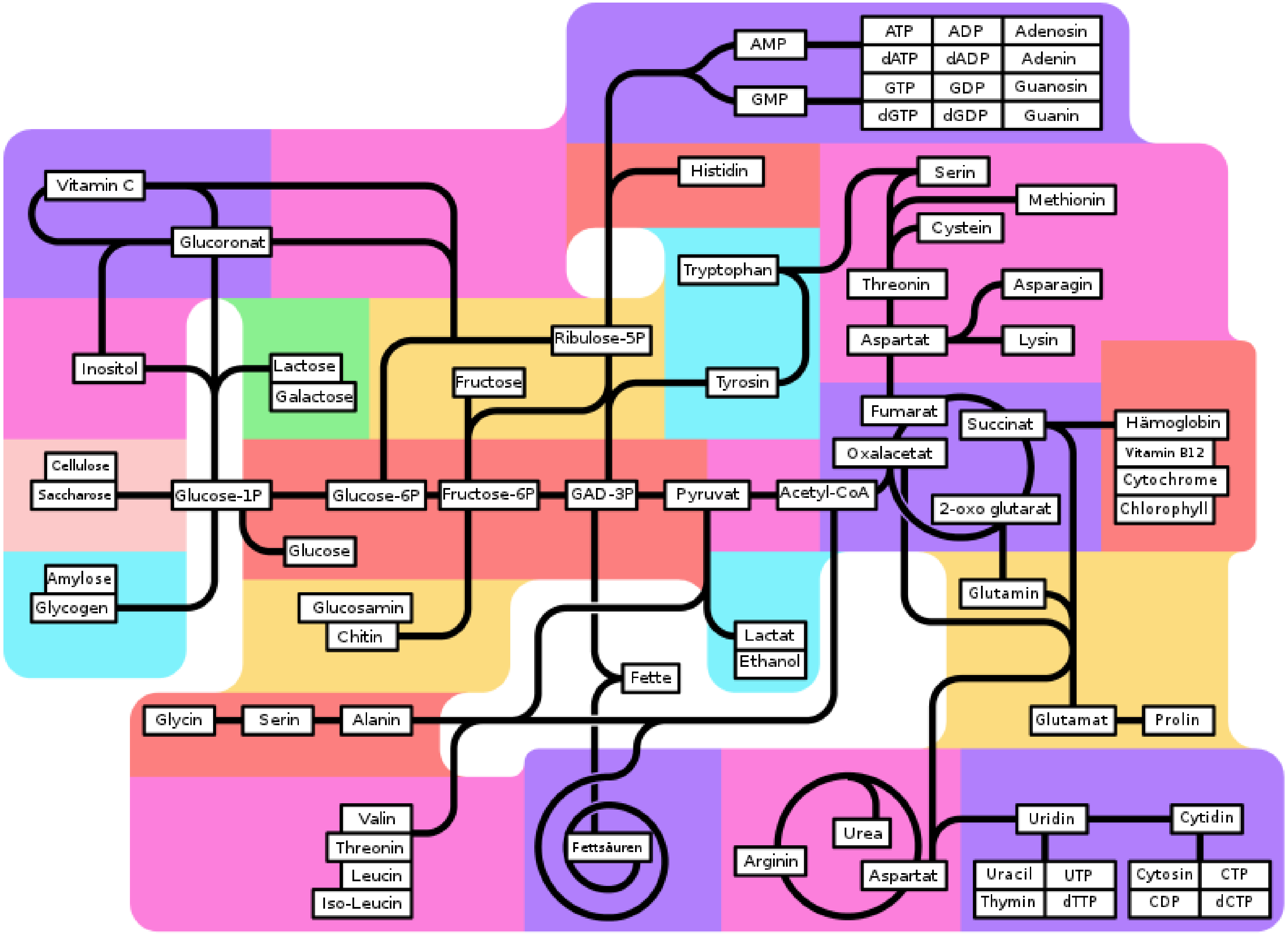
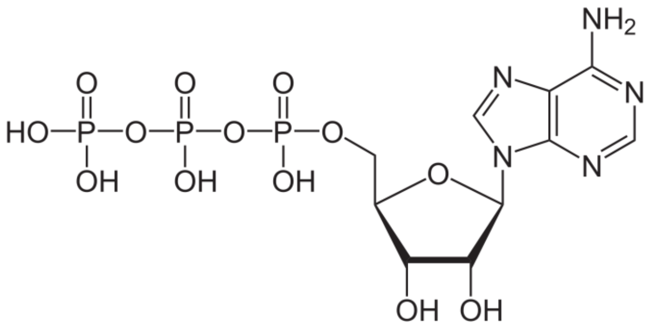
Metabolism



AMP
GMP
ATP
ADP
Adenosin
dATP
dADP
Adenin
GTP
GDP
Guanosin
dGTP
dGDP
Guanin
Vitamin C
Glucoronat
Histidin
Serin
Methionin
Cystein
Tryptophan
Threonin
Asparagin
Aspartat
Lysin
Inositol
Lactose
Galactose
Ribulose-5P
Fructose
Tyrosin
Fumarat
Succinat
Hämoglobin
Vitamin B12
Cytochrome
Chlorophyll
Oxalacetat
Cellulose
Saccharose
Glucose-1P
Glucose-6P
Fructose-6P
GAD-3P
Pyruvat
Acetyl-CoA
2-oxo glutarat
Glucose
Amylose
Glycogen
Glucosamin
Chitin
Glutamin
Lactat
Ethanol
Fette
Glycin
Serin
Alanin
Glutamat
Prolin
Valin
Threonin
Leucin
Iso-Leucin
Fettsäuren
Urea
Arginin
Aspartat
Uridin
Cytidin
Uracil
UTP
Thymin
dTTP
Cytosin
CTP
CDP
dCTP

Metabolism

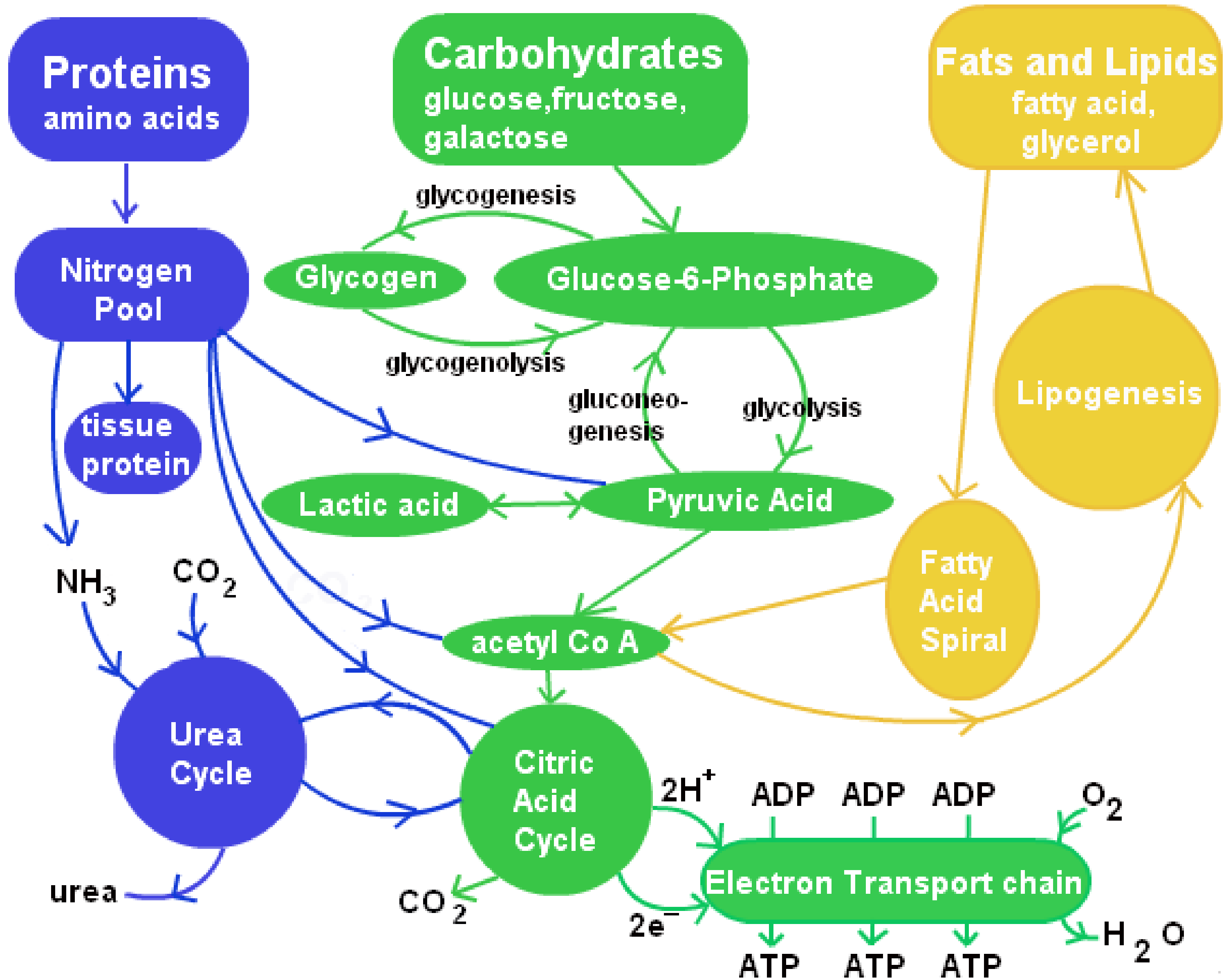
- catabolism + anabolism
- intake and distribution of nutrients, water and oxygen, their biotransformation, removal of waste metabolites from the organism
- gain of energy from chemical bonds in food, its conversion to ATP



- **energy is needed for:** muscle contraction
  Na^+/K^+ transport
  proteosynthesis
  Ca^{2+} export

- **at the organ level:** muscle
  heart
  kidney

Metabolism



Proteins
amino acids
Carbohydrates
glucose,fructose,
galactose
Fats and Lipids
fatty acid,
glycerol
glycogenesis
Nitrogen
Pool
Glycogen
Glucose-6-Phosphate
glycogenolysis
gluconeo-
genesis
glycolysis
Lipogenesis
tissue
protein
Lactic acid
Pyruvic Acid
Fatty
Acid
Spiral
NH_3
CO_2
acetyl Co A
Urea
Cycle
Citric
Acid
Cycle
$2H^+$
ADP
ADP
ADP
O_2
urea
CO_2
Electron Transport chain
$2e^-$
ATP
ATP
ATP
H_2O

Energy store

- **glycogen** (storage saccharide) – approx. 500 g (400 g muscles and 100 g liver); energy for app. 30-90 min of activity
- **glucose** – around 20 g in blood (100 kcal); energy mainly for brain and blood cells
- **fat** – app. 112.000 kcal, it means around 80 % of stores in organism
- **proteins** – app. 25.000 kcal, normally not used to produce energy

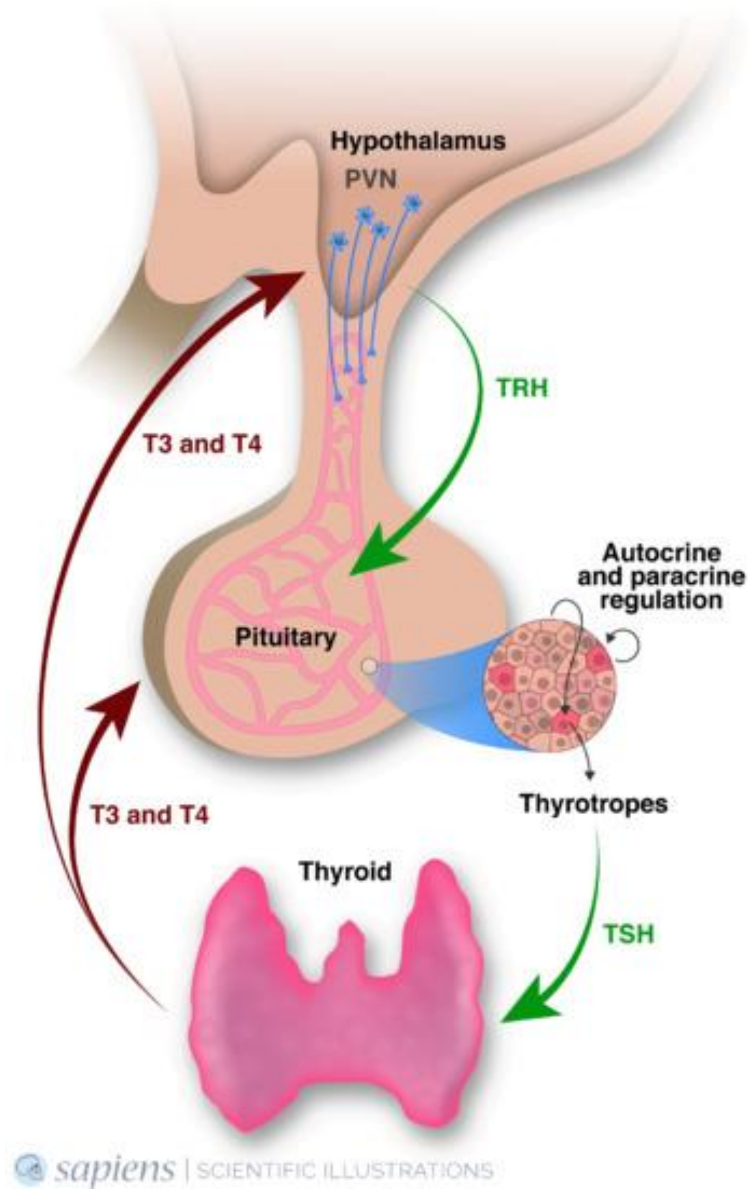
Units: **calorie (cal); joule (J)**

cal = 4,18 J
J = 0,239 cal

kcal = 1000 cal = 4,18 kJ

Control of metabolism

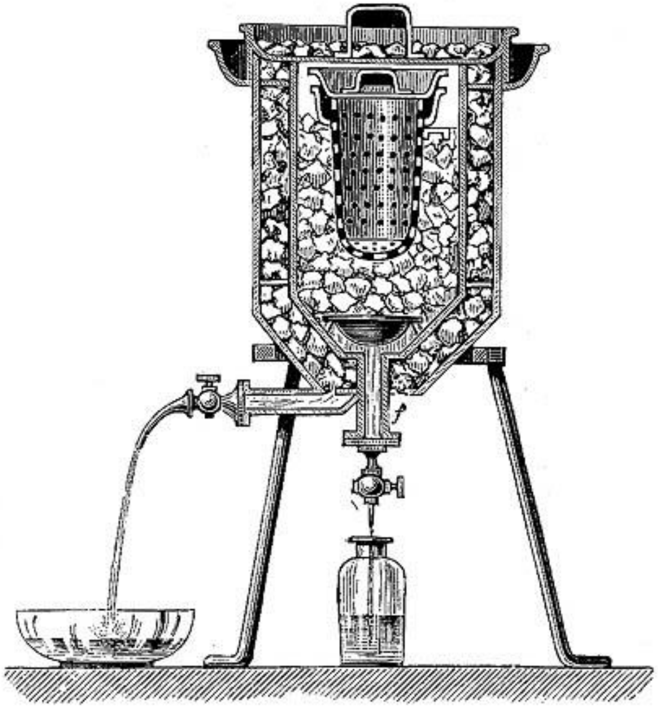
- energy demand and consumption
- endocrine hypothalamic-pituitary-thyroid axis
- thyrotropin-releasing hormone (TRH) from hypothalamus
- stimulation of the anterior pituitary to produce thyroid-stimulating hormone (TSH)
- stimulates the thyroid to produce thyroid hormones triiodothyronine (T3) and thyroxine (T4)
- thyroid hormones increase the basal metabolic rate
- negative feedback loop in the axis



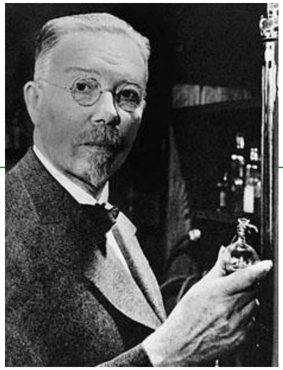
Measurement of metabolism

Direct calorimetry

- **Antoine-Laurent de Lavoisier** (1743-1794)
- relationship between the level of metabolism and the heat production
- respiratory gas exchange is the combustion



Measurement of metabolism



Indirect calorimetry (respirometry)

- **August Krogh** (1874-1949), **Barcroft**
- relationship of O_2 consumption, CO_2 release and level of metabolism

- energy equivalent (EE) = amount of energy released from substrate which is burned using 1 liter of O_2 (on average 20,2 kJ)
- respiratory coefficient (RQ) depends on the specific-dynamic effect of the nutrients; determinates the combusted nutrients

$$RQ = \frac{CO_2}{O_2}$$

- $C_6H_{12}O_6 + \mathbf{6O_2} \rightarrow \mathbf{6CO_2} + 6H_2O$
- pure saccharides (RQ = 1), proteins (RQ = 0,8), lipids (RQ = 0,7)
- on average RQ = 0,85

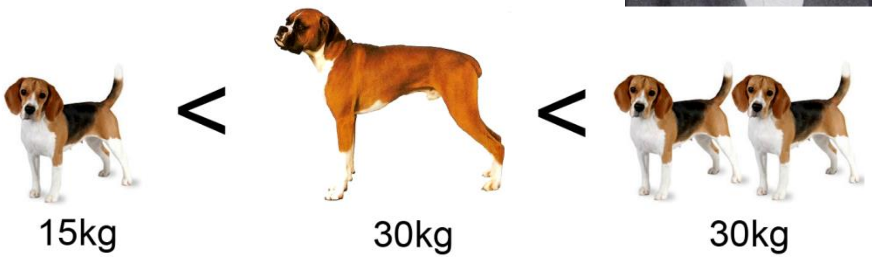
Basal a total metabolism

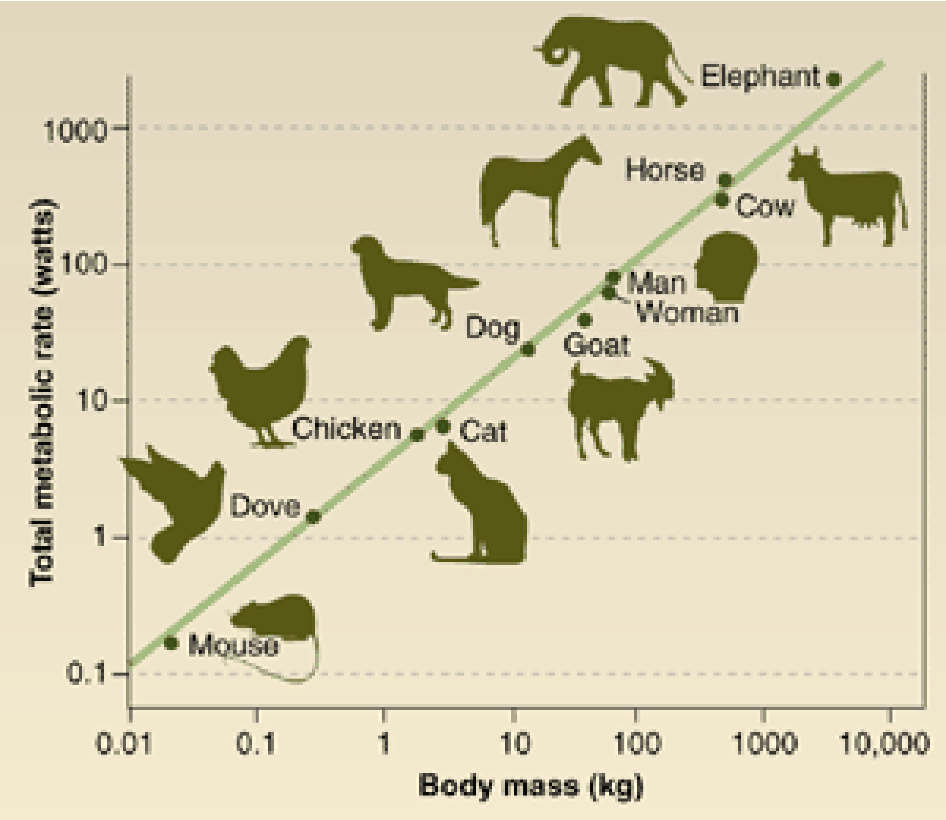
- **basal M** = lowest amount of energy necessary to provide basic functions of the organism
  - absolute mental and physical calm
  - termoneutral zone (naked 27 °C, dressed 20 °C)
  - restricted food income (last meal 12 hours before measurement, proteins restricted 3 days before measurement)
- men 171 kJ/h/m^2, women 151 kJ/h/m^2

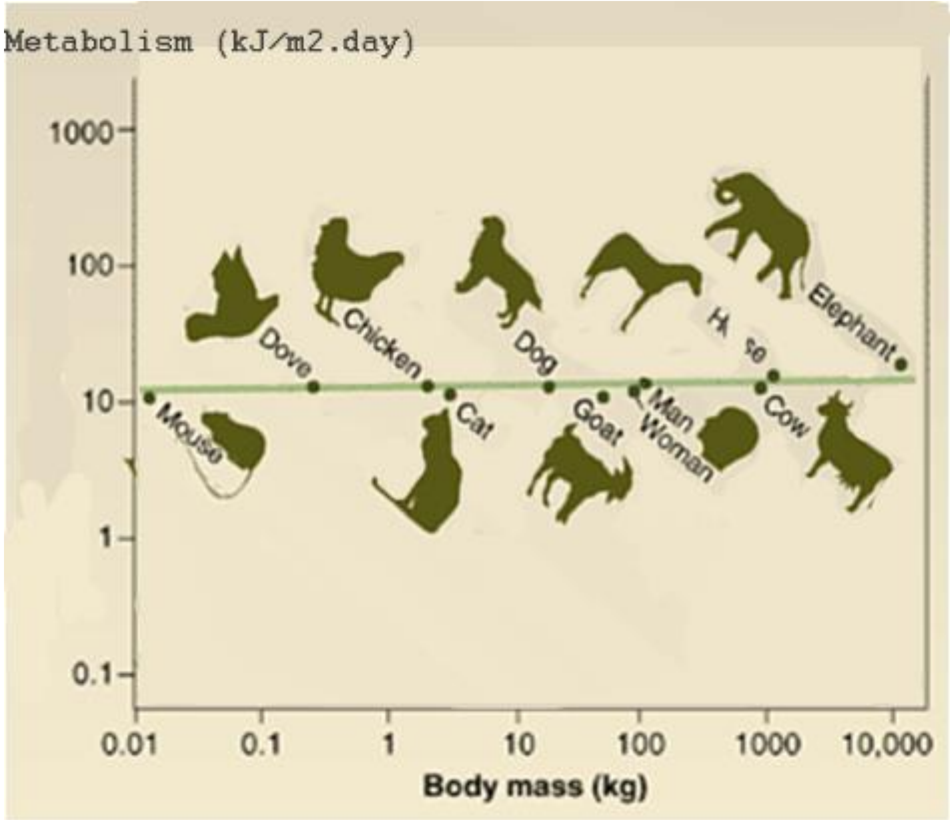
- **total M** = BM + activity + effect of temperature

Surface hypothesis

- Max Rubner (1854 - 1932)
- the metabolic rate of birds and mammals that maintain a steady body temperature is roughly proportional to their body surface area







Calculation of basal metabolism rate (BMR)

- Harris and Benedict, 1918

BMR (women)
= 665,51 + (9,56 × weight in kg) + (1,85 × height in cm) − (4,68 × age in years)
kcal/day (convert to **kJ/day**)

BMR (men)
= 66,47 + (13,75 × weight in kg) + (5,00 × height in cm) − (6,76 × age in years)
kcal/day (convert to **kJ/day**)

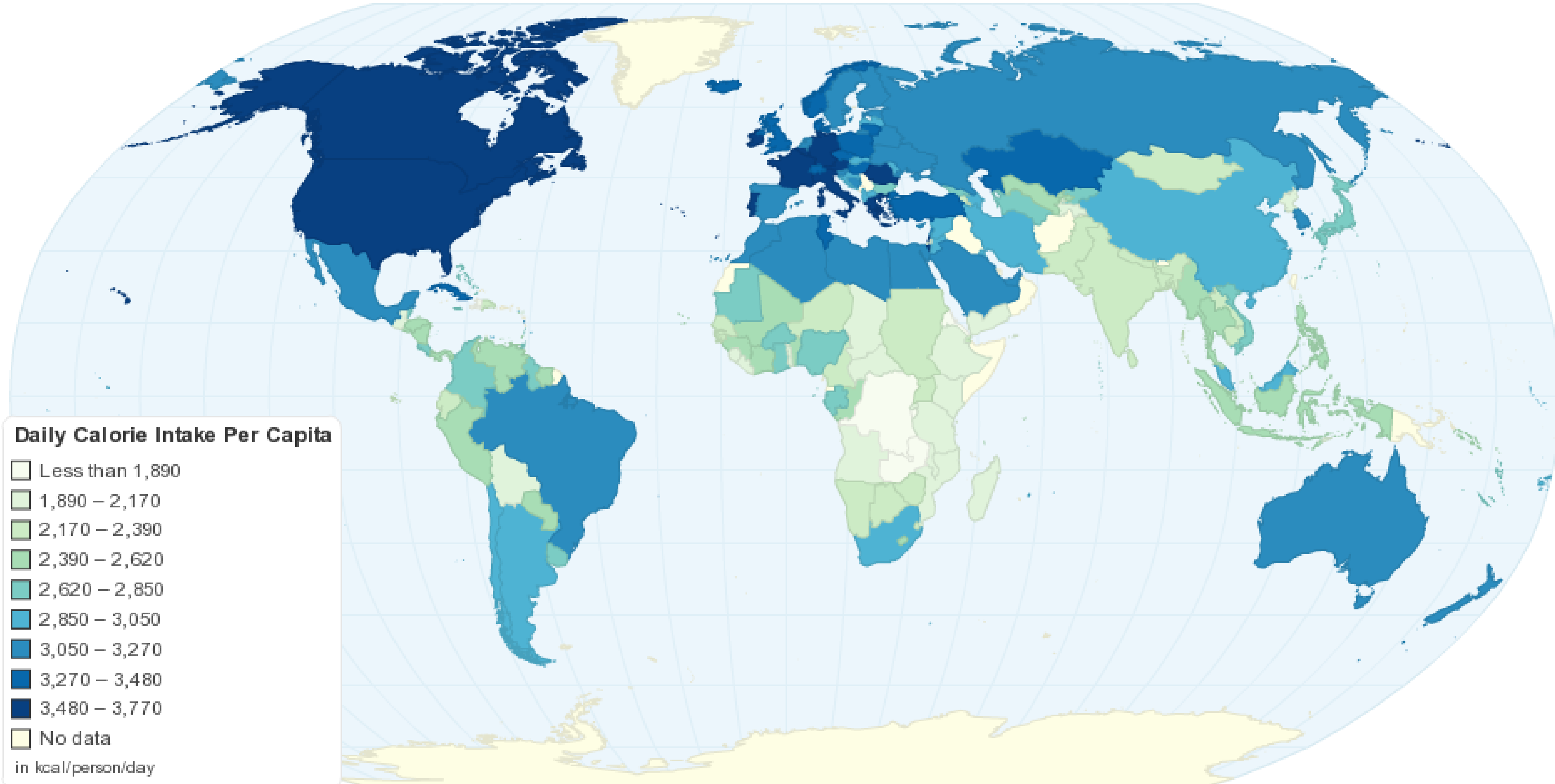
1 kcal = 1000 cal = 4,18 kJ

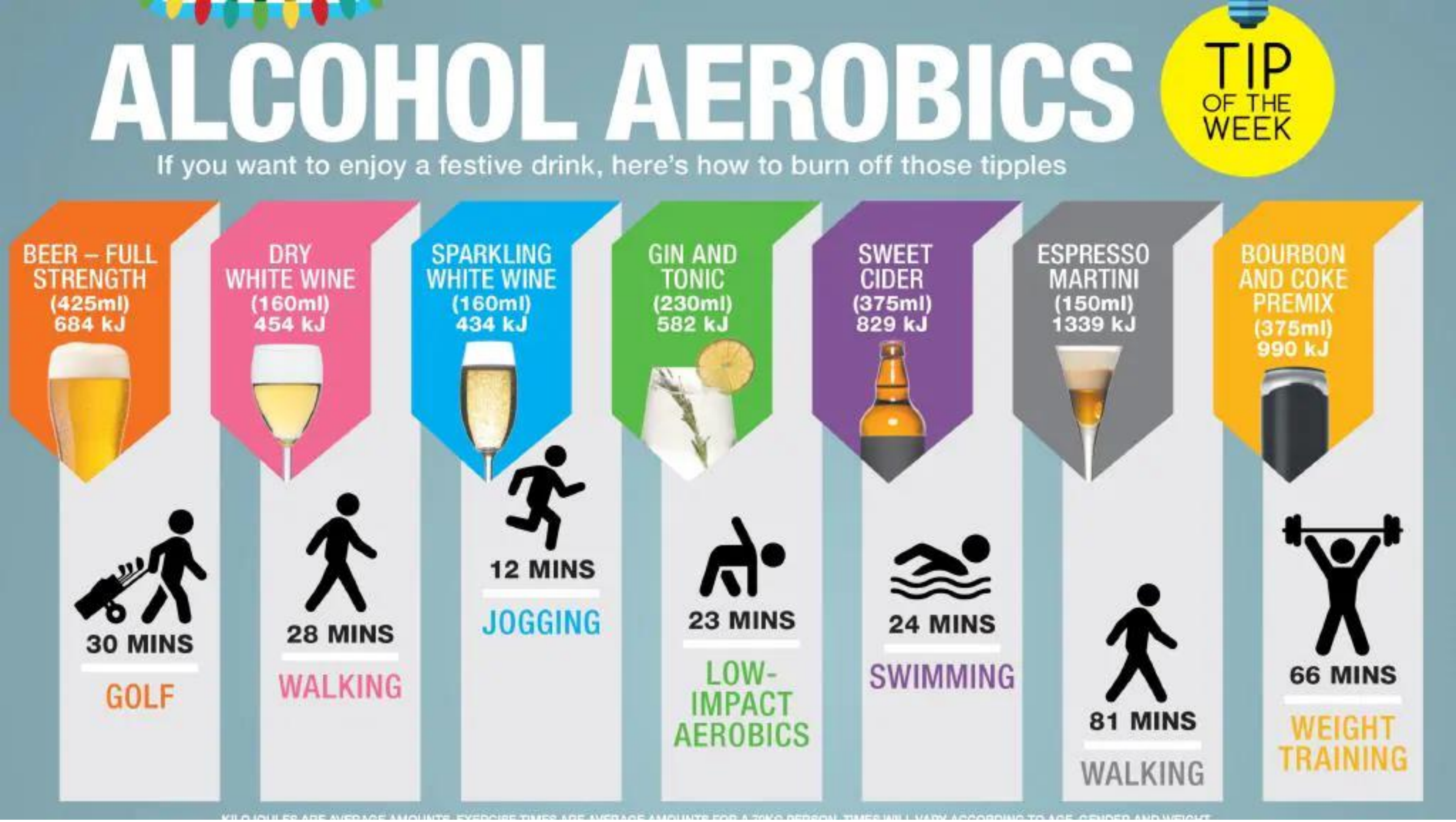
Example:
man (age 29; weight 66 kg; height 171 cm): 1633 kcal/day = 6826 kJ/day

Estimated Calorie Requirements (in Kilocalories) for Each Gender and Age Group at Three Levels of Physical Activity[a]

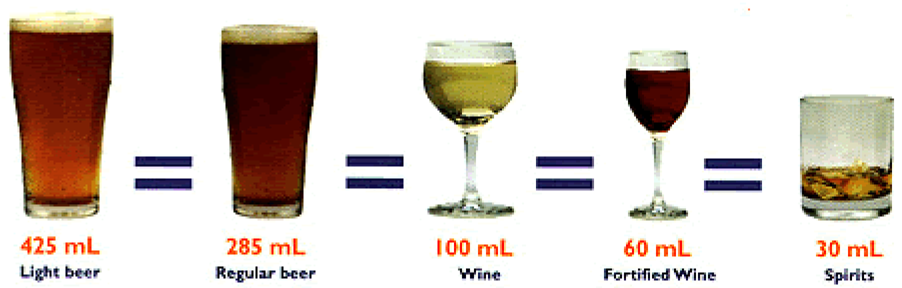
	Activity Level[b,c,d]			
Gender	Age (years)	Sedentary[b]	Moderately Active[c]	Active[d]
Child	2–3	1,000	1,000–1,400[e]	1,000–1,400[e]
Female	4–8	1,200	1,400–1,600	1,400–1,800
	9–13	1,600	1,600–2,000	1,800–2,200
	14–18	1,800	2,000	2,400
	19–30	2,000	2,000–2,200	2,400
	31–50	1,800	2,000	2,200
	51+	1,600	1,800	2,000–2,200
Male	4–8	1,400	1,400–1,600	1,600–2,000
	9–13	1,800	1,800–2,200	2,000–2,600
	14–18	2,200	2,400–2,800	2,800–3,200
	19–30	2,400	2,600–2,800	3,000
	31–50	2,200	2,400–2,600	2,800–3,000
	51+	2,000	2,200–2,400	2,400–2,800

Source: HHS/USDA Dietary Guidelines for Americans, 2005


Daily Calorie Intake Per Capita
Less than 1,890
1,890 – 2,170
2,170 – 2,390
2,390 – 2,620
2,620 – 2,850
2,850 – 3,050
3,050 – 3,270
3,270 – 3,480
3,480 – 3,770
No data
in kcal/person/day



ALCOHOL AEROBICS
TIP OF THE WEEK
If you want to enjoy a festive drink, here's how to burn off those tipples
BEER – FULL STRENGTH (425ml) 684 kJ
30 MINS
GOLF
DRY WHITE WINE (160ml) 454 kJ
28 MINS
WALKING
SPARKLING WHITE WINE (160ml) 434 kJ
12 MINS
JOGGING
GIN AND TONIC (230ml) 582 kJ
23 MINS
LOW-IMPACT AEROBICS
SWEET CIDER (375ml) 829 kJ
24 MINS
SWIMMING
ESPRESSO MARTINI (150ml) 1339 kJ
81 MINS
WALKING
BOURBON AND COKE PREMIX (375ml) 990 kJ
66 MINS
WEIGHT TRAINING

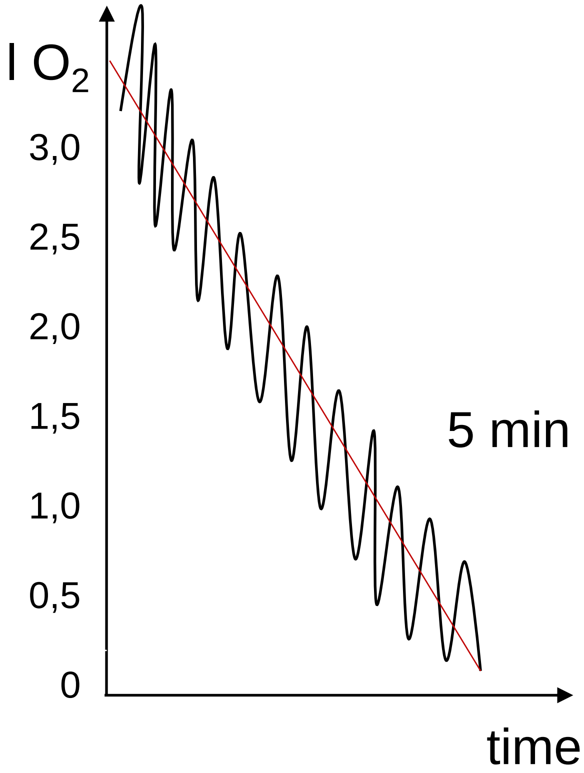


425 mL
Light beer
285 mL
Regular beer
100 mL
Wine
60 mL
Fortified Wine
30 mL
Spirits

Practice: Human metabolism

- spirometry according to Krogh
- natrokalcid: NaOH (absorbs CO_2) + $CaCl_2$ (absorbs H_2O)
- BMR: men 171 kJ/hr/m^2, women 151 kJ/hr/m^2

V_5 = x (l O_2 per 5 min)
V_1 = x / 5 (l O_2/min)
$BM_1 = V_1$ x EE (kJ/min)
BM = … (**kJ/day, kcal/day**)
BM = BM_1 x 60 / S (**kJ/h/m^2**)
BM = BM_1 x 60 / m (**kJ/h/kg**)



Practice: Measurement of insect metabolism

- larvae of *Galleria mellonella*, *Bombyx mori*, *Tenebrio molitor* or *Zophobas morio*

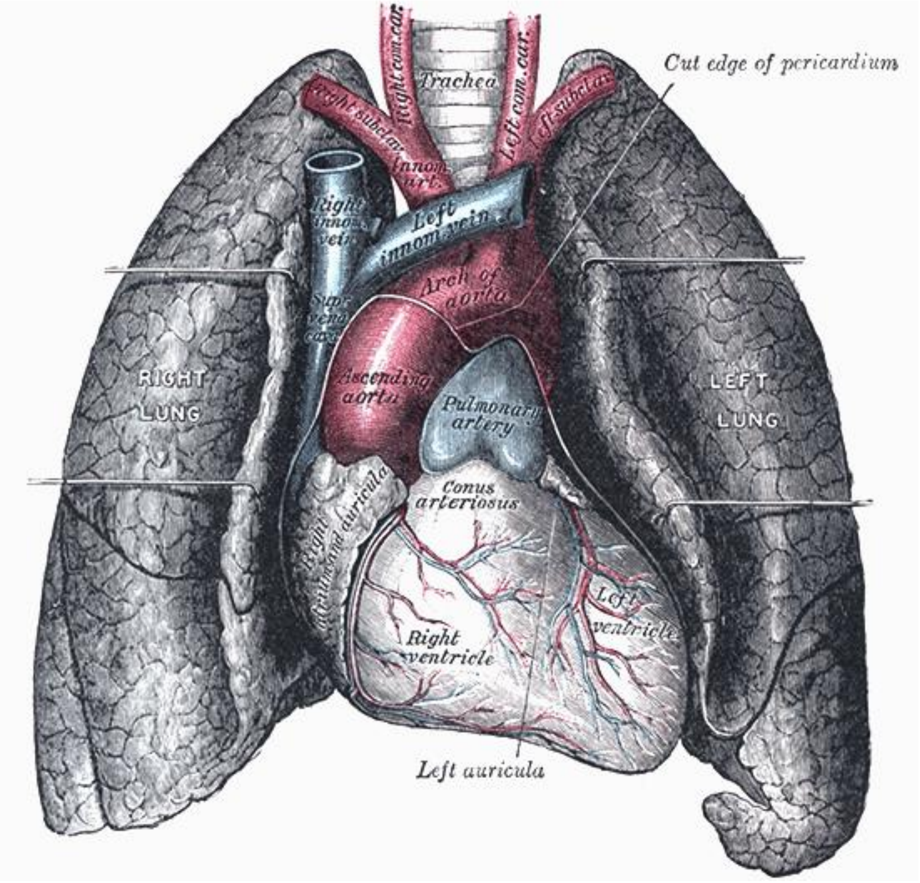


1. Weight the model organisms … ***m*** (g)
2. Prepare chambre for measurement
3. Measure 4 x 3 min oxygen consumption (ΔO_2)
4. Calculate mean of oxygen cons. ΔO_2 (ml / 3 min / *m* g)
5. Convert to **liter** and use **EE** to multiply (kJ / 3 min / *m* g)
6. Convert per hour and gram of weight (**kJ/hod/g**)
7. Compare to human (kg vs. g!)

Time (min)	ΔO_2 (ml)
3	
6	
9	
12	
Mean	

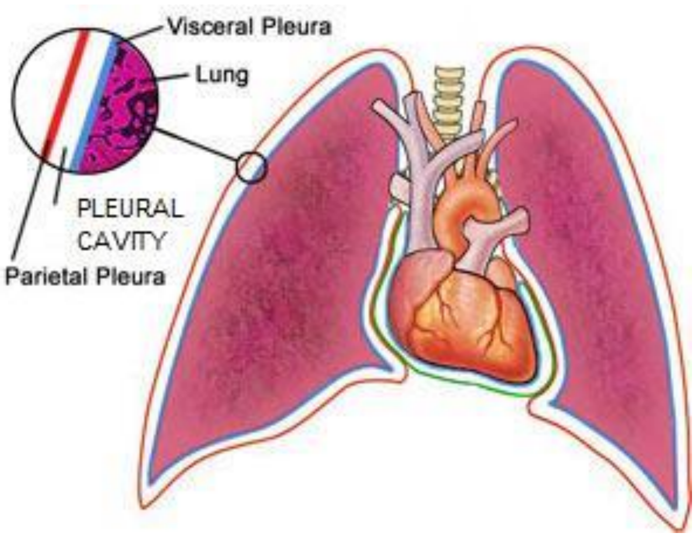
x ml / 3 min

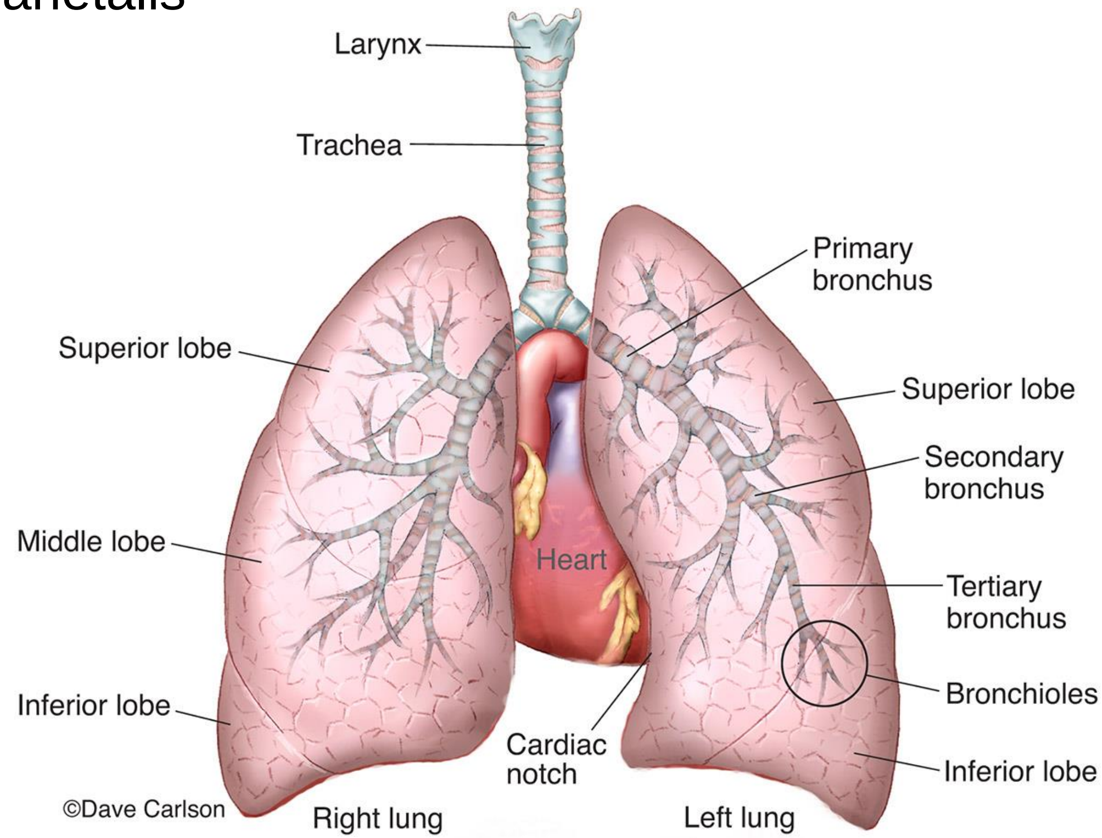
Breathing and pulmonary ventilation



Respiratory system

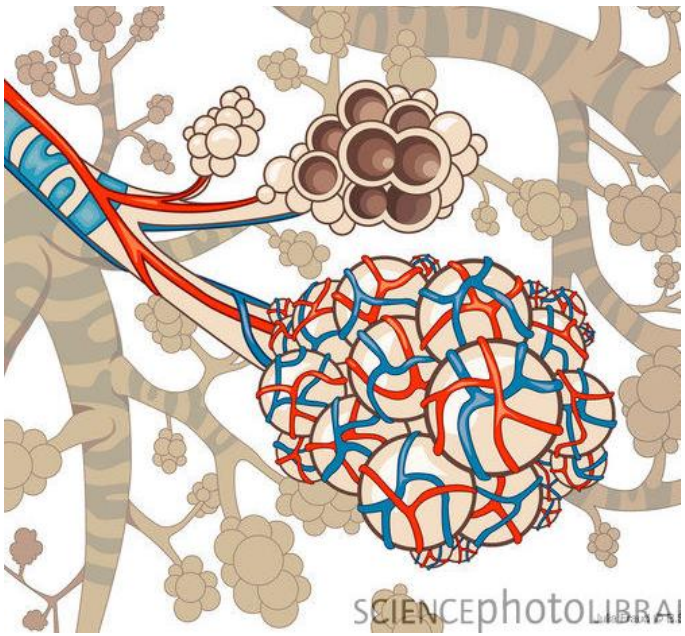
- respiratory exchange
- oxygen intake – diffusion, gill, trachea, skin, lungs etc.
- lungs freely in chest
- stretched by underpressure
- pleura visceralis, pleura parietalis
- pneumothorax

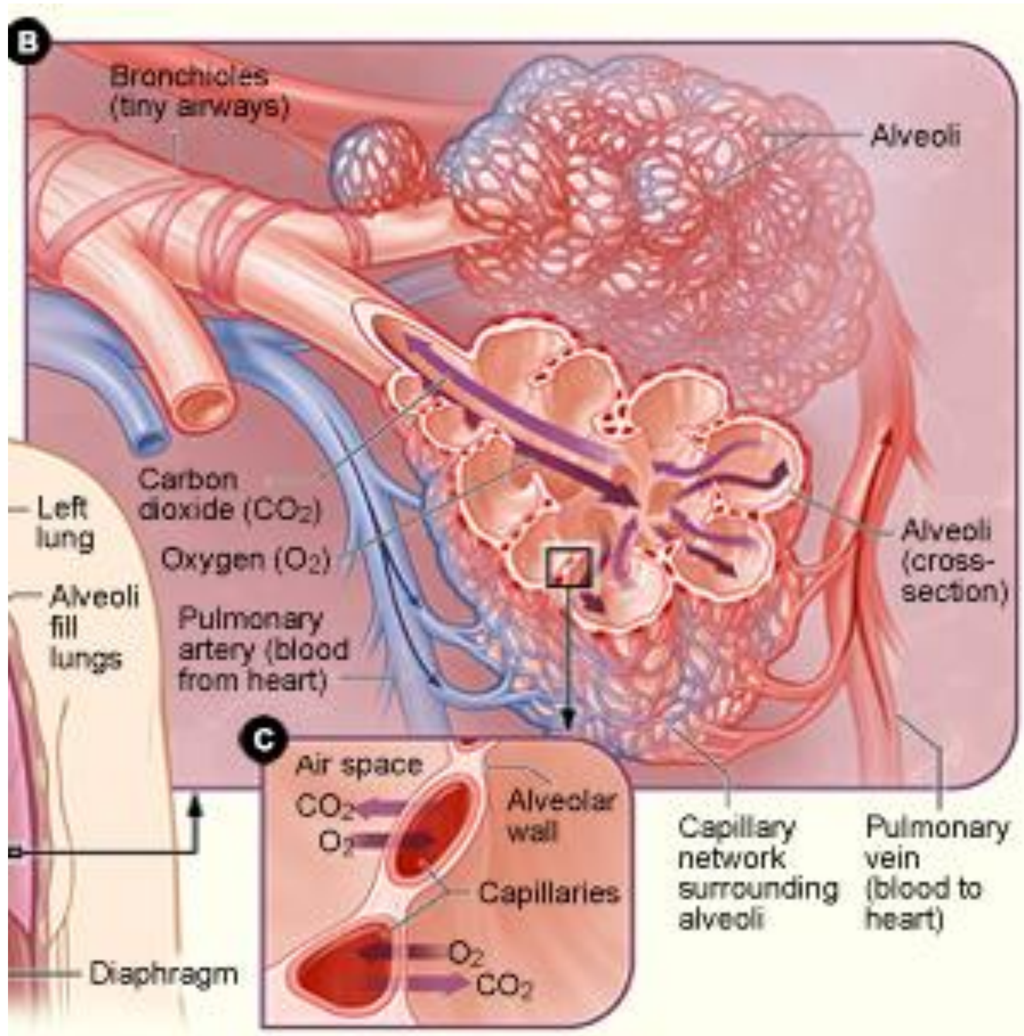




Respiratory system

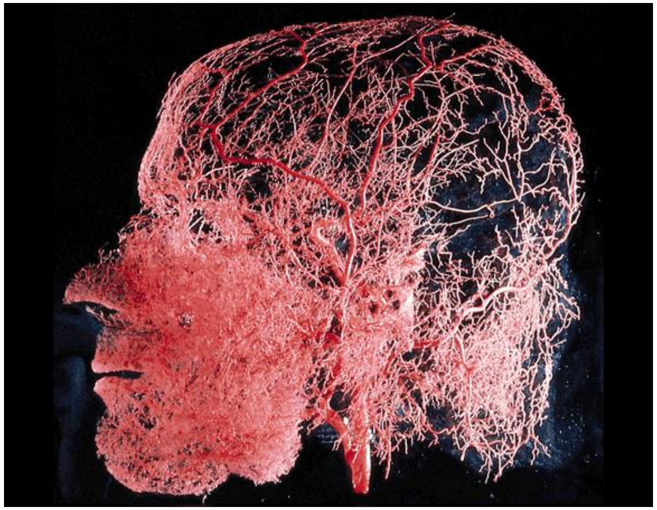
- alveolo-capillary exchange (membrane ~ 1µm), diffusion
- pulmonary alveoli





Control of pulmonary ventilation

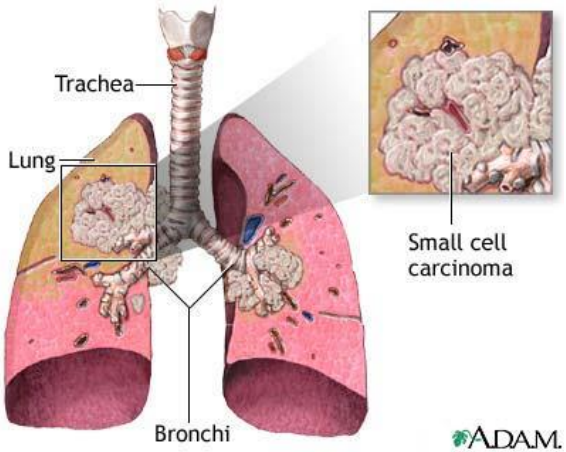
- air is composed of: 21 % O_2; 78 % N; 1 % Ar; 0,03 % CO_2
- hypoxia vs. density of vascular system



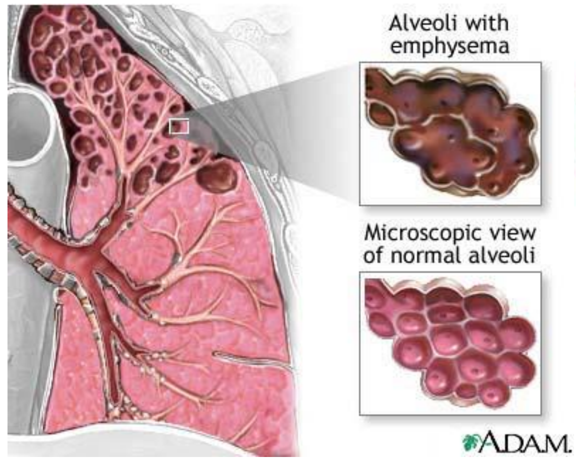
- **respiratory center: medulla oblongata** (inspirium/exspirium)
- chemoreceptors - blood pH (cervical artery, aortic bodies)
- baroreceptors - lung expansion (↑ pressure activates exhalation)
- proprioreceptors - muscles and tendons (activity intensifies breathing)
- thermoreceptors (heat intensifies breathing)

Respiratory disorders

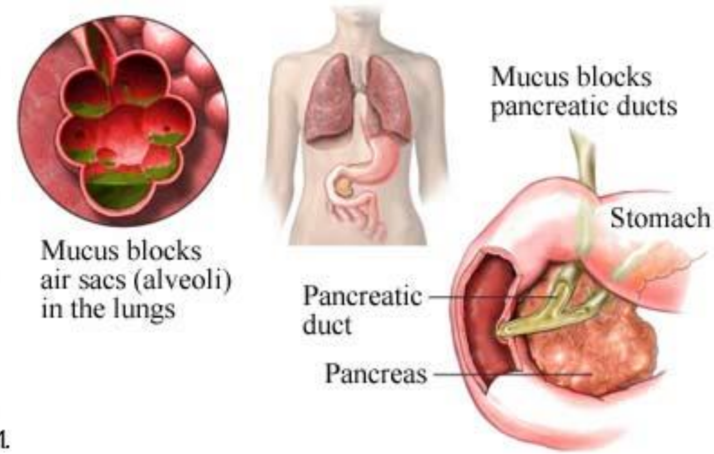
Lung cancer



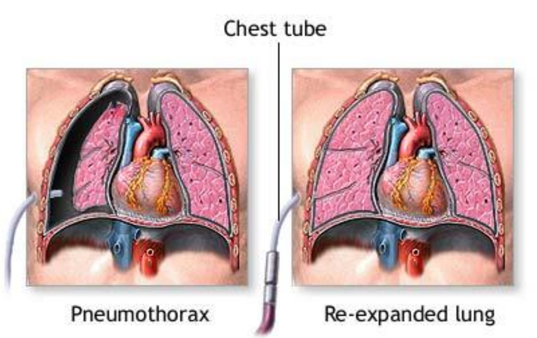
Emphysema



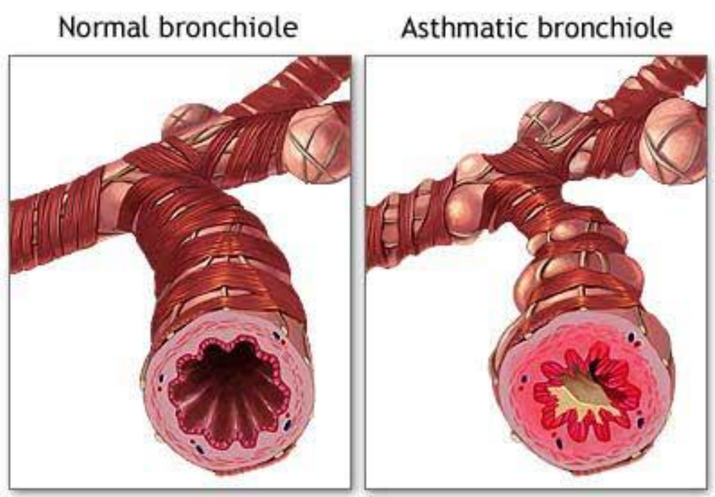
Cystic fibrosis



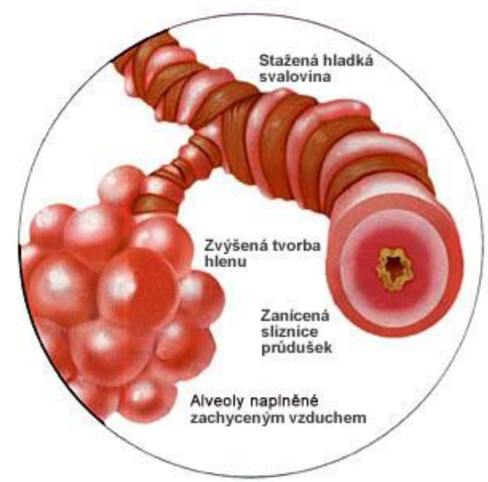
Pneumothorax



Asthma



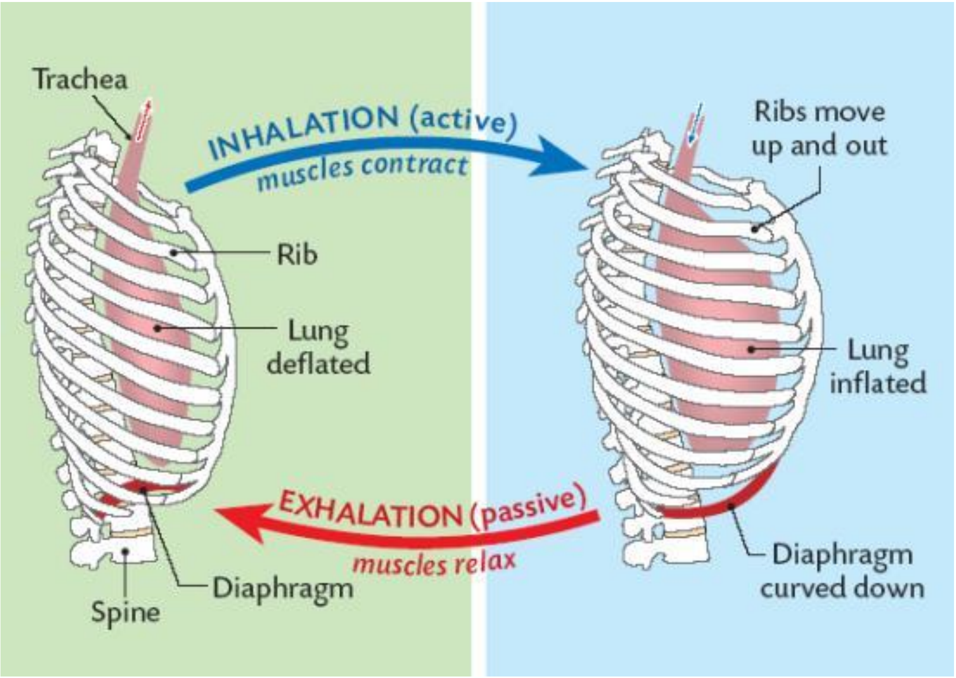
chronic obstructive pulmonary disease



Mechanism of pulmonary ventilation

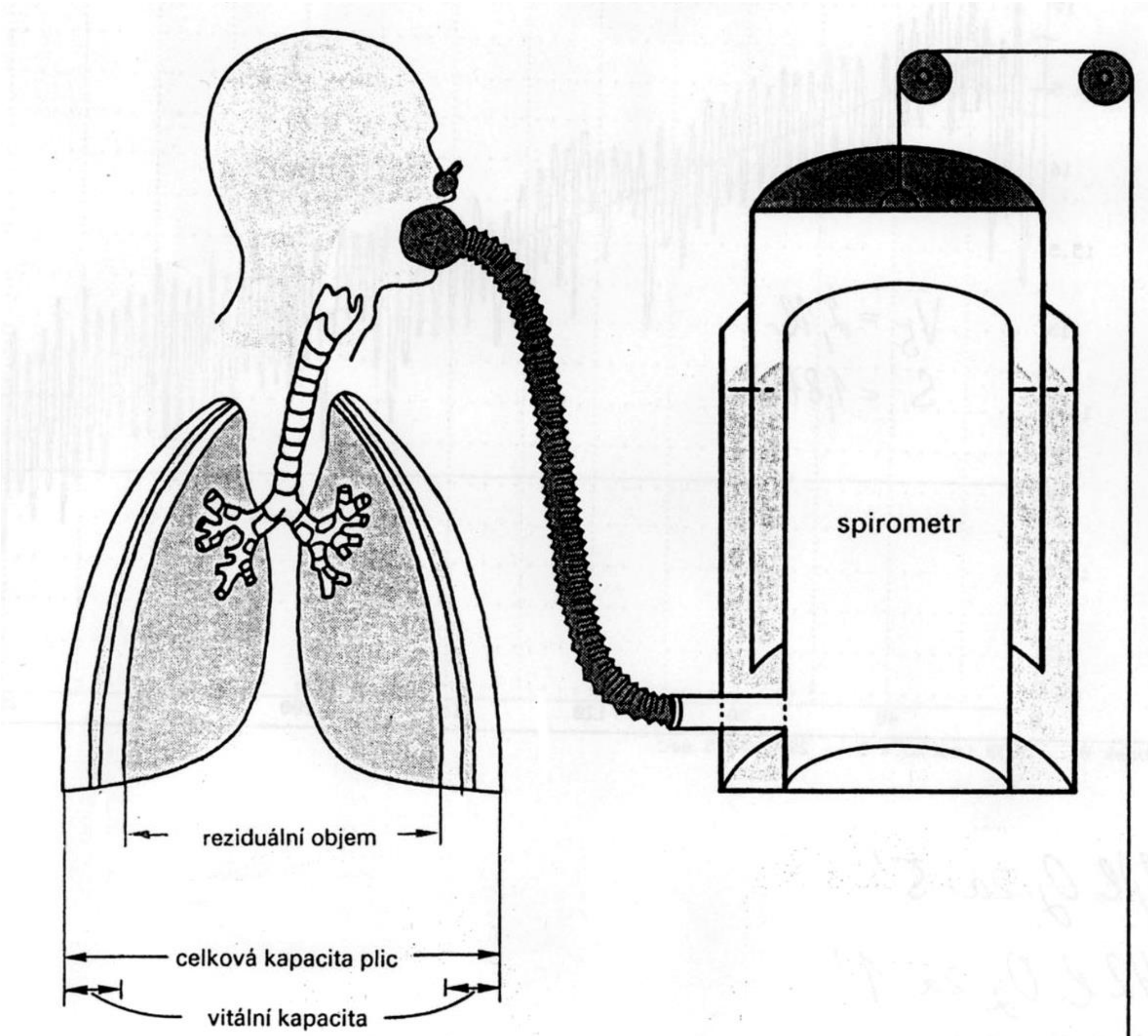
Inspirium
- active
- diaphragm, muscles of rib cage and other muscles
- forceful inhalation

Exspirium
- passive
- active chest compression

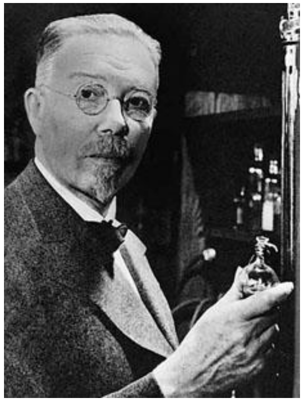


- frequency of breath:
  human 16-20 breaths/min
  children 26 breaths/min, newborns 44 breaths/min
  horse 8-16 breaths/min, mouse up to 200 breaths/min
- thoracic (female) vs. abdominal (men)

Krogh/Hutchinson respirometer

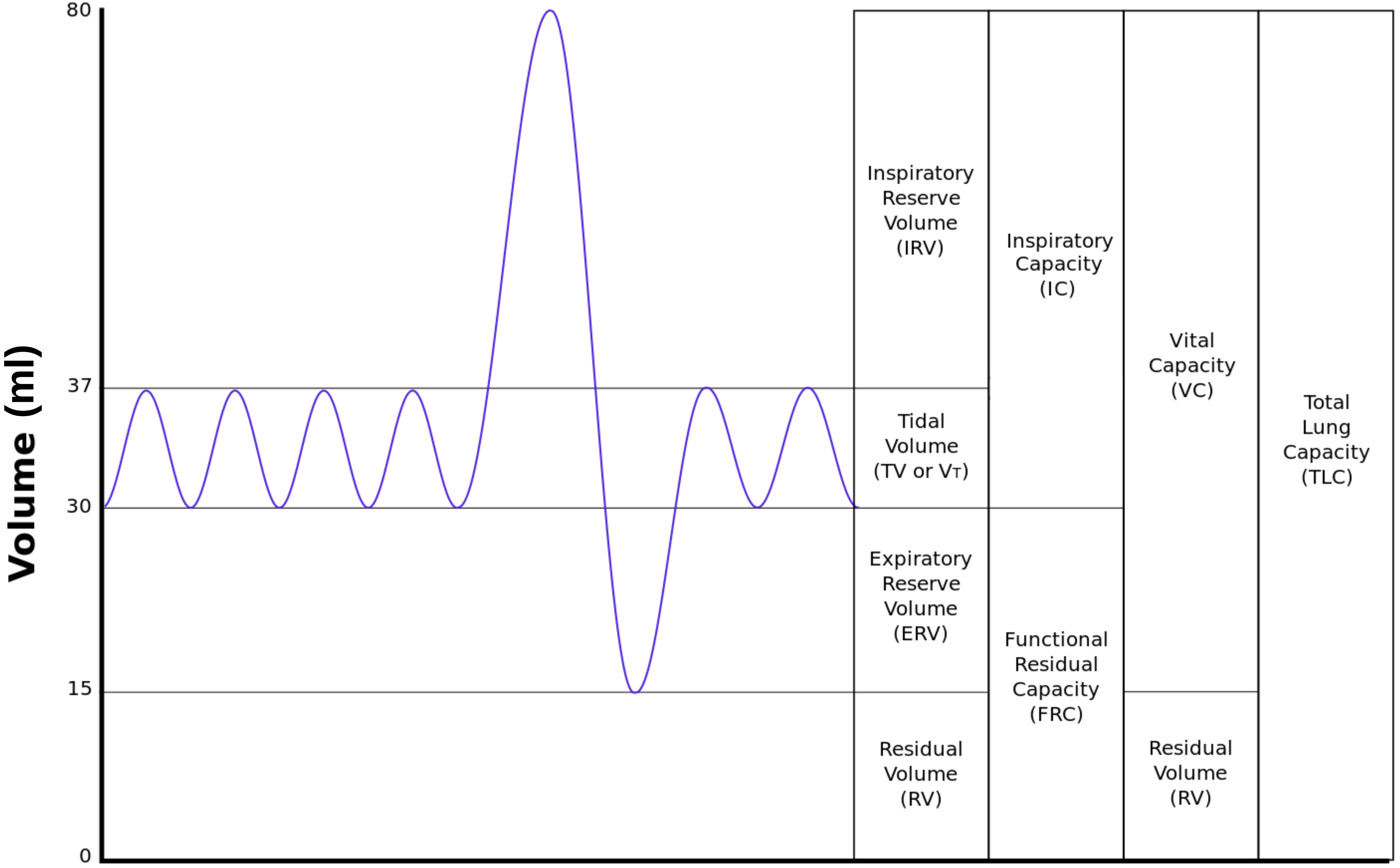


John Hutchinson
(1811-1861)



August Krogh
(1874-1949)

Vital capacity (VC)

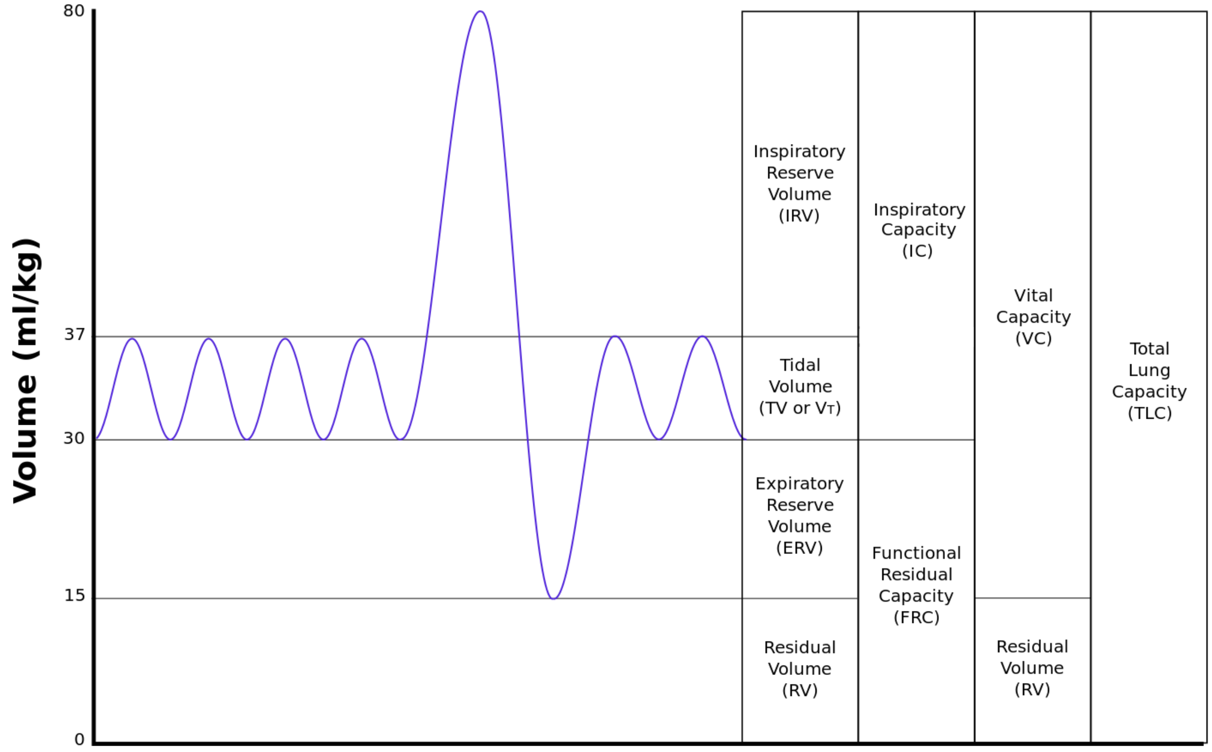


Vital capacity (VC)

Inspiratory reserve volume (IRV)	2500 ml
Tital volume (TV)	500 ml
Exspiratory reserve volume (ERV)	1000 ml

Residual volume (RV) 800-1700 ml
(collapse + minimal)

Factors:
- age
- sex
- skin area
- fitness
- pathologies
- etc.



Practice: Forced vital capacity (FVC)

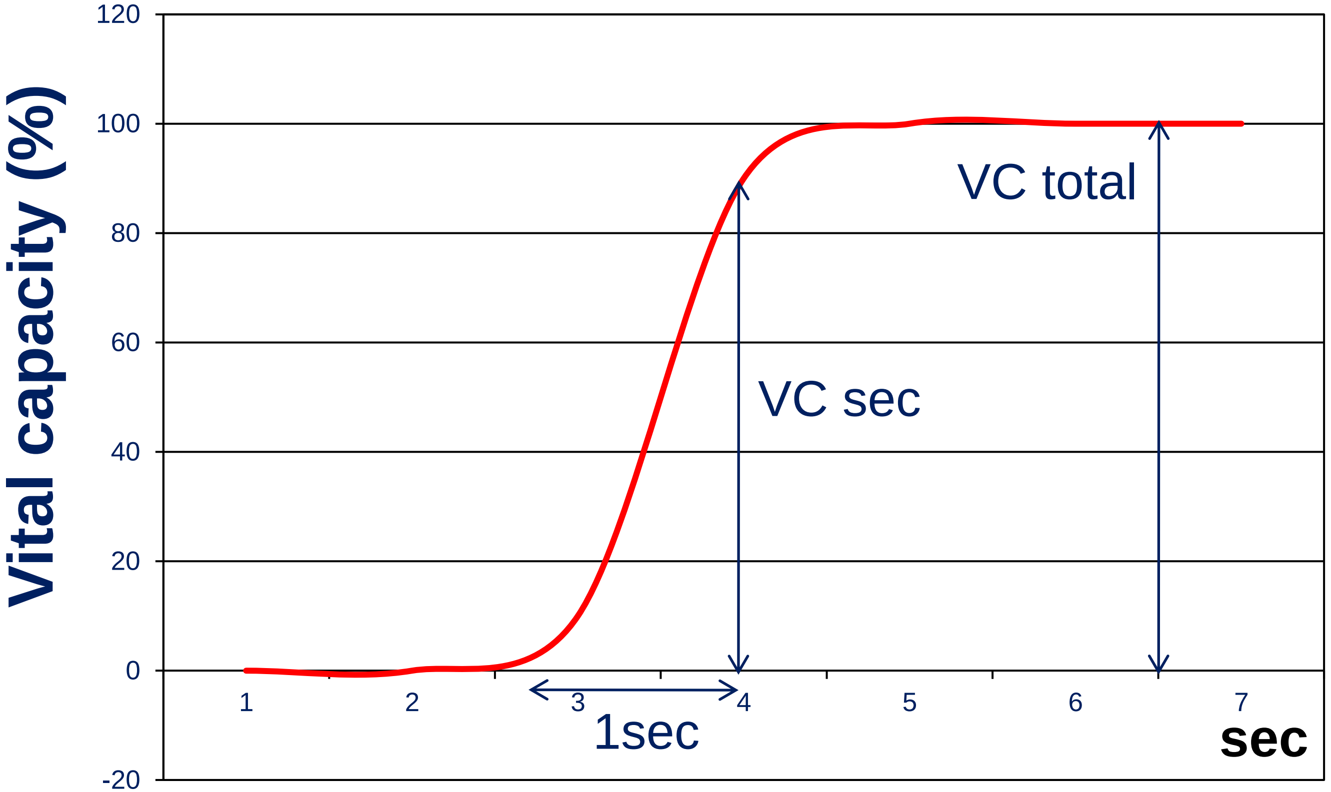
- the determination of the vital capacity from a maximally forced expiratory effort
- Hutchinson‘s respirometer
- normal VC: **Women ~3100 ml** **Men ~4600 ml**
- normal VC: **Women 2000 ml/m^2** **Men 2500 ml/m^2**
- theoretical VC (European population):

♀ **Women:** 5,2 x height (m) – 0,018 x age – 4,36 (+/- 0,42)

♂ **Men:** 5,2 x height (m) – 0,022 x age – 3,6 (+/- 0,58)

Practice: Dynamic test (FEV_1)

- volume that has been exhaled at the end of the first second of forced expiration
- Krogh‘s respirometr; normally > 85 %
- **restrictive pulmonary diseases** – lower vital capacity (< 75 %)
- **obstructive pulmonary diseases** – lower FEV_1, normal VC



Dynamic test of pulmonary ventilation

- normal
- fibrosis, scars, deformities (restrictive)
- mucus production, inflammation, bronchoconstriction, asthma (obstructive)