

M U N I
M E D

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

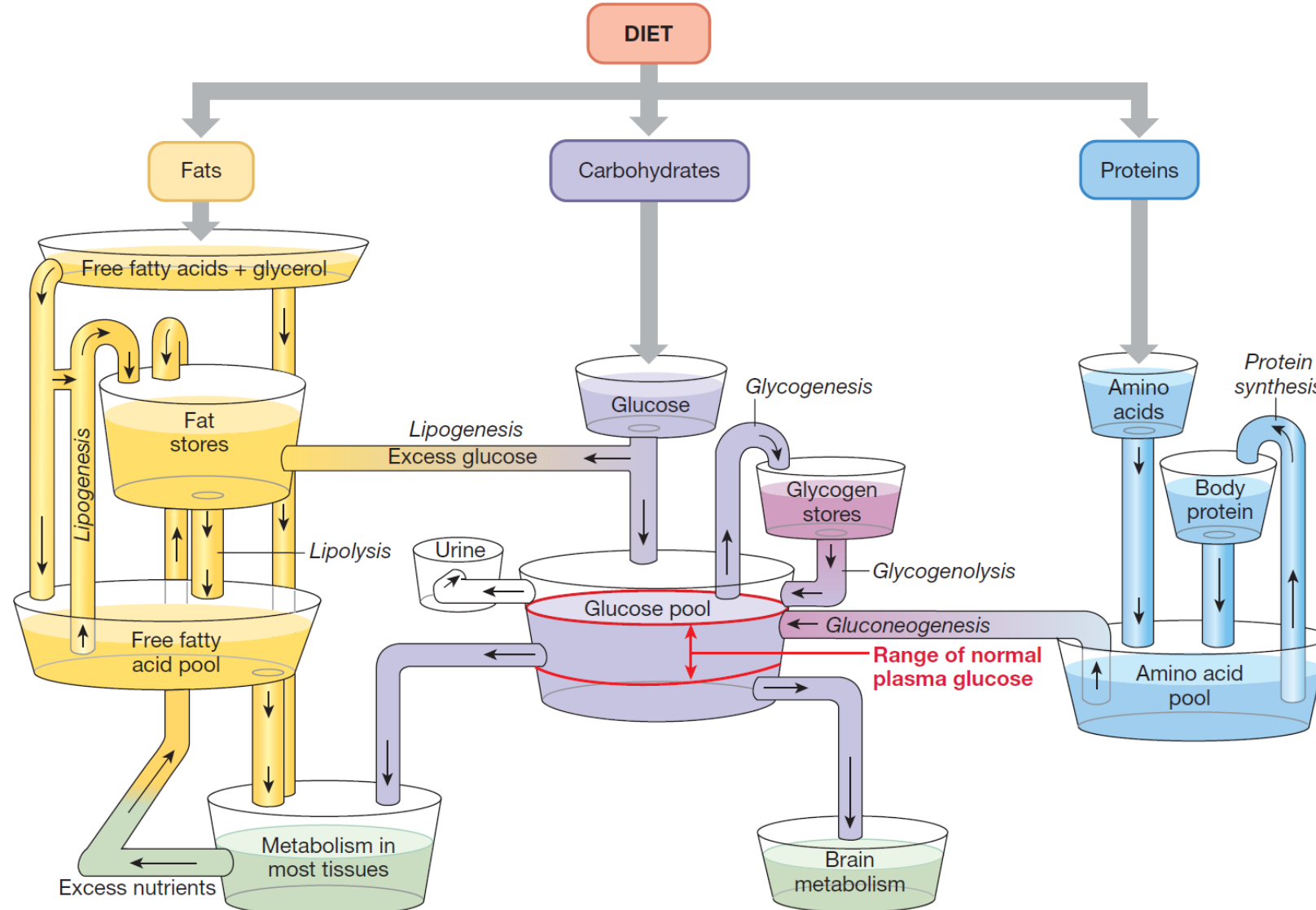
□ Saccharides, lipids, proteins

□ 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

Nutrient pools and metabolism



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

Metabolism of saccharides

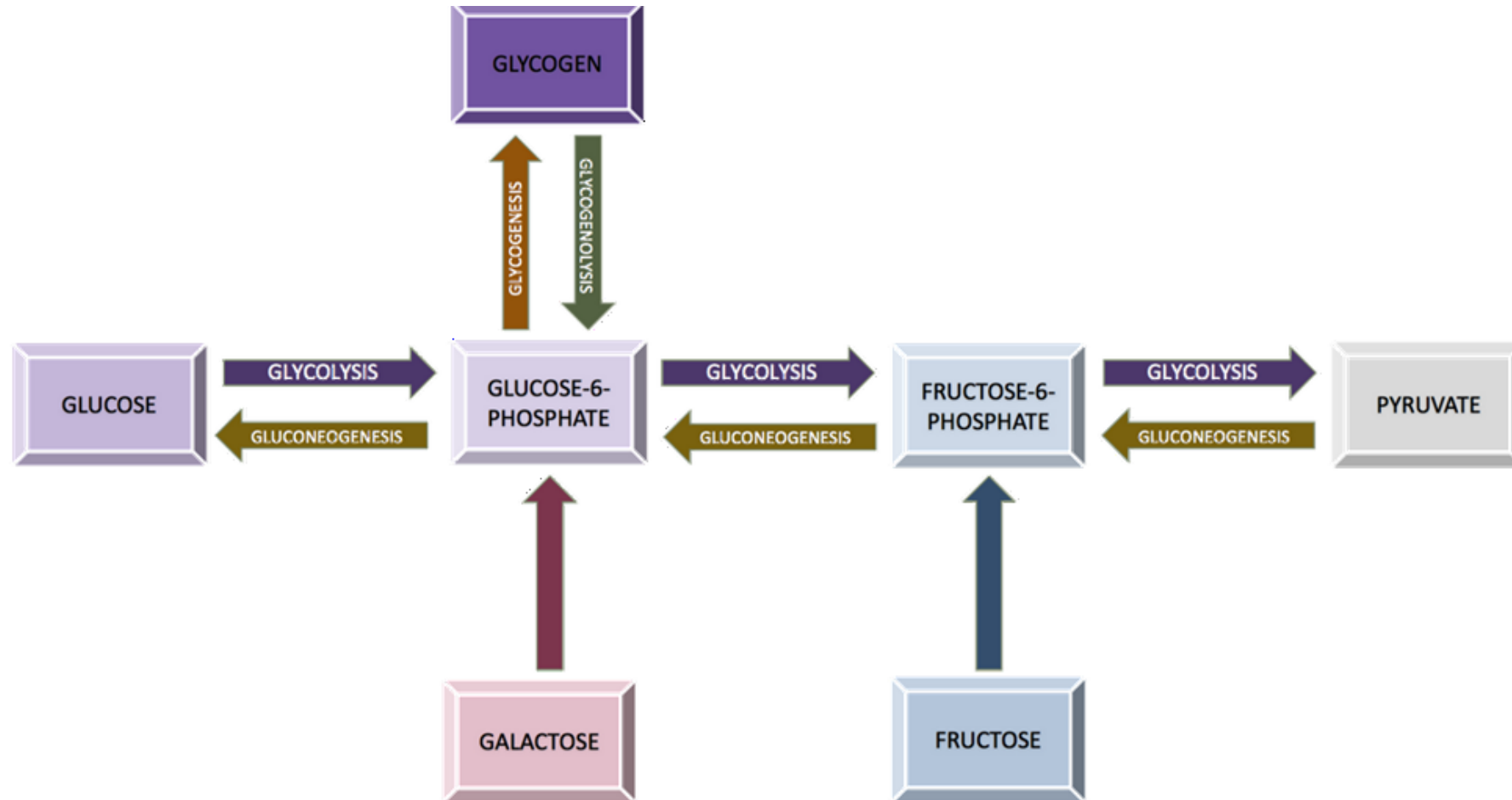
- Energy source
- Functions of saccharides:
 - Part of glycoproteins and glycolipids
 - Inevitable for nucleic acids and coenzyme synthesis
 - Part of extracellular matter
- Saccharides:
 - Monosaccharides
 - Oligosaccharides
 - Polysaccharides
- Digestion and absorption
 - Saliva (salivary amylase)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

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

Metabolism of saccharides

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



Metabolic disorders - saccharides

□ **Diabetes mellitus**

□ **McArdle syndrom** (glycogenesis from deficiency of myophosphorylase

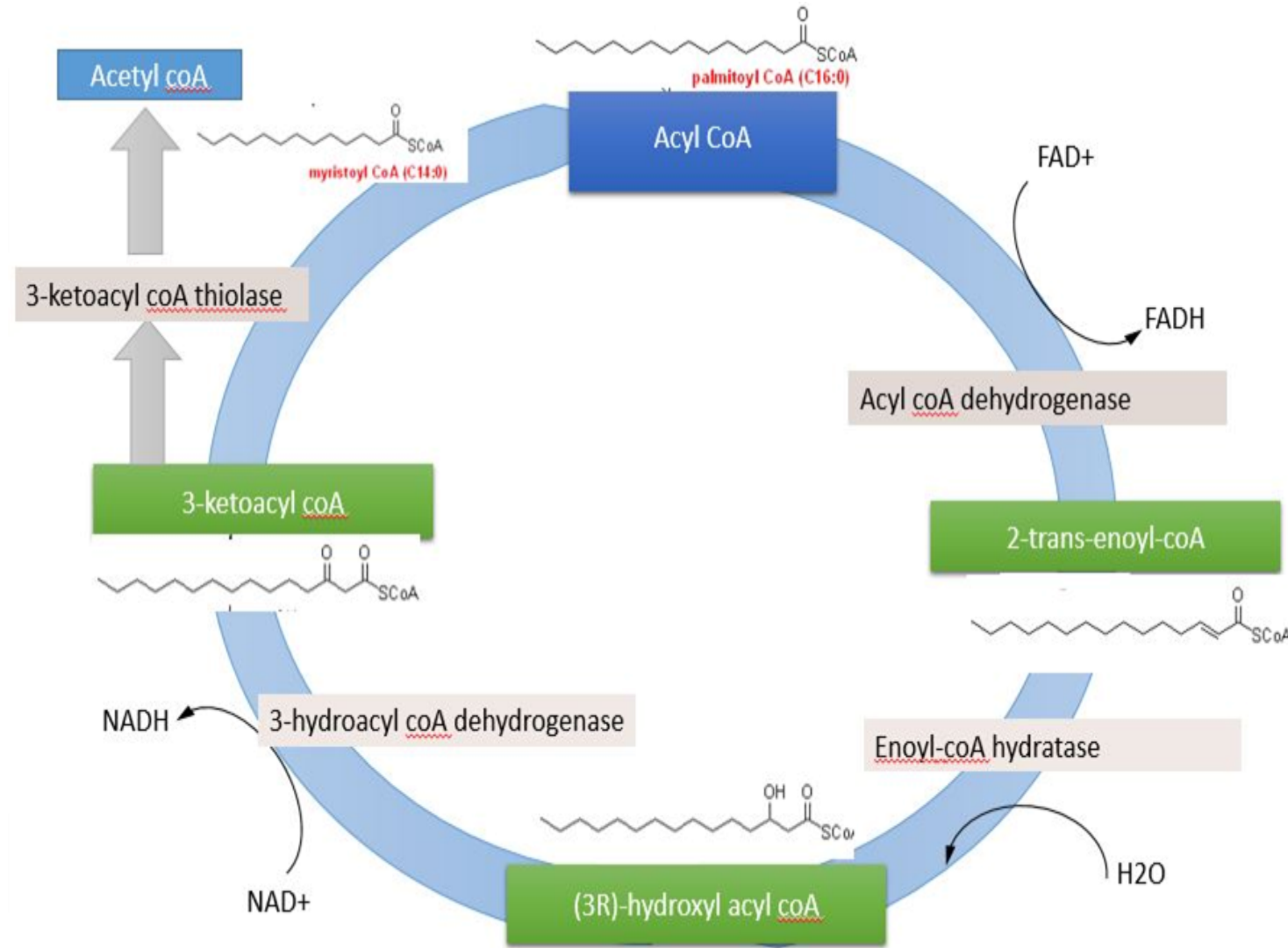
→ accumulation of glycogen in muscles: muscle stiffness, rigor during exercise, lower tolerance of load)

□ **Galactosemia**(inherited deficiency of phosphogalactosauridyltransferase; disorders of growths and development)

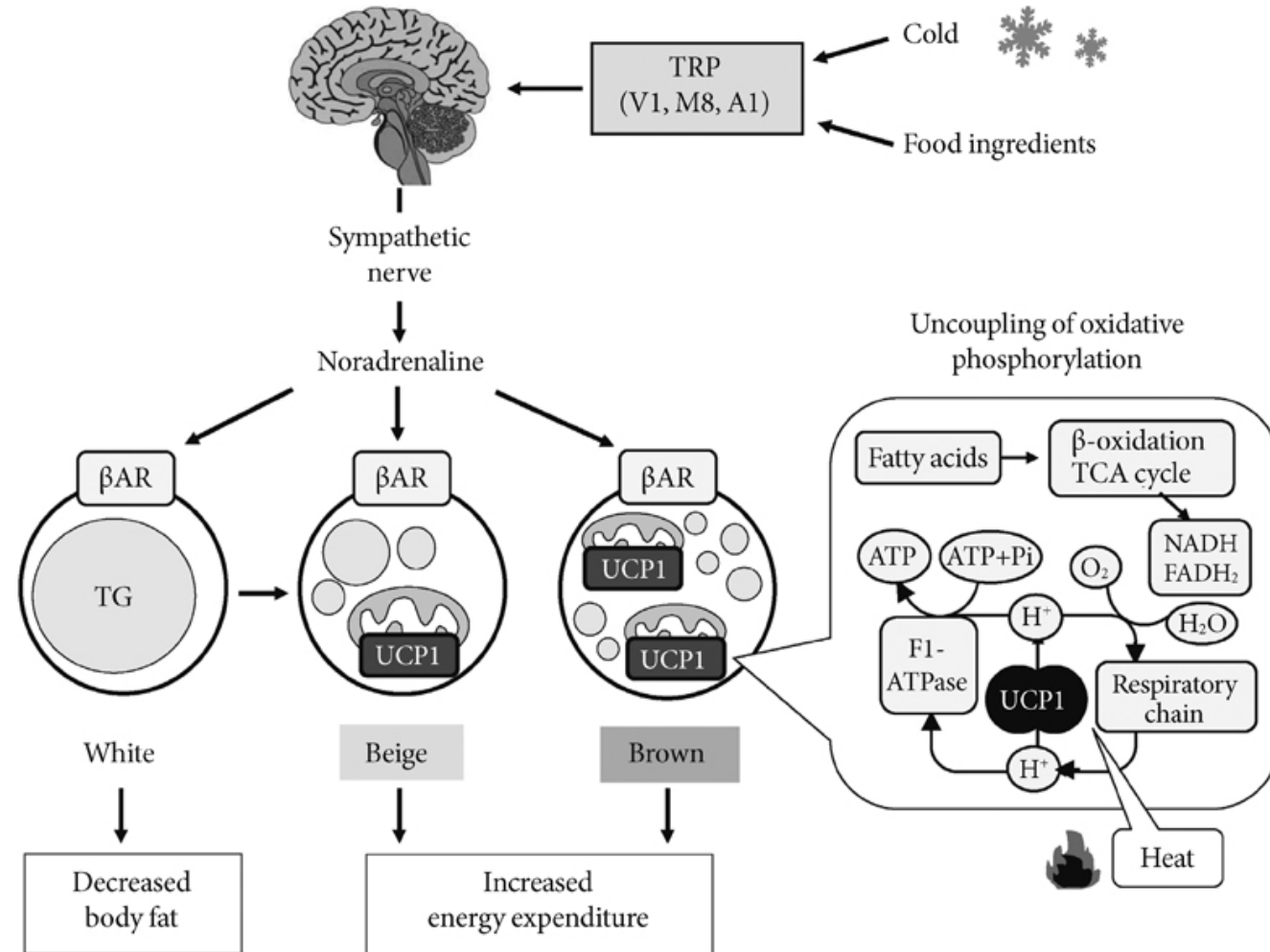
Metabolism of lipids

- 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-esterase, phospholipase a₂, enteric lipase(deesterification)

Metabolism of lipids



Fat tissue

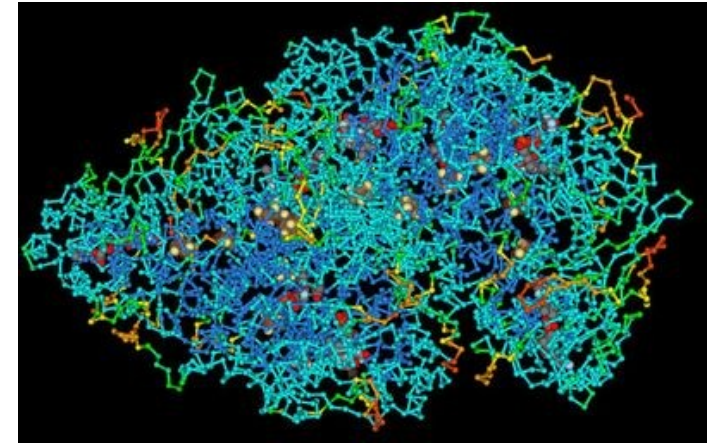


Metabolic disorders - lipids

- Hyperlipidemia
- Hyperlipoproteinemia
- Infrequent disorders of lipid metabolism

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



Metabolism of proteins

Digestion and absorption

- Stomach (pepsin)
- Duodenum (trypsin, chymotrypsin, carboxypeptidase)
- Jejunum (membrane peptidases)

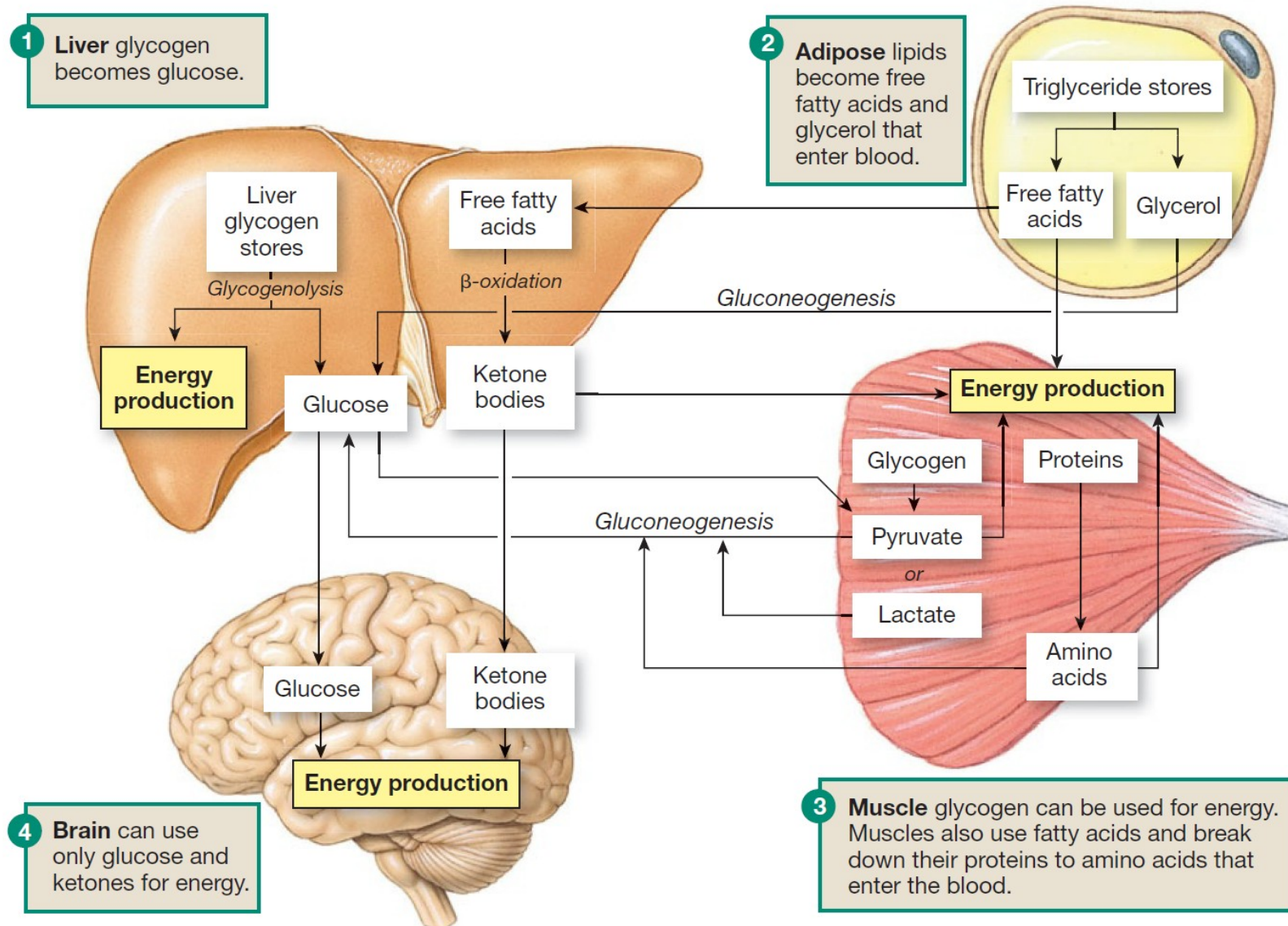
Functions of proteins:

- Structural (collagen, elastin, ...)
- Motoric (actin, myosin, ...)
- Informational (protein hormones)
- Protective (immunoglobulins, complement, antigens, ...)
- Transport (albumin)

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 immunoglobulines (with no antibodies specificity) – monoclonal immunopathy
- Defect proteinemia = some components of plasma proteins are missing or lowered – syndromes of immunodeficiency, polyclonal hypergamaglobulinemia

Energy storage



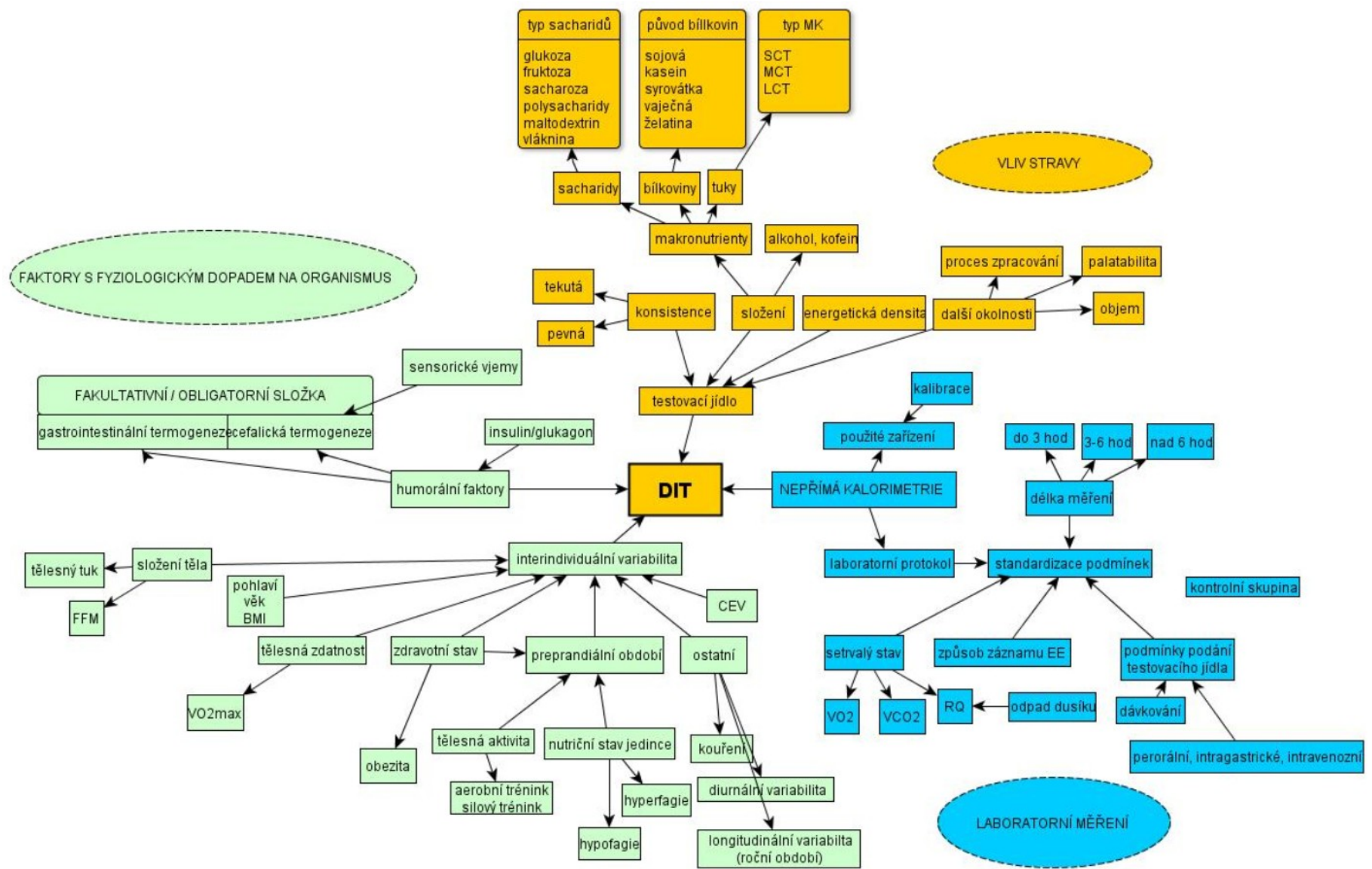
Metabolism

= 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

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



Bazal metabolic rate (BMR)

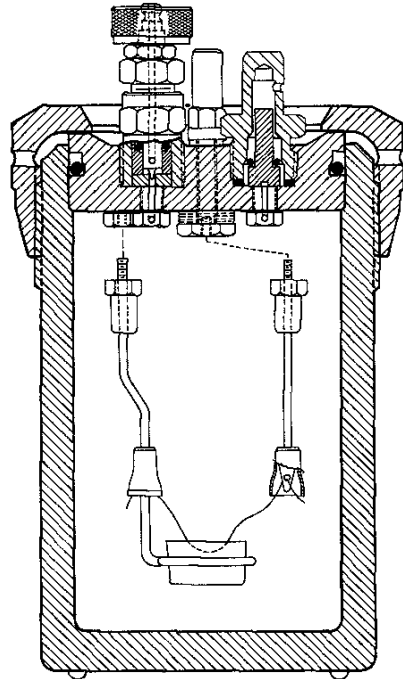
- Energy for maintaining all vital functions
- Thermoneutral environment
- 12 - 14 hours after a meal
- 24 hours without exhausting physical work
- Elimination of all negative physical and mental factors

Direct calorimetry

= measuring the energy released by burning food outside the body
(oxidation of compounds in a calorimeter)

□ Calorimetry:

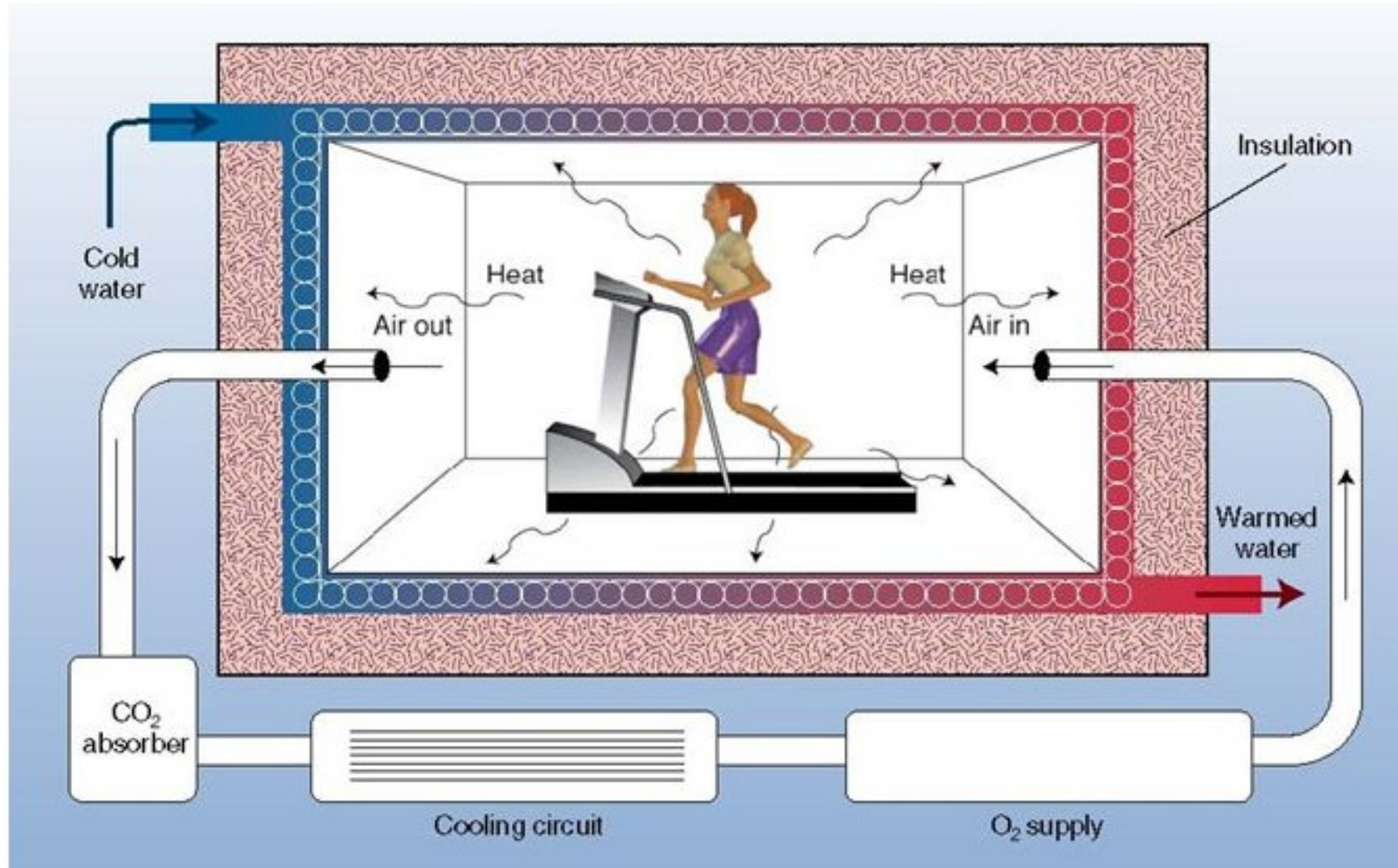
- adiabatic = heating of the calorimeter content
- isothermal = generated heat is dissipated



Direct calorimetry



Direct calorimetry



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

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 \longrightarrow 21.1 kJ = 5.05 kcal
- EE proteines \longrightarrow 18.0 kJ = 4.31 kcal
- EE lipides \longrightarrow 19.0 kJ = 4.55 kcal
- In a mixed diet (60% carbohydrates, 30% fat, 10% protein):
- EE = 20.1 kJ = 4.81 kcal

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

Indirect calorimetry

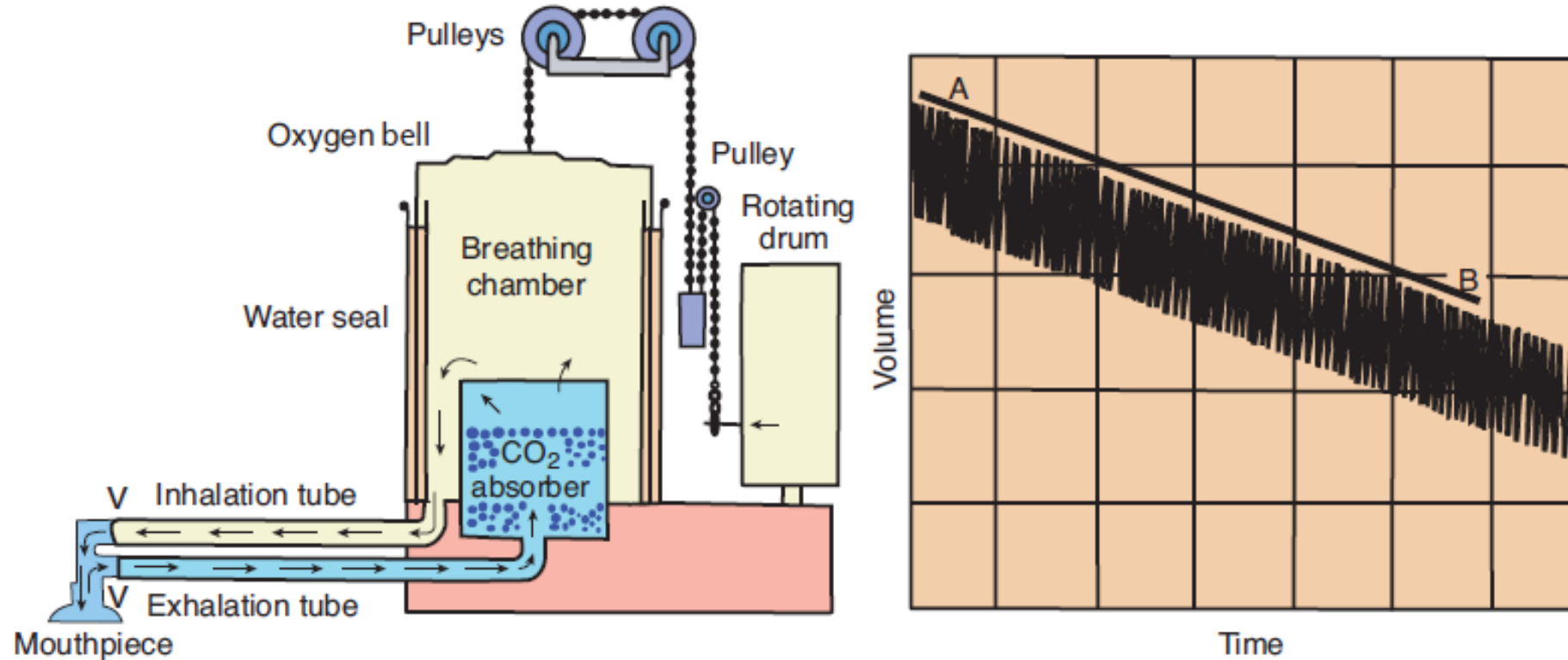


FIGURE 27–8 Diagram of a modified Benedict apparatus, a recording spirometer used for measuring human O_2 consumption, and the record obtained with it. The slope of the line AB is proportionate to the O_2 consumption. V: one-way check valve.

Respiratory quotient

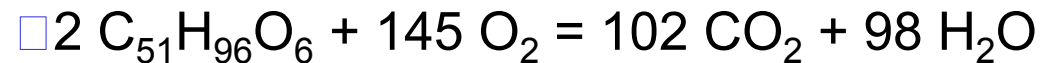
$$\text{RQ} = \text{VCO}_2 : \text{VO}_2$$

□ Saccharides (glu)



$$\square \text{RQ} = 6/6 = 1.00$$

□ Lipides



$$\square \text{RQ} = 102/145 = 0.703 (0.70)$$

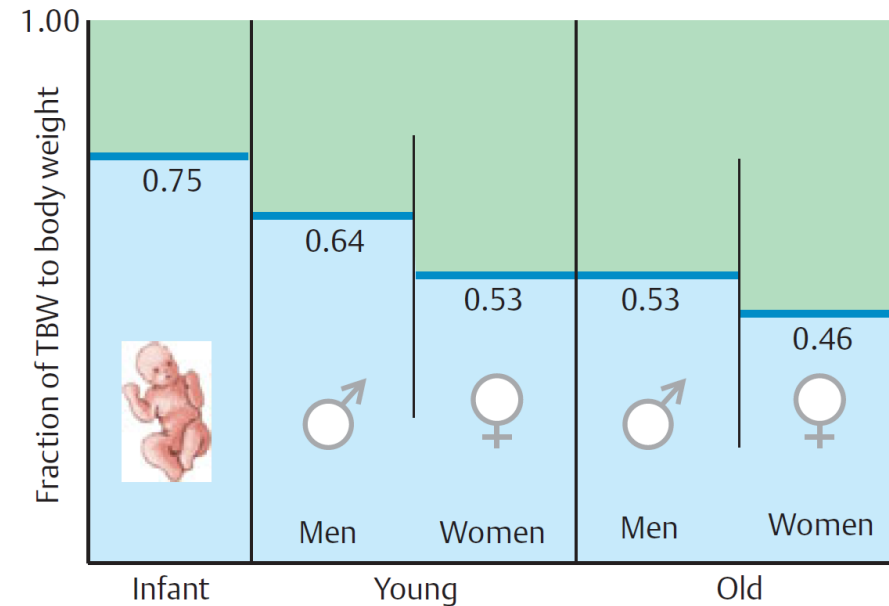
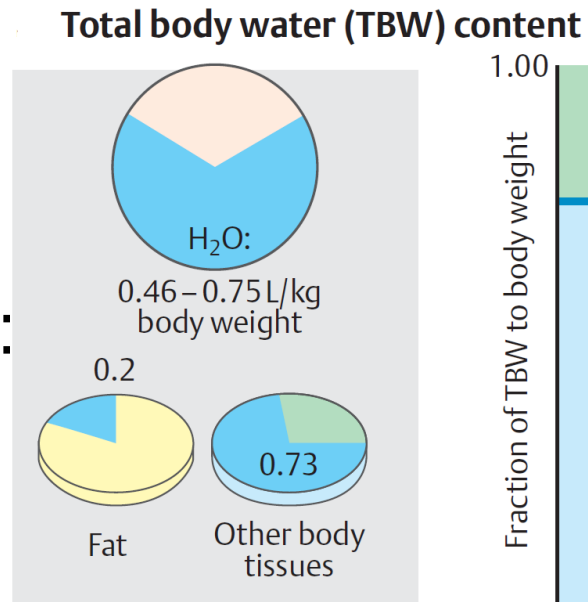
Respiratory quotient

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

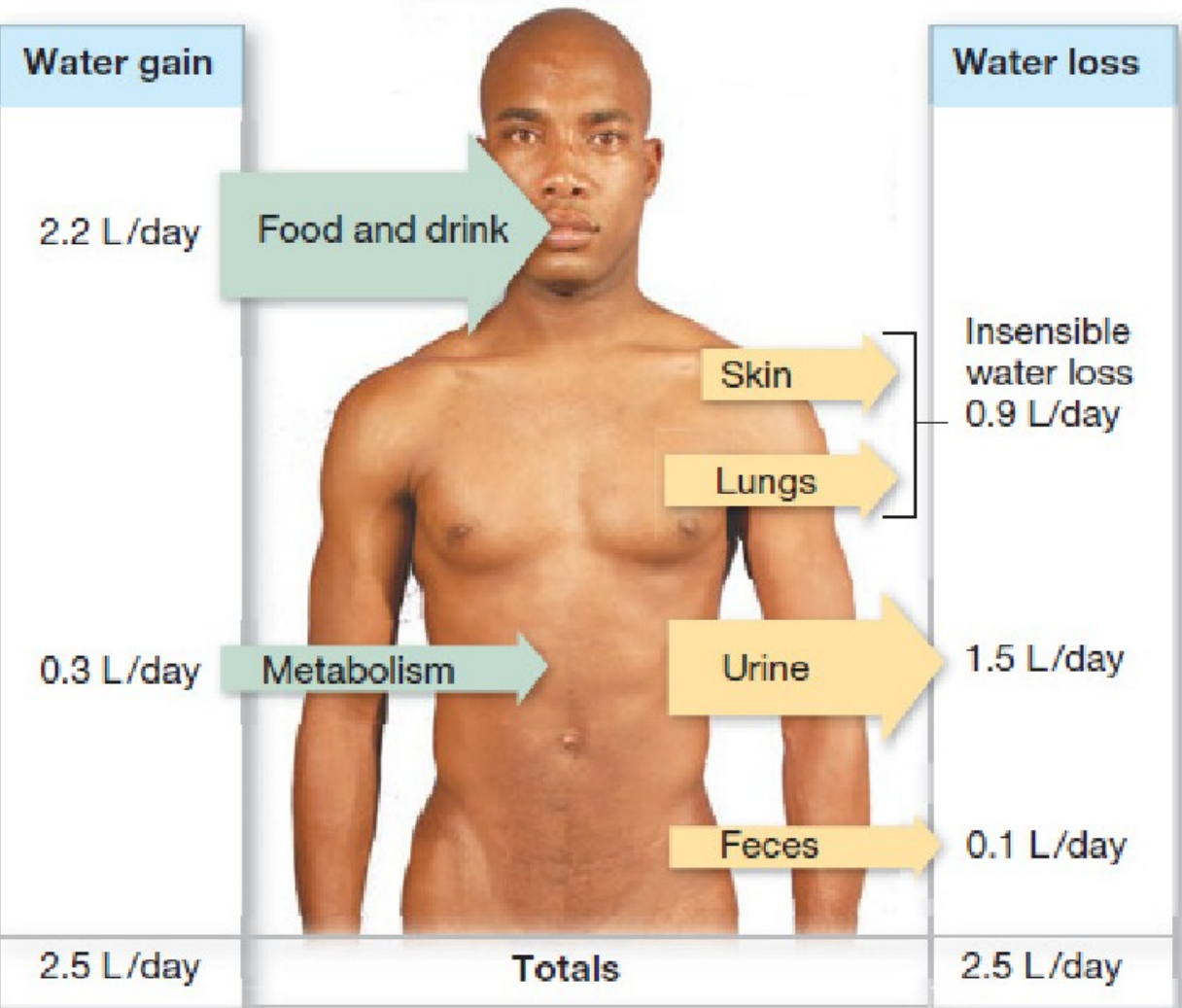
- Hyperventilation RQ decreases
- Workload RQ increases
- Acidosis RQ increases
- Alkalosis RQ decreases

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



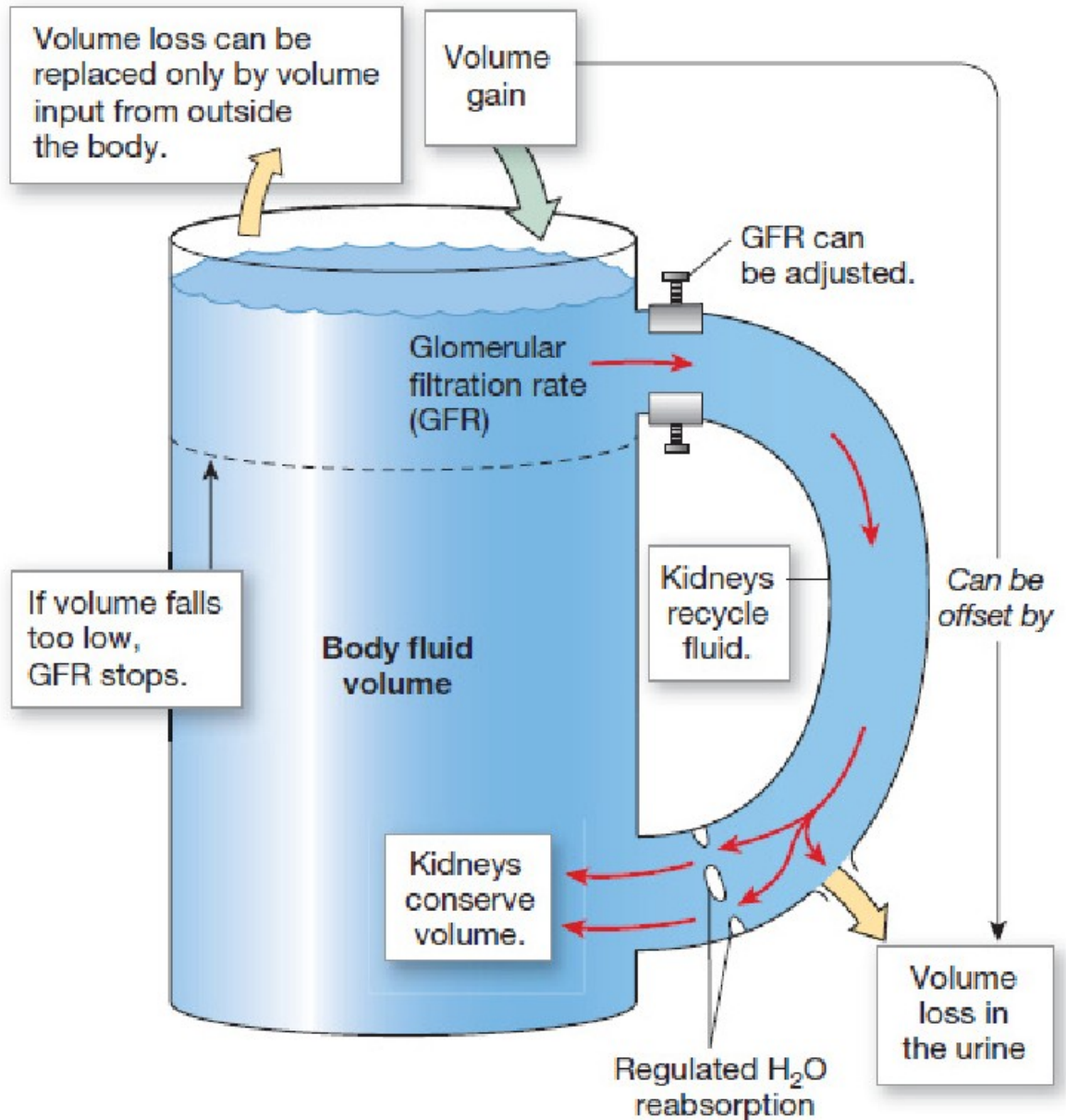
WATER BALANCE IN THE BODY



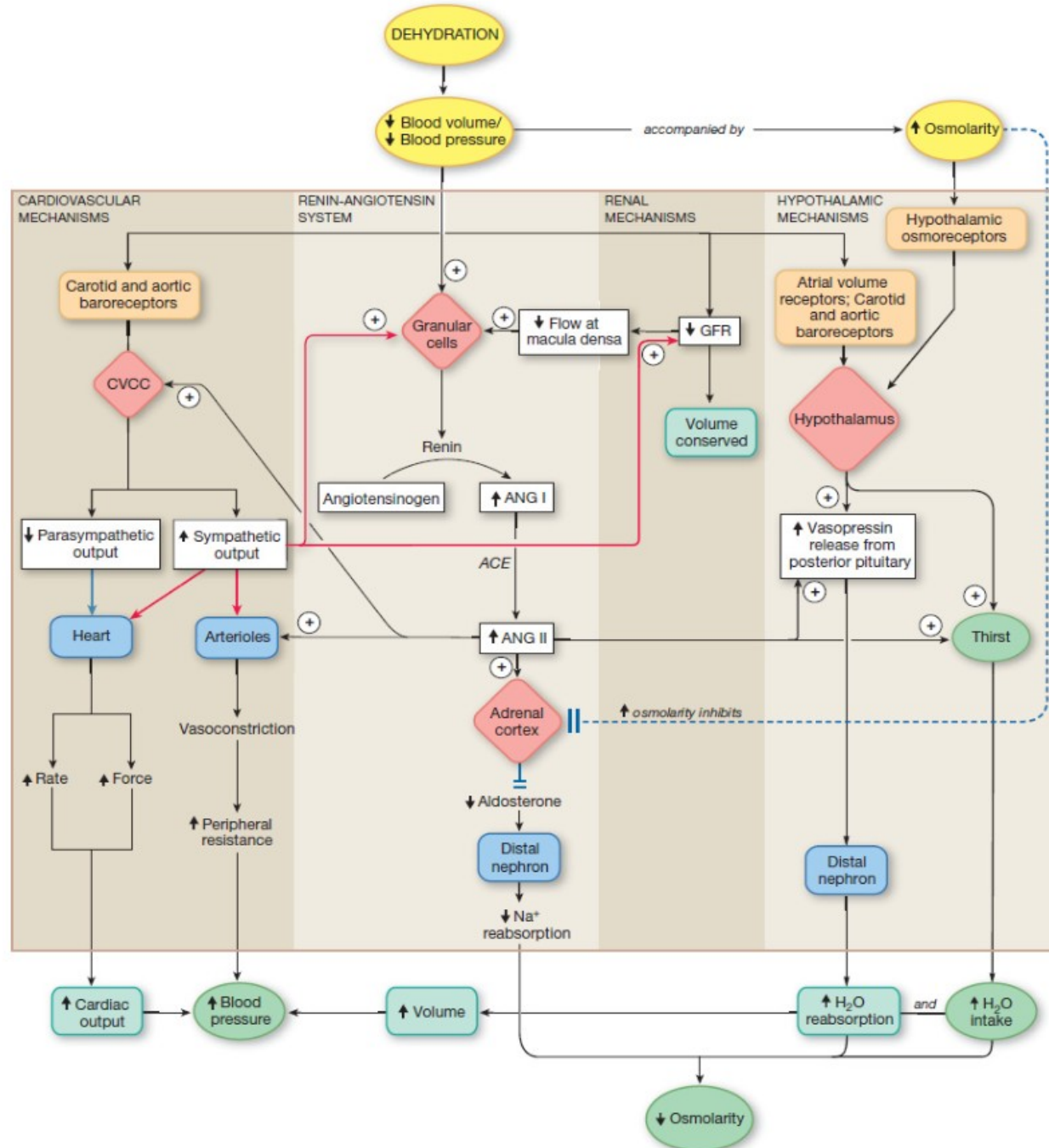
$$\text{Intake } 2.2 \text{ L/day} + \text{Metabolic production } 0.3 \text{ L/day} - \text{Output } 2.5 \text{ L/day} = 0$$

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

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

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