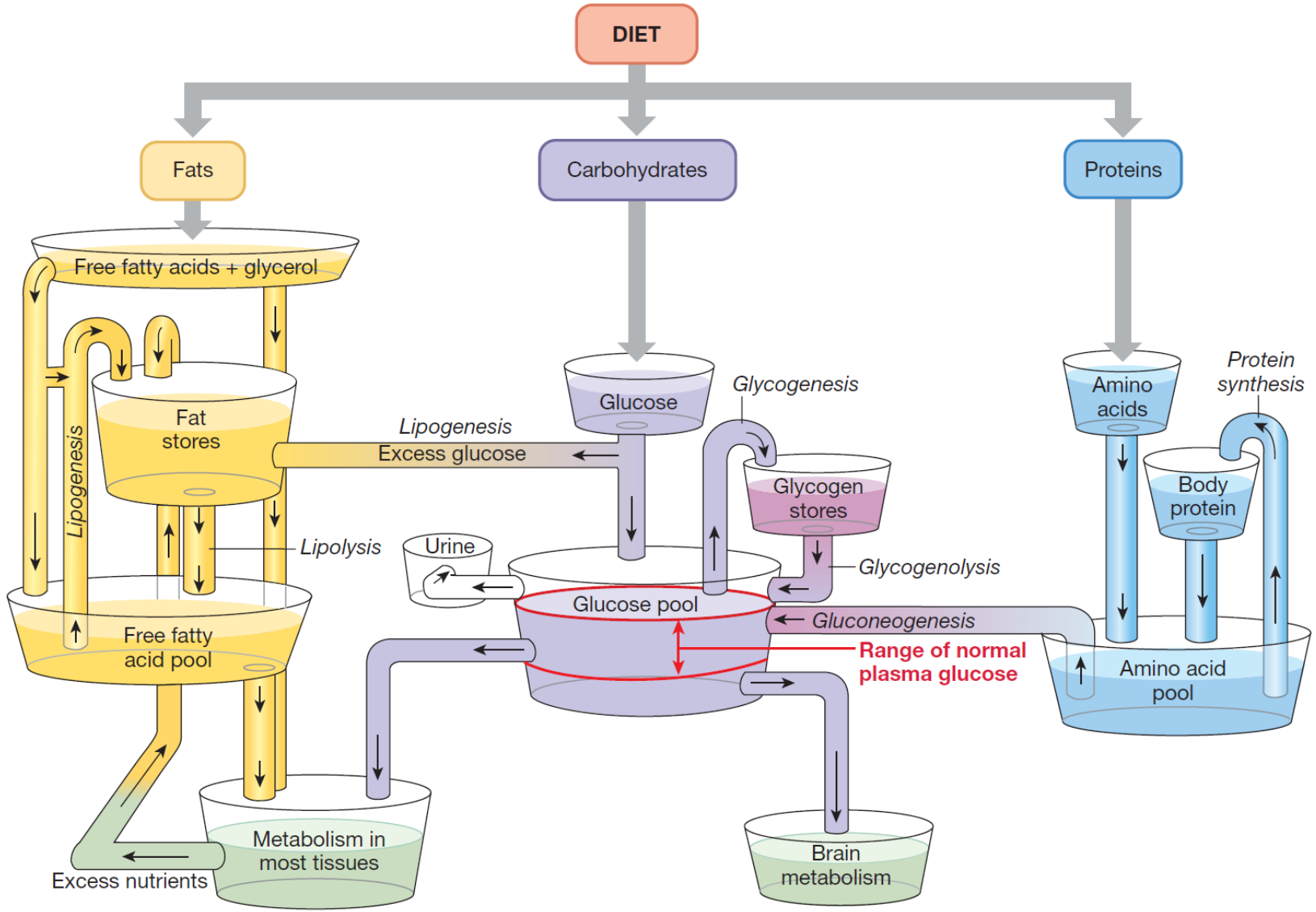

Fig. 22.3 Adapted from L. L. Langley, *Homeostasis* (New York: Reinhold, 1965).

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Metabolism of saccharides

- Energy source
- Functions of saccharides:
  - Part of glycoproteins and glycolipids
  - Inevitable for nucleic acids and coenzyme synthesis
  - Part of extracellular matter
- Saccharides:
  - Monosaccharides
  - Oligosaccharides
  - Polysaccharides
- Digestion and absorption
  - Saliva (salivary amylase)
  - Pancreatic juice (a-amylase)
  - Epithelium of duodenum and jejunum (isomaltase, maltase, saccharase, lactase)

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Metabolism of saccharides

- The key substrate is **glucose**
- Postprandial plasma glucose level: **3.5 – 5.5 mmol/l**
- Glycemia. Hypoglycemia, hyperglycemia
- Glycolysis, gluconeogenesis
- Glycogenolysis, glycogenesis

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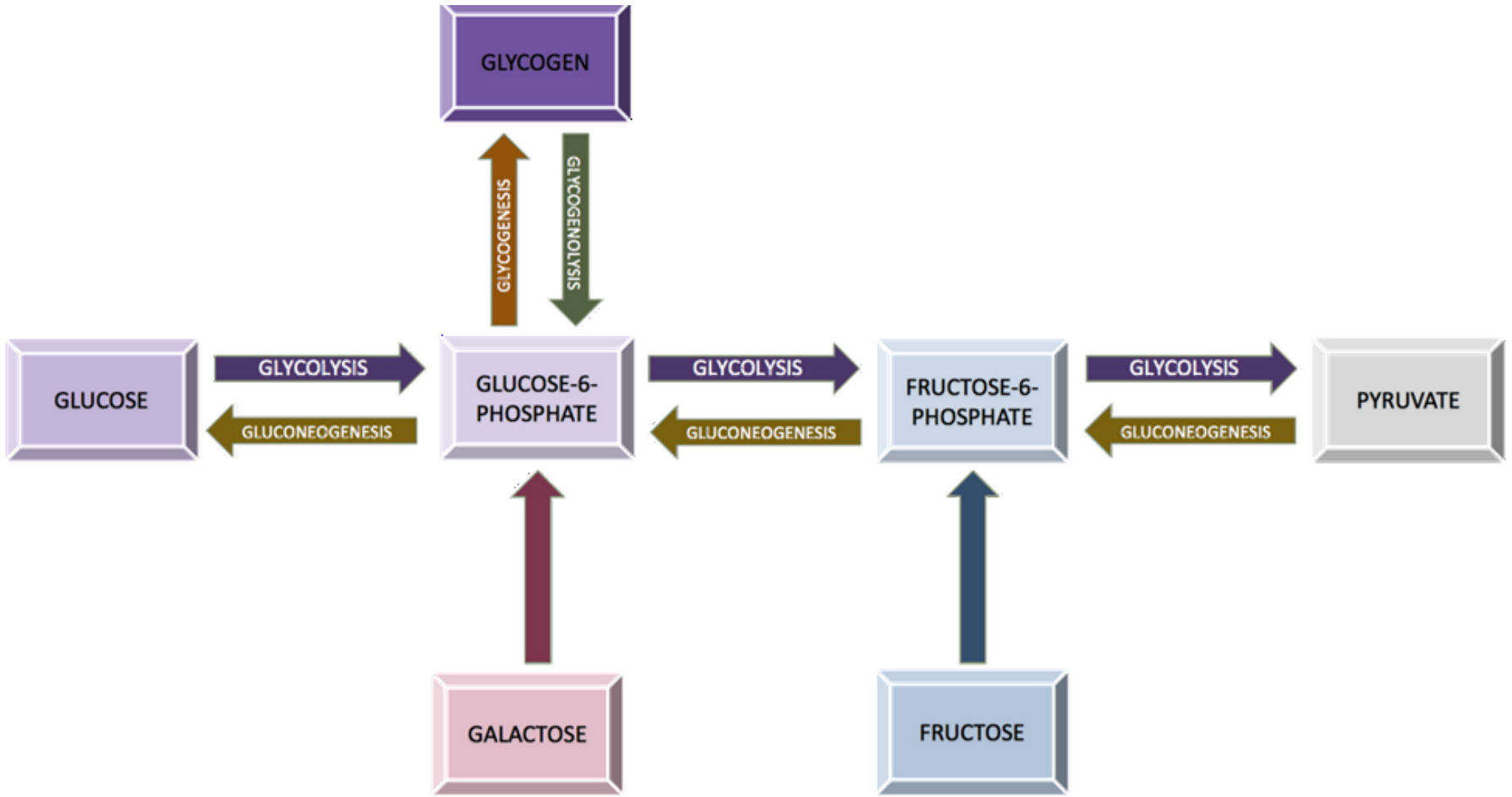
Metabolism of saccharides

- Morning glucose intake - 70% consumed by peripheral tissues (muscles), 30% - splanchnic organs (liver)



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Metabolic disorders - saccharides

- **Diabetes mellitus**
- **McArdle syndrom** (glycogenesis from deficiency of myophosphorylase → accumulation of glycogen in muscles: muscle stiffness, rigor during exercise, lower tolerance of load)
- **Galactosemia**(inherited deficiency of phosphogalactosauridyltransferase; disorders of growths and development)

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Metabolism of lipids

- Main and most profitable form of energy store
- Lipid functions:
  - Part of biological membranes - fospholipids
  - Energy storage
  - Protective cover for organisms
  - Precursors of some important substances
  - Vitamin solvents (A, D, E, K)
- Lipids:
  - Triglycerides
  - Sterols
  - Phospholipids
- Digestion and absorption
  - Bile acids salts (emulsification)
  - Pancreatic lipase, cholesterol-estherase, phospholipase a_2, enteric lipase(deestherification)

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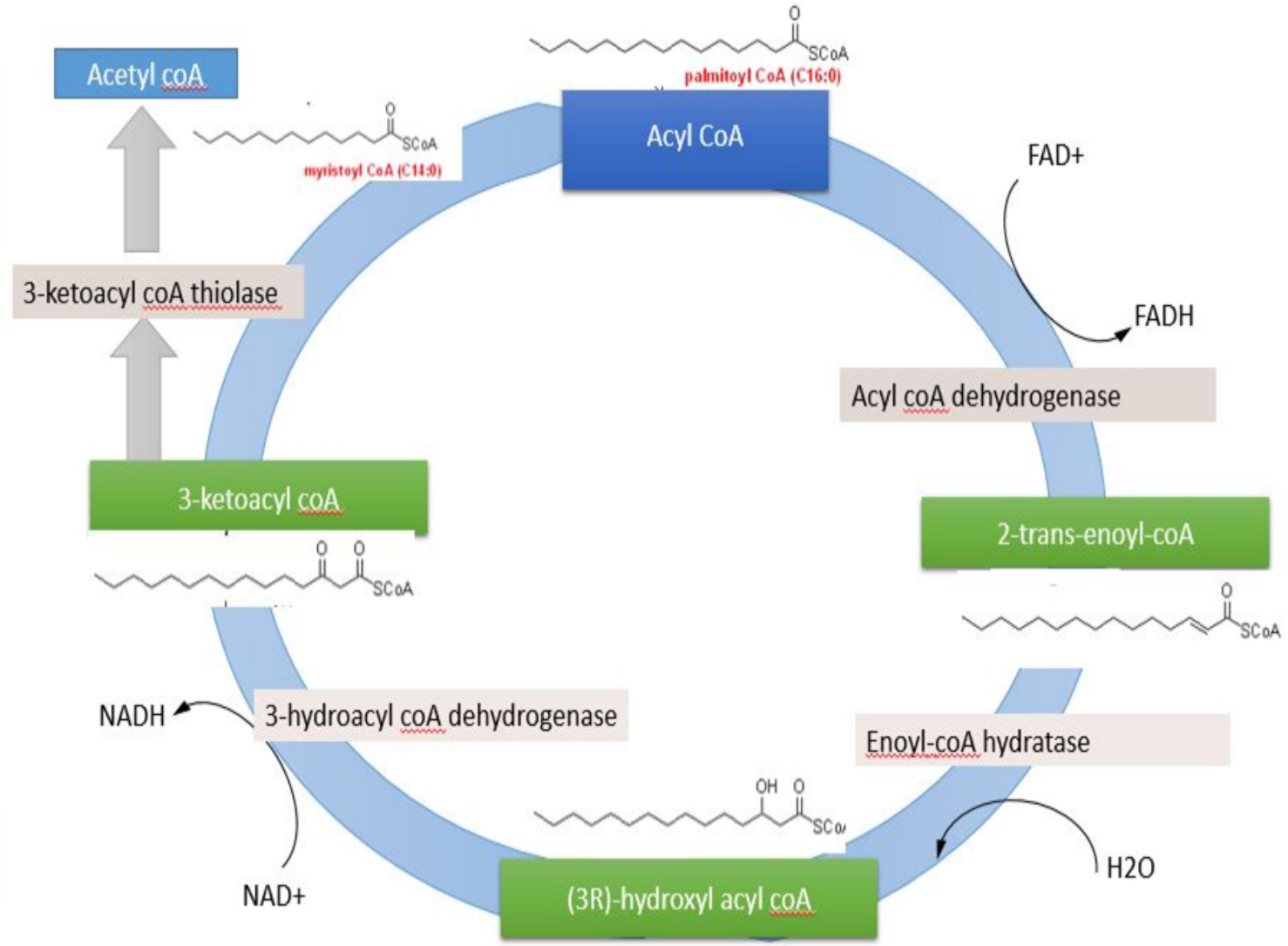
Metabolism of lipids



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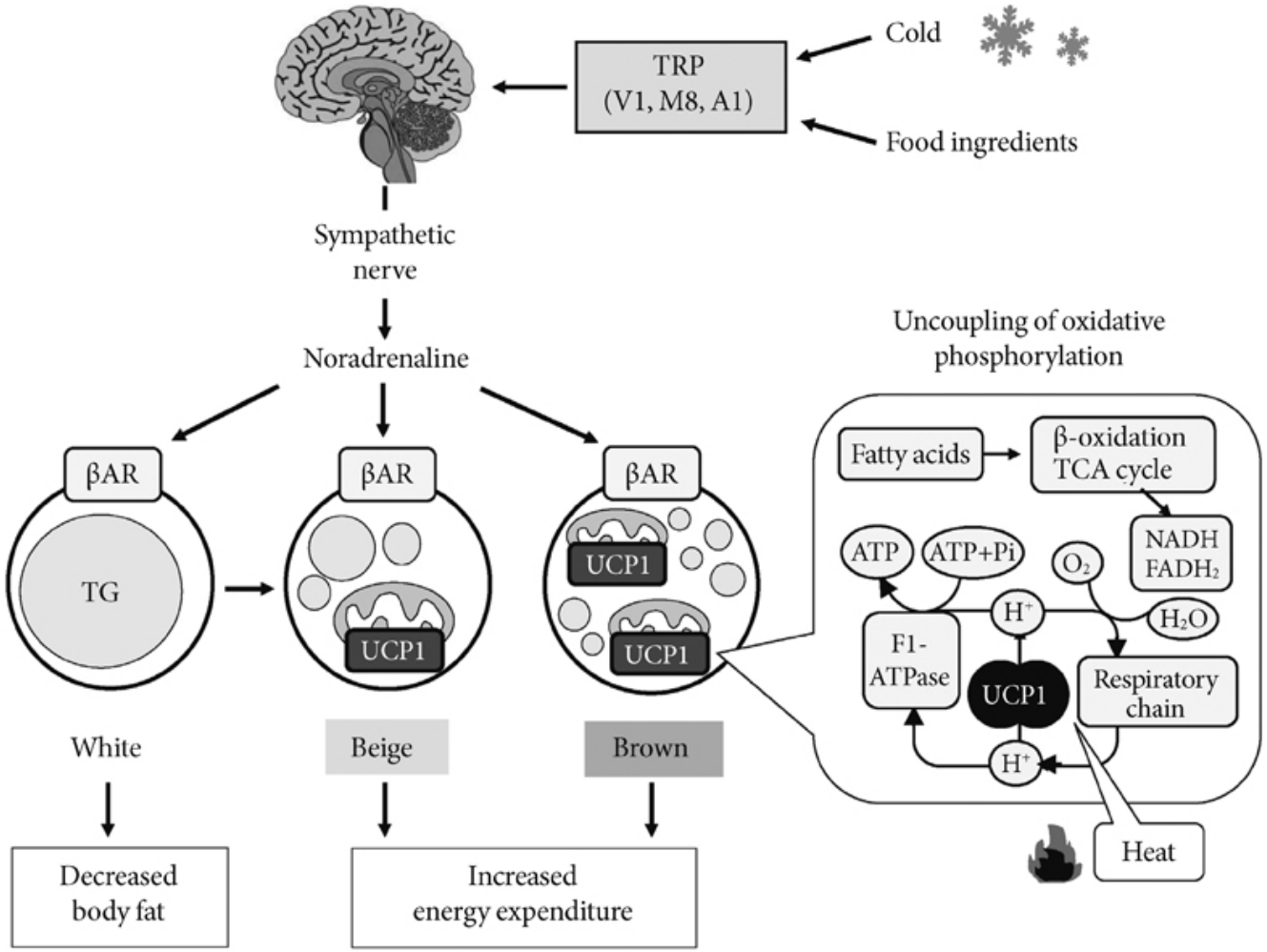
Fat tissue



http://www.e-dmj.org/ViewImage.php?Type=F&aid=284781&id=F1&afn=2004_DMJ_37_1_22&fn=dmj-37-22-g001_2004DMJ

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Metabolic disorders - lipids

- Hyperlipidemia
- Hyperlipoproteinemia
- Infrequent disorders of lipid metabolis

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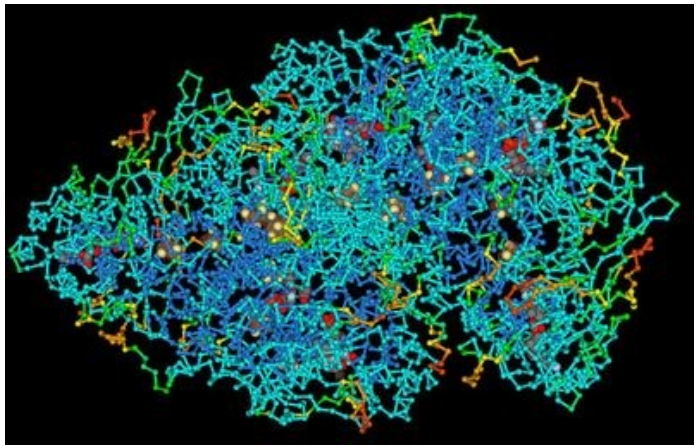
Metabolism of proteins



- Total proteins in body: 10 kg
- Protein minimum: 0.5 g / kg of body mass
- Protein optimum: 0.7 g / kg of body mass
- Increased supply (growth, convalescence, pregnancy, lactation): 1.5 – 2.0
- **Aminoacides**
  - Essential (not synthesised)
  - Non-essential (from glucose metabolism – citrate cycle)
  - 0.5 – 1.5 g / day

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Metabolism of proteins

- Digestion and absorption
  - Stomach (pepsin)
  - Duodenum (trypsin, chymotrypsin, carboxypeptidase)
  - Jejunum (membrane peptidases)
- Functions of proteines:
  - Structural (collagen, elastin, …)
  - Motoric (actin, myosin, …)
  - Informational (protein hormones)
  - Protective (immunoglobulins, complement, antigens, …)
  - Transport (albumin)

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Metabolic disorders – proteins

- Proteinemia = plasmatic level of proteins.
- Dysproteinemia = change in representation of particular proteins (fractions shift) – nephrotic syndrome, cirrhosis, inflammatory reactions
- Paraproteinemia = presence of pathological imunoglobulines (with no antibodies specificity) – monoclonal immunopathy
- Defect proteinemia = some components of plasma proteins are missing or lowered – syndromes of immunodeficiency, polyclonal hypergamaglobulinemia

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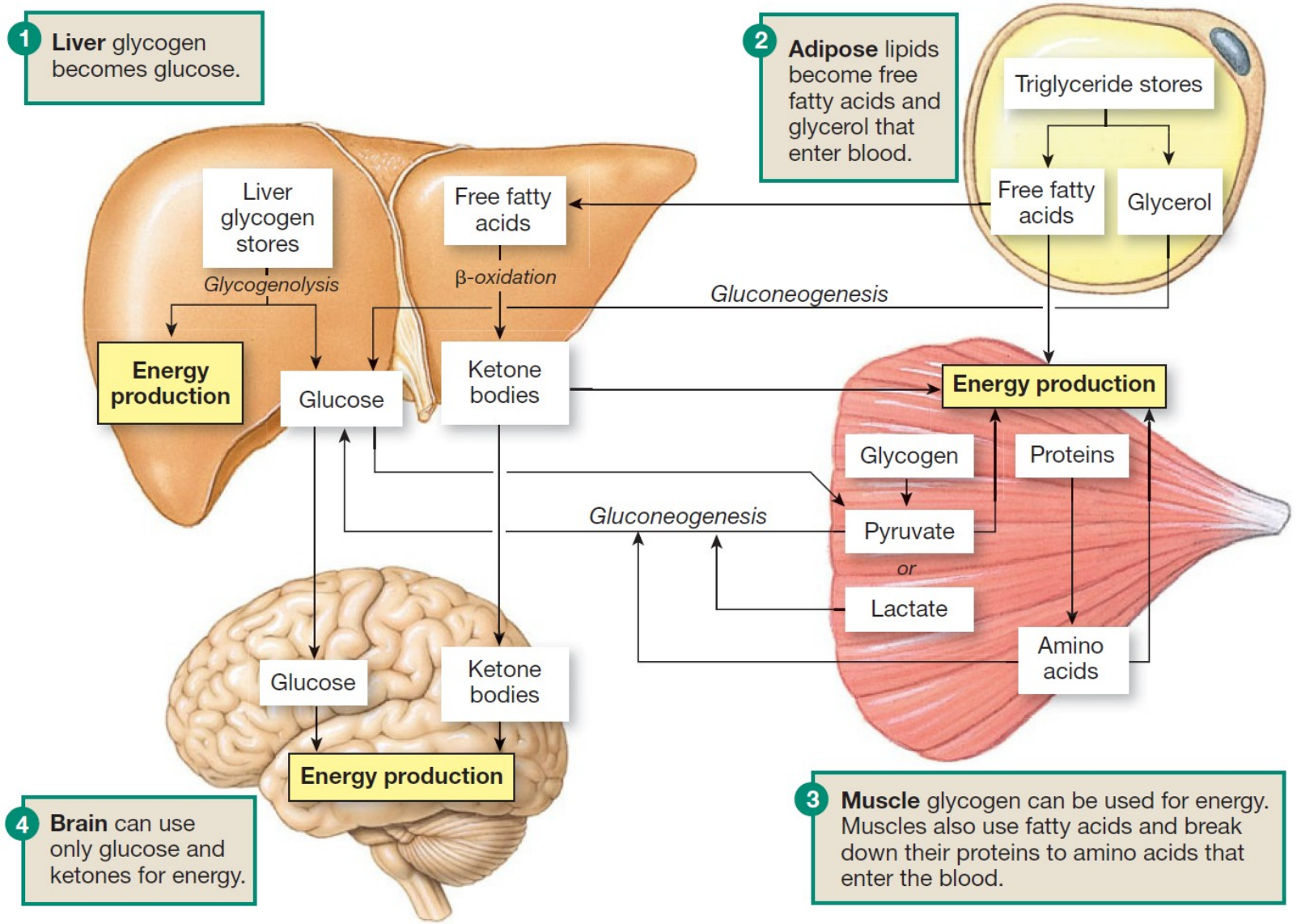
Energy storage



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Metabolism

= summary of all chemical (and physical) processes included in:

- Production of energy from internal and external sources
- Synthesis and degradation of structural and functional tissue components
- Excretion of waste products and toxins from body

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Metabolic rate

- Physical work (oxygen debt compensation)
- Specific-dynamic effect of food (assimilation of nutrients in the body)
- External temperature
- Height, weight and body surface
- Gender
- Age
- Emotions
- Body temperature
- Thyroid hormone level (T4, T3)
- Adrenaline and norepinephrine levels

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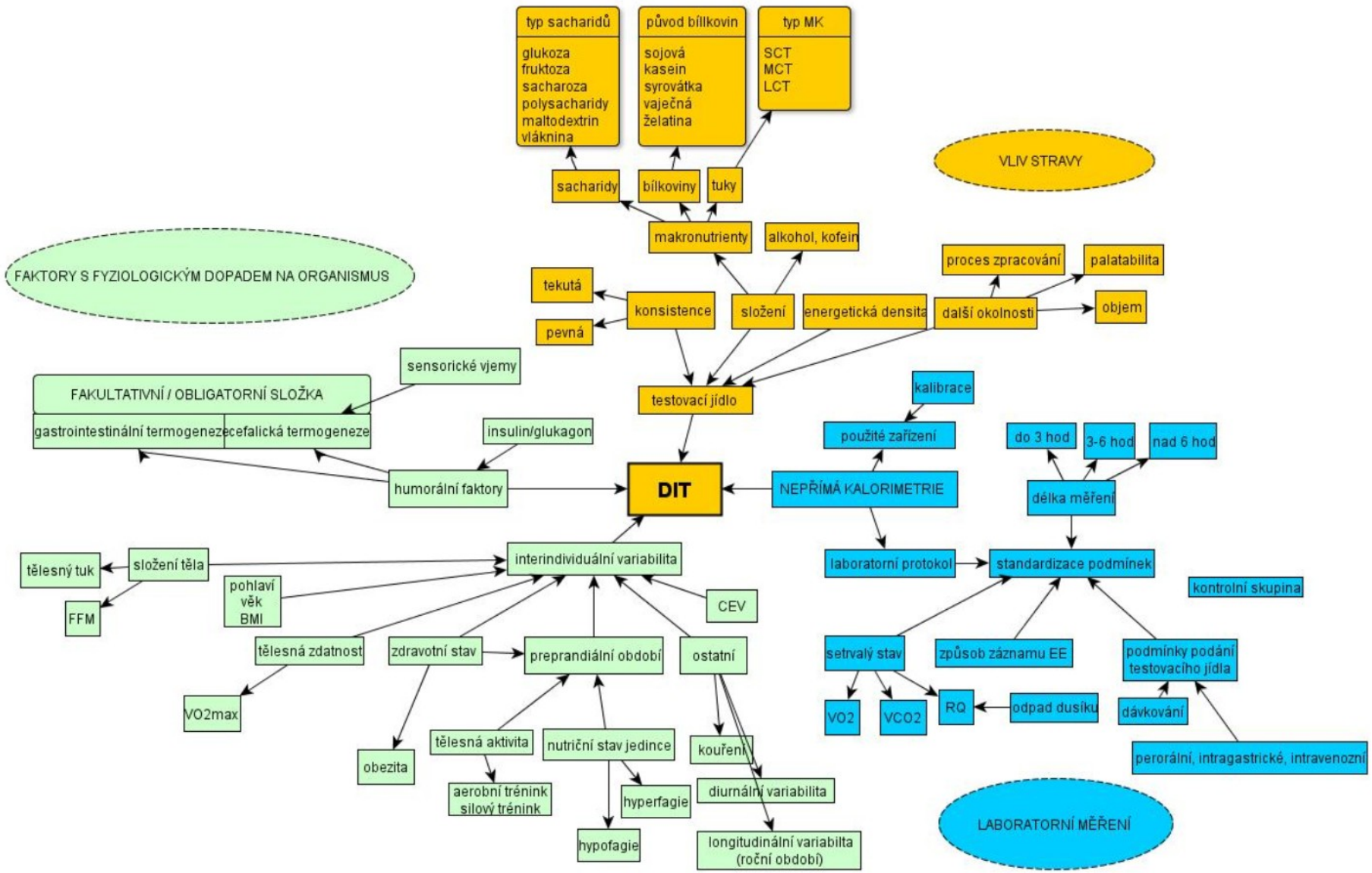
typ sacharidů
glukoza
fruktoza
sacharoza
polysacharidy
maltodextrin
vláknina
původ bílkovin
sojová
kasein
syrovátka
vaječná
želatina
typ MK
SCT
MCT
LCT
VLIV STRAVY
sacharidy
bílkoviny
tuky
makronutrienty
alkohol, kofein
FAKTORY S FYZIOLOGICKÝM DOPADEM NA ORGANISMUS
tekutá
pevná
konsistence
složení
energetická densita
další okolnosti
proces zpracování
palatabilita
objem
sensorické vjemy
FAKULTATIVNÍ / OBLIGATORNÍ SLOŽKA
gastrointestinální termogeneze
cefalická termogeneze
testovací jídlo
kalibrace
použité zařízení
insulin/glukagon
humorální faktory
DIT
NEPŘÍMÁ KALORIMETRIE
do 3 hod
3-6 hod
nad 6 hod
délka měření
tělesný tuk
složení těla
FFM
pohlaví
věk
BMI
interindividuální variabilita
CEV
laboratorní protokol
standardizace podmínek
kontrolní skupina
tělesná zdatnost
zdravotní stav
preprandiální období
ostatní
setrvalý stav
způsob záznamu EE
podmínky podání testovacího jídla
VO2max
obezita
tělesná aktivita
nutriční stav jedince
kouření
VO2
VCO2
RQ
odpad dusíku
dávkování
aerobní trénink
silový trénink
hyperfagie
diurnální variabilita
perorální, intragastrické, intravenozní
hypofagie
longitudinální variabilta (roční období)
LABORATORNÍ MĚŘENÍ

Bazal metabolic rate (BMR)

- Energy for maintaining all vital functions
- Thermoneutral environment
- 12 - 14 hours after a meal
- 24 hours without exhausting physical work
- Elimination of all negative physical and mental factors

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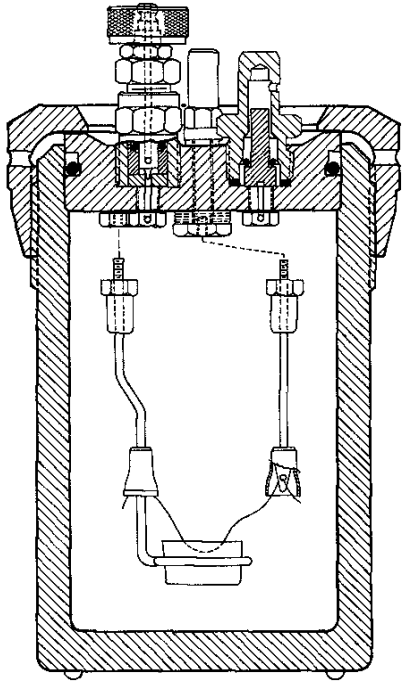
Direct calorimetry

= measuring the energy released by burning food outside the body

(oxidation of compounds in a calorimeter)

- Calorimetry:
  - adiabatic = heating of the calorimeter content
  - isothermal = generated heat is dissipated



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Direct calorimetry

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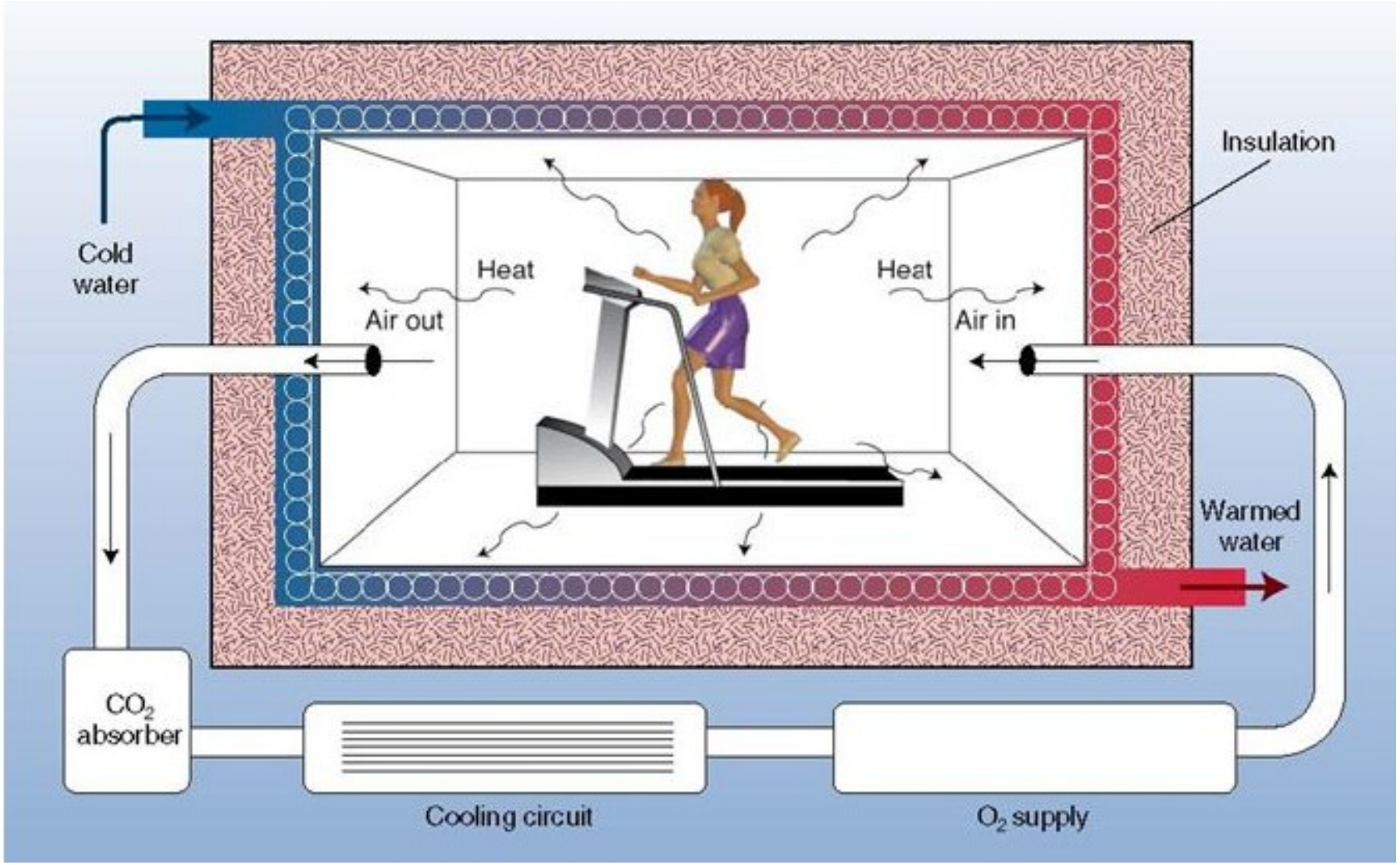
Direct calorimetry



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BMR. Calculation

1. Harris-Benedictova rovnice

$$BMR\ (kcal) = 66{,}5 + 13{,}8 \times hmotnost\ (kg) + 5{,}0 \times výška\ (cm) - 6{,}8 \times věk\ (roky)$$

Rovnice 1: Výpočet BMR pro muže

$$BMR\ (kcal) = 655 + 9{,}6 \times hmotnost\ (kg) + 1{,}8 \times výška\ (cm) - 4{,}7 \times věk\ (roky)$$

Rovnice 2: Výpočet BMR pro ženy

2. Faustova rovnice

Výpočet pomocí Faustova vzorce není přesný, jedná se pouze o orientační předpoklad energetického výdeje.

$$BMR\ (kcal) = hmotnost\ (kg) \times 24$$

Rovnice 3: Výpočet BMR pro muže

$$BMR\ (kcal) = hmotnost\ (kg) \times 23$$

Rovnice 4: Výpočet BMR pro ženy

3. Cunninghamova rovnice

Výpočet pomocí Faustova vzorce nerozlišuje pohlaví.

$$BMR\ (kcal) = 500 + 22 \times FFM\ (kg)$$

Rovnice 5: Výpočet BMR pro muže

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Energy expenditure

ENERGY EQUIVALENT (EE):

- the amount of energy released when consuming 1 liter of O_2
- The thermal oxygen coefficient of individual nutrients differs, so the EE also differs
- EE saccharides → 21.1 kJ = 5.05 kcal
- EE proteines → 18.0 kJ = 4.31 kcal
- EE lipides → 19.0 kJ = 4.55 kcal
- In a mixed diet (60% carbohydrates, 30% fat, 10% protein):
- EE = 20.1 kJ = 4.81 kcal

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Indirect calorimetry

- The amount of consumed O_2
- Influence of diet composition - energy equivalent = universal constant for calculation of energy expenditure under the assumption of mixed diet intake
- Open system
- Close system

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Indirect calorimetry

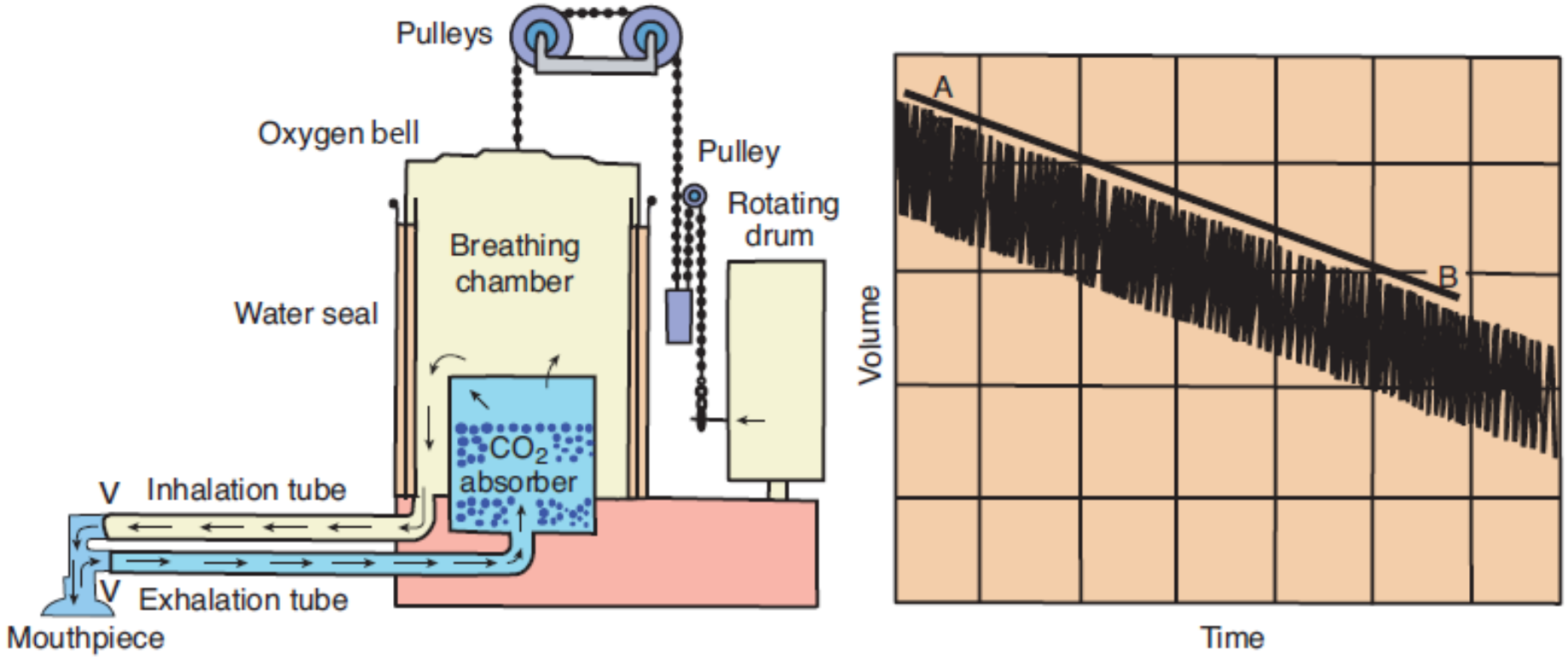

FIGURE 27–8 Diagram of a modified Benedict apparatus, a recording spirometer used for measuring human O_2 consumption, and the record obtained with it. The slope of the line AB is proportionate to the O_2 consumption. V: one-way check valve.

Barret, K.E., Boitano, S., Barman, S.M., Brooks, H.L. Ganong´s Review of Medical Physiology. 23rd Ed. McGraw-Hill Companies 2010

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Respiratory quotient

RQ = $VCO_2 : VO_2$

- Saccharides (glu)
  - $C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_20$
  - RQ = 6/6 = 1.00
- Lipides
  - $2\ C_{51}H_{96}O_6 + 145\ O_2 = 102\ CO_2 + 98\ H_2O$
  - RQ = 102/145 = 0.703 (0.70)

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Respiratory quotient

Substrate or metabolic process	RQ
saccharides/glycogen	1
lipids	0.7
proteins	0.9
glucogenesis	0.4
lipolysis	0.7
lipogenesis	2.75

- Hyperventilation RQ decreasis
- Workload RQ increases
- Acidosis RQ increases
- Alkalosis RQ decriases

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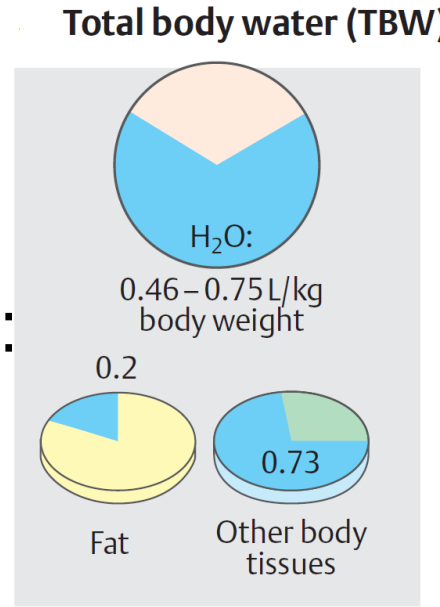
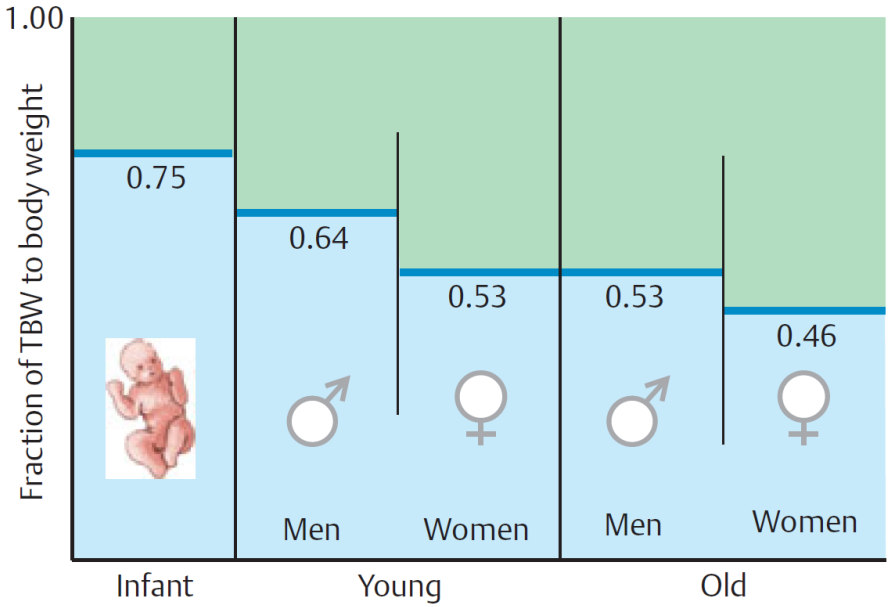
Water

- 50-70% of body mass, newborns
- 2/3 intracellularly, and 1/3 extracellularly
- metabolism
- compartmentalisation
- functions in the human body:
  - the transport medium
  - solvent
  - wetting
  - protection of the mucous membranes





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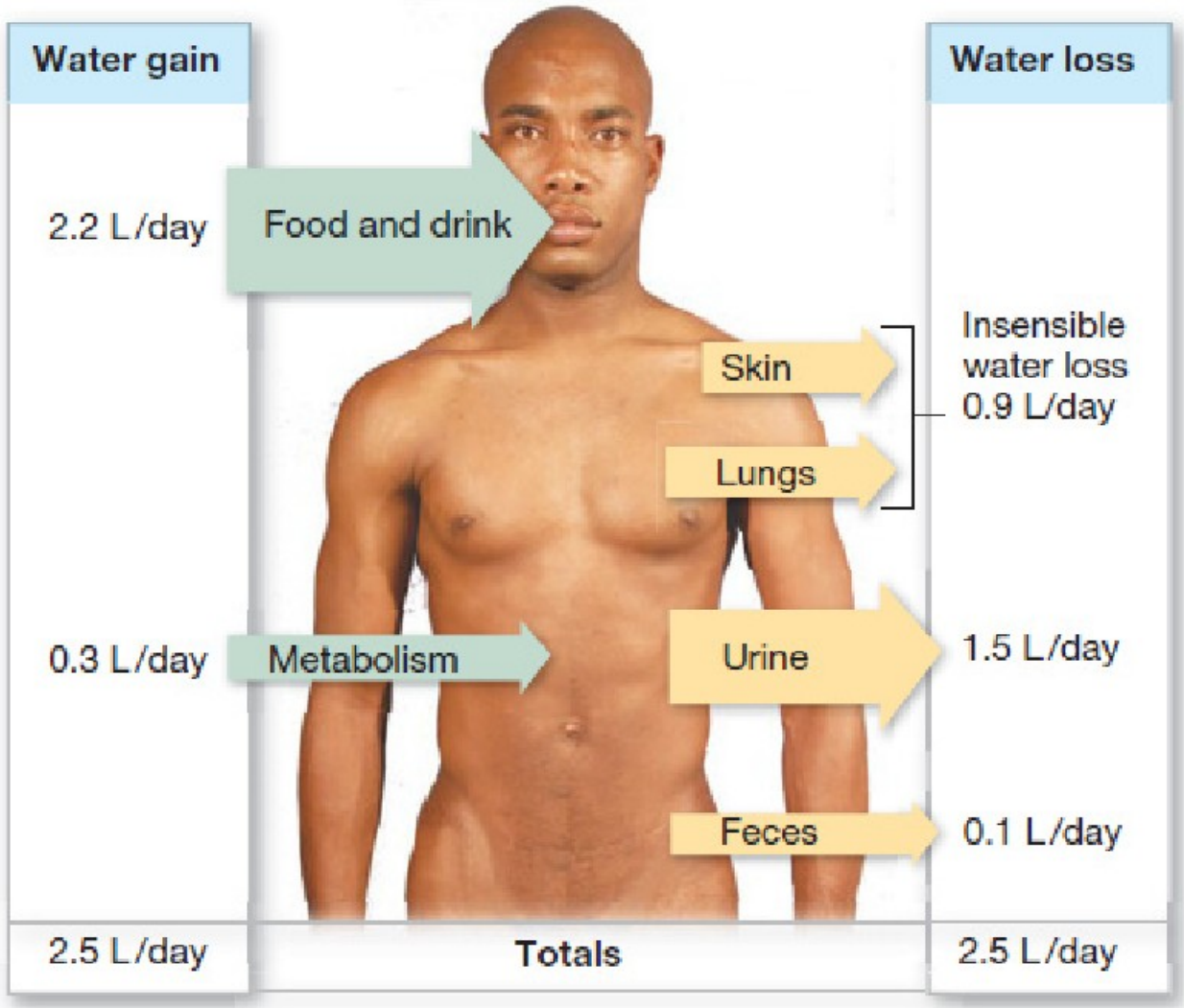
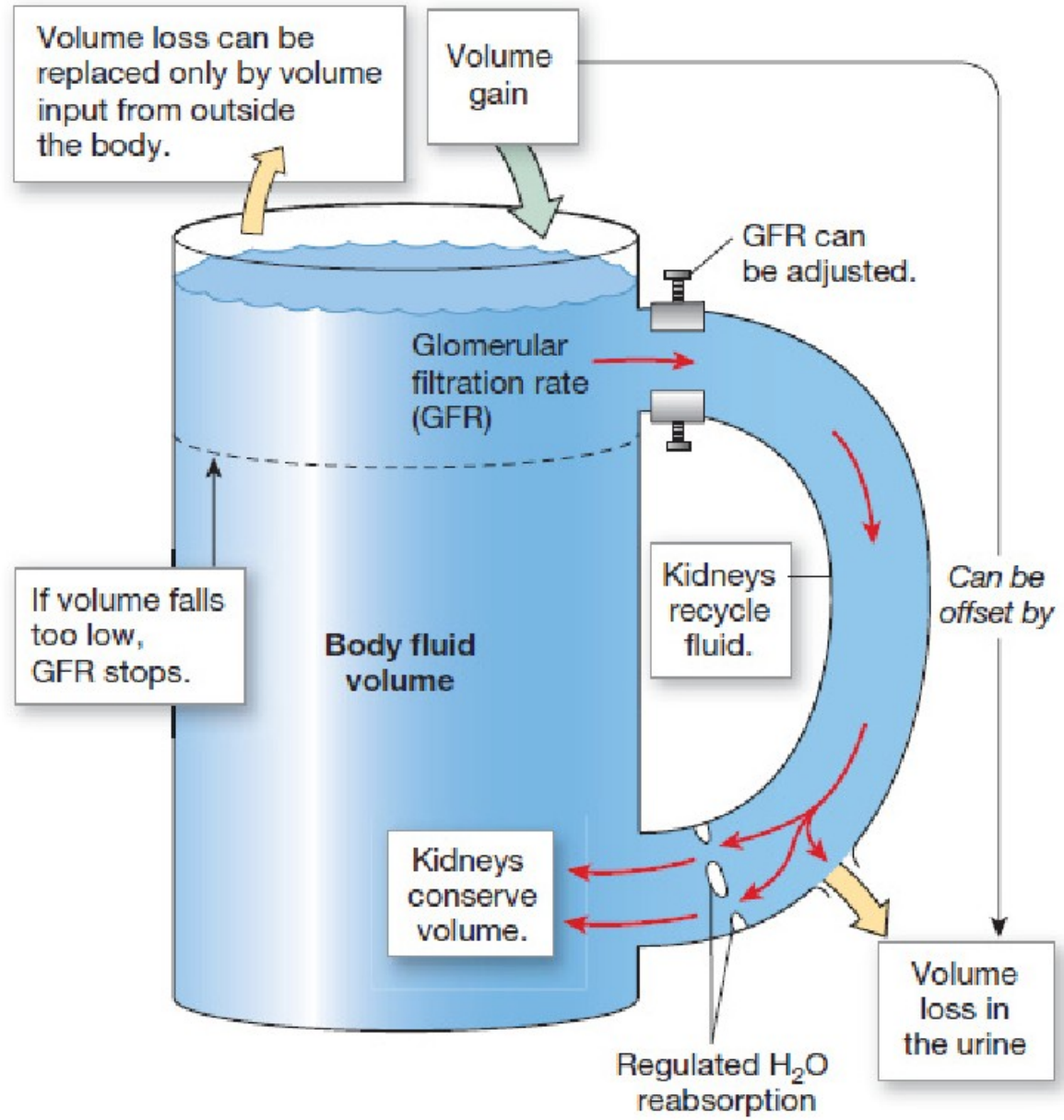
WATER BALANCE IN THE BODY



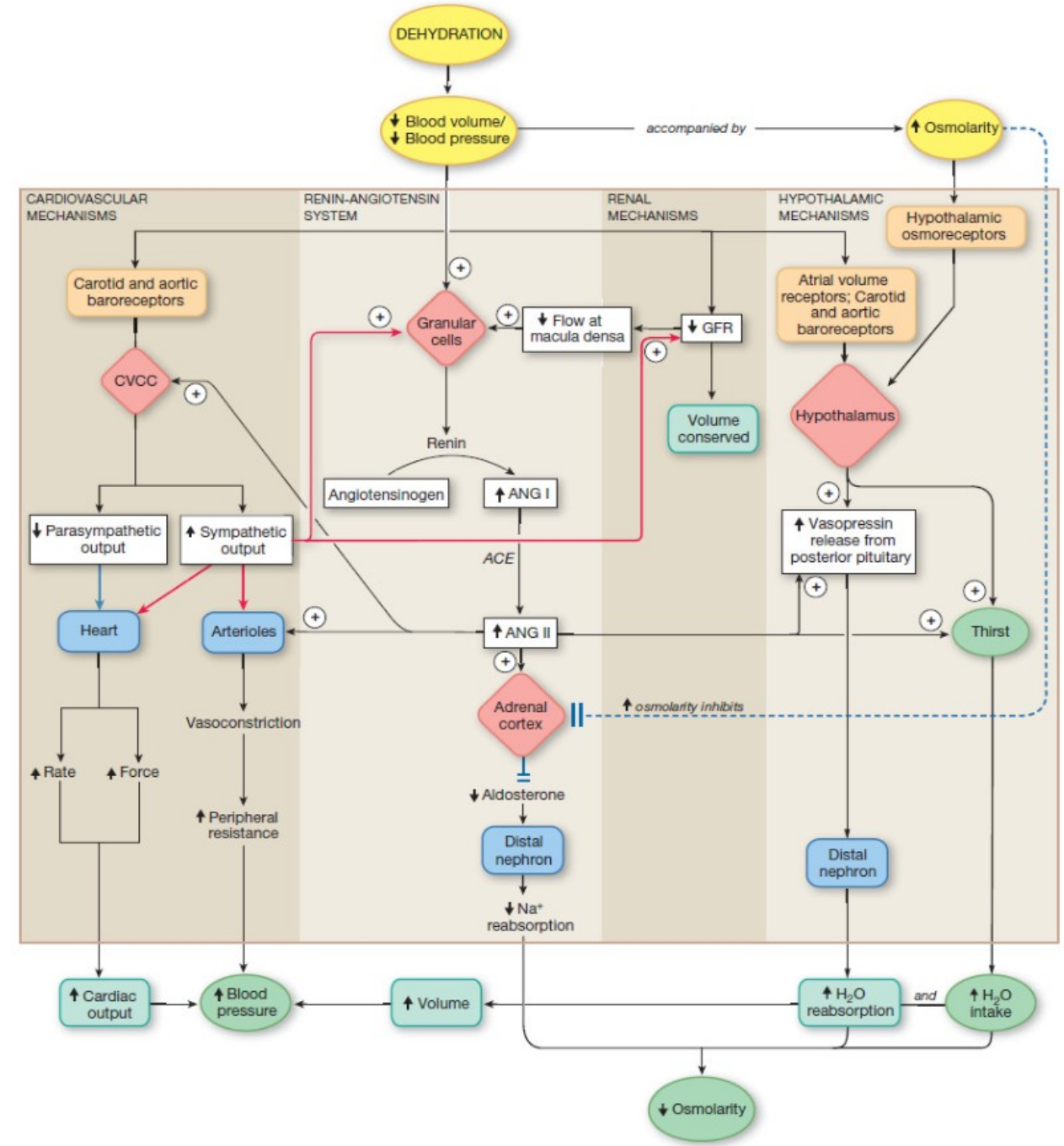
Intake		Metabolic production		Output	
2.2 L/day	+	0.3 L/day	−	2.5 L/day	= 0

THE KIDNEYS CONSERVE VOLUME

Kidneys cannot restore lost volume. They only conserve fluid.



HOMEOSTATIC COMPENSATION FOR SEVERE DEHYDRATION



Vitamins

- all organic compounds of diet, necessary for life, health and growth;
- NO source of energy;
- soluble in:
- in water
- in lipids

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Vitamin	Deficiency disease(s)	Overdose syndrome/symptoms	Food sources
Vitamin K	Bleeding diathesis	Decreased anticoagulation effect of warfarin	Leafy green vegetables such as spinach; egg yolks; liver
Vitamin E	Deficiency is very rare; mild hemolytic anemia in newborn infants	Possible increased incidence of congestive heart failure	Many fruits and vegetables, nuts and seeds, and seed oils
Vitamin D	Rickets and osteomalacia	Hypervitaminosis D	Eggs, liver, certain fish species such as sardines, certain mushroom species such as shiitake
Vitamin A	Night blindness, hyperkeratosis, and keratomalacia	Hypervitaminosis A	from animal origin: fish in general, liver and dairy products; from plant origin: orange, ripe yellow fruits, leafy vegetables, carrots, pumpkin, squash, spinach

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Vitamin	Deficiency disease(s)	Overdose syndrome/symptoms	Food sources
Vitamin C	Scurvy	Stomach Pain, Diarrhoea and Flatulence	Many fruits and vegetables, liver
Vitamin B_{12}	Vitamin B_{12} deficiency anemia	None proven	Meat, poultry, fish, eggs, milk
Vitamin B_9	Megaloblastic anemia and deficiency during pregnancy is associated with birth defects, such as neural tube defects	May mask symptoms of vitamin B_{12} deficiency; other effects.	Leafy vegetables, pasta, bread, cereal, liver
Vitamin B_7	Dermatitis, enteritis		Raw egg yolk, liver, peanuts, leafy green vegetables
Vitamin B_6	Anemia, Peripheral neuropathy	Impairment of proprioception, nerve damage (doses > 100 mg/day)	Meat, vegetables, tree nuts, bananas
Vitamin B_5	Paresthesia	Diarrhea; possibly nausea and heartburn	Meat, broccoli, avocados
Vitamin B_3	Pellagra	Liver damage (doses > 2g/day) and other problems	Meat, fish, eggs, many vegetables, mushrooms, tree nuts
Vitamin B_2	Ariboflavinosis, glossitis, angular stomatitis		Dairy products, bananas, green beans, asparagus
Vitamin B_1	Beriberi, Wernicke-Korsakoff syndrome	Drowsiness and muscle relaxation	Pork, whole meal grains, brown rice, vegetables, potatoes, liver, eggs

Thank you for your attention

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