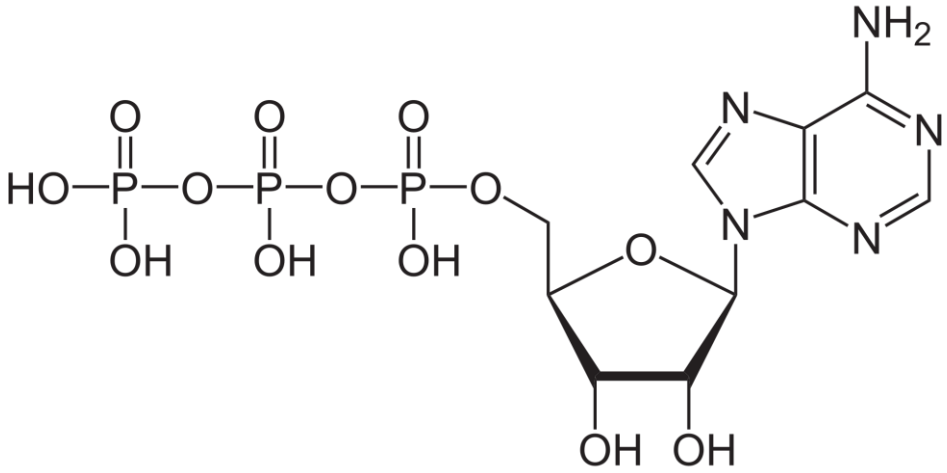
Metabolism

- nutrient conversion
- basal metabolism
- total metabolism
- practical part: human metabolism
- practical part: insect metabolism

Metabolism and biotransformation of nutrients

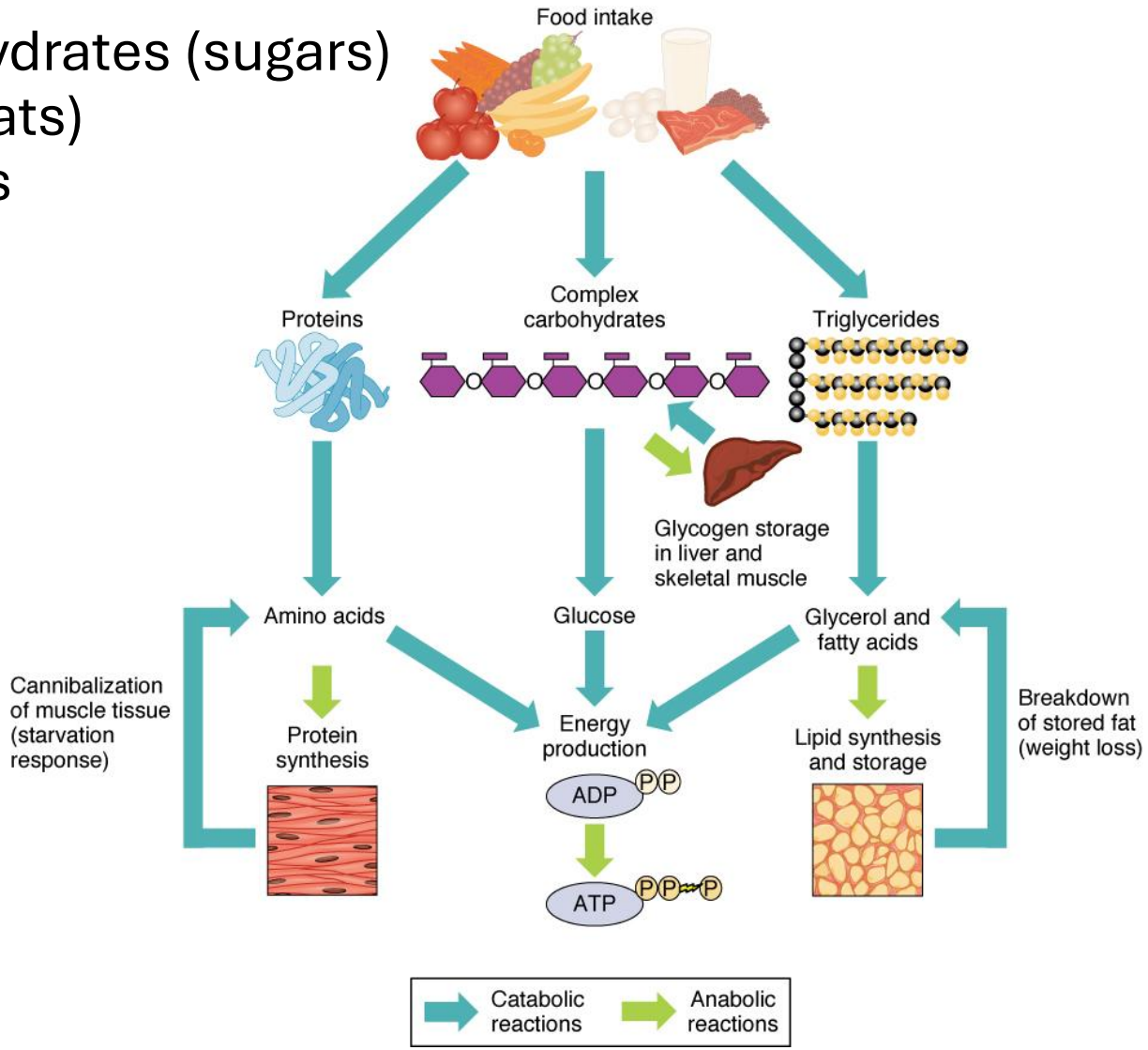
- catabolism + anabolism
- intake and distribution of nutrients, water and oxygen, their biotransformation, removal of waste metabolites from the organism
- gain of energy from chemical bonds in food, its conversion to ATP

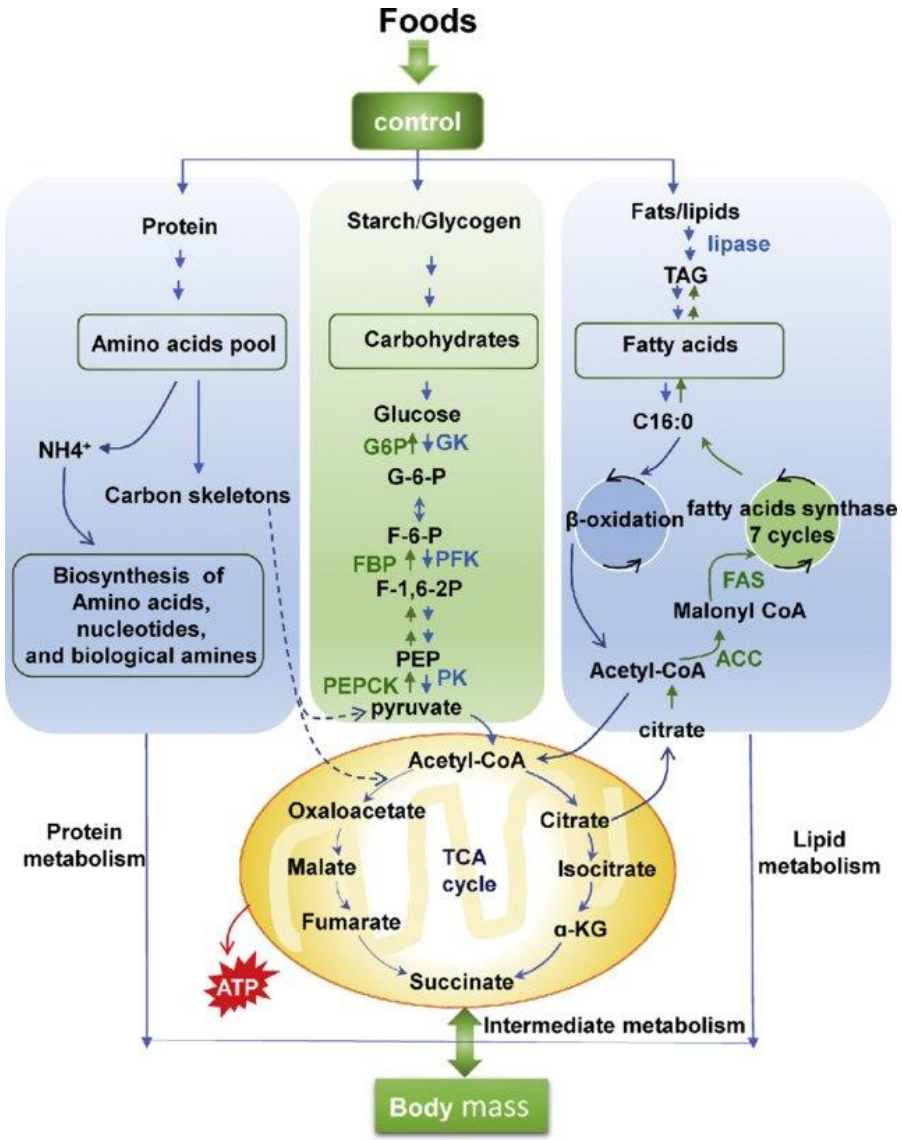
- energy is needed for:
  - muscle contraction
  - Na+/K+ transport
  - proteosynthesis
  - Ca2+ export
- at the organ level:
  - muscle
  - heart
  - kidney



Metabolism from the perspective of biochemistry

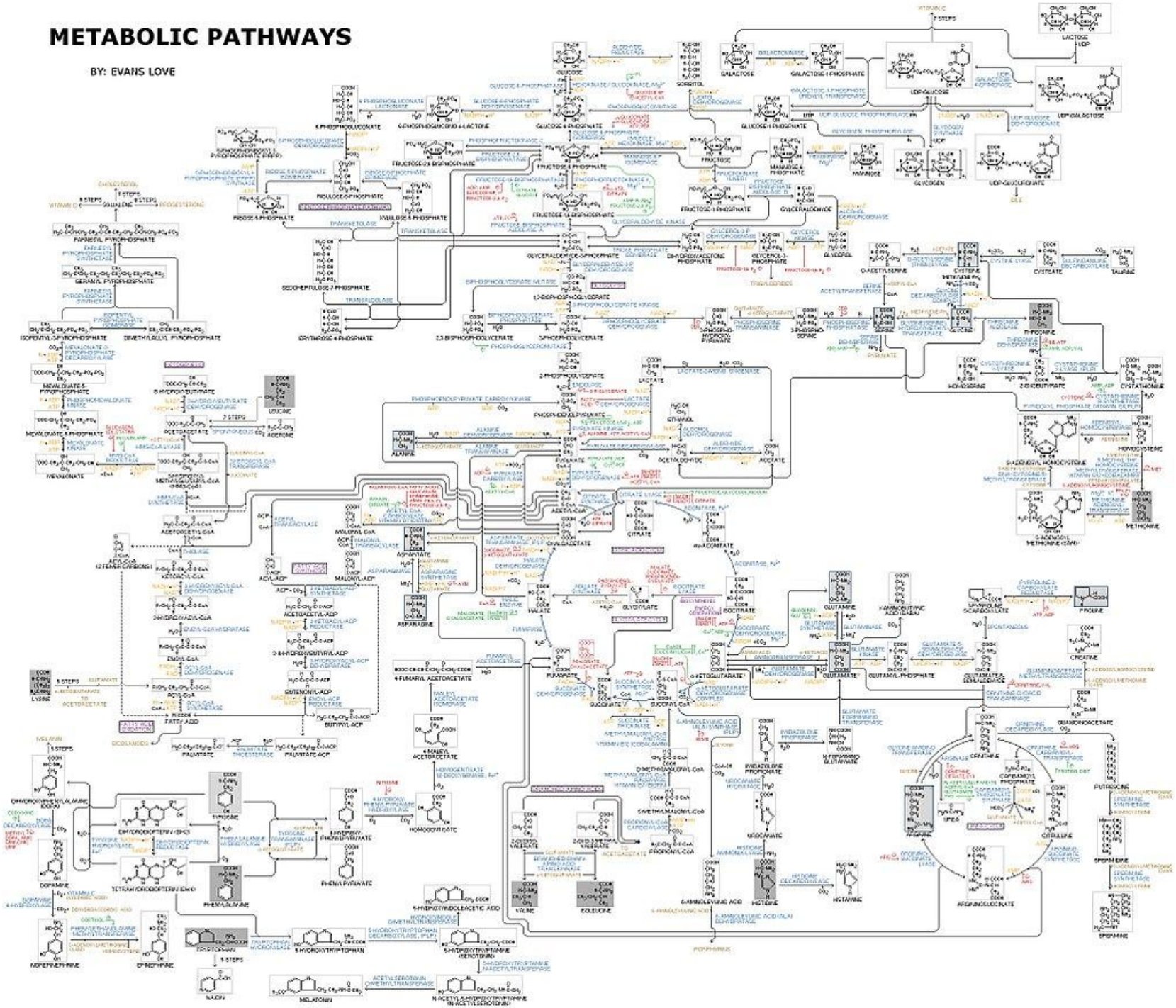
- carbohydrates (sugars)
- lipids (fats)
- proteins





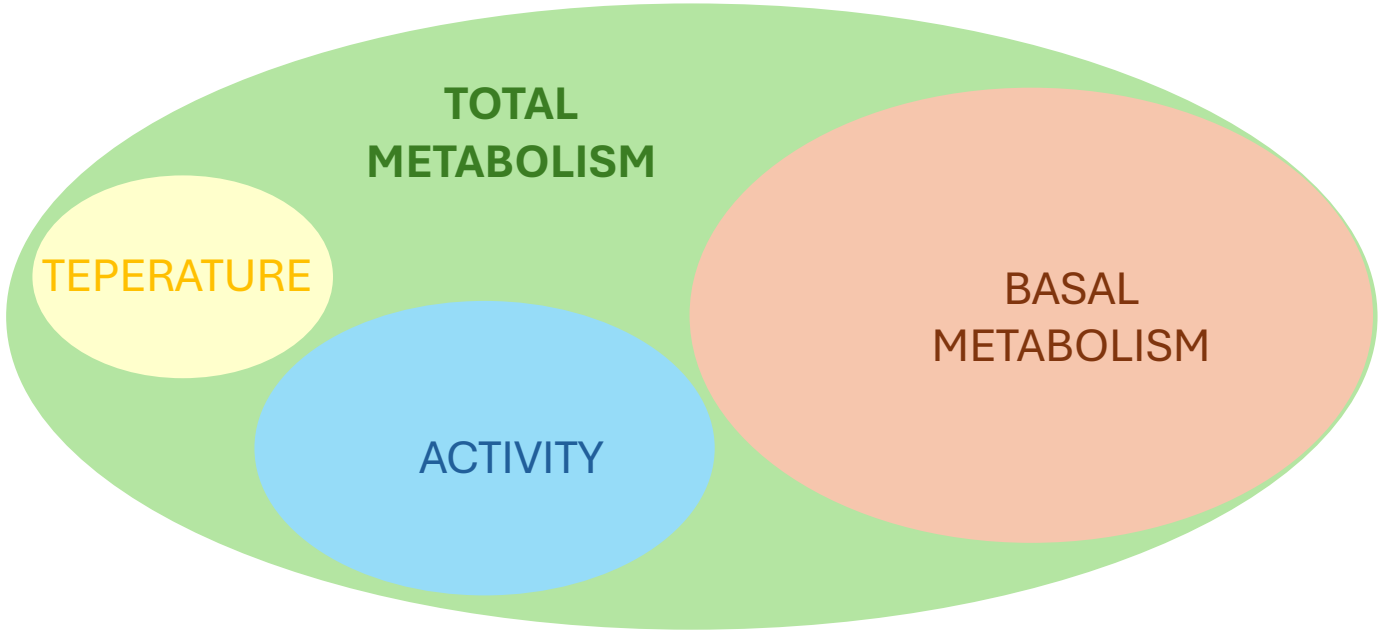
METABOLIC PATHWAYS

BY: EVANS LOVE



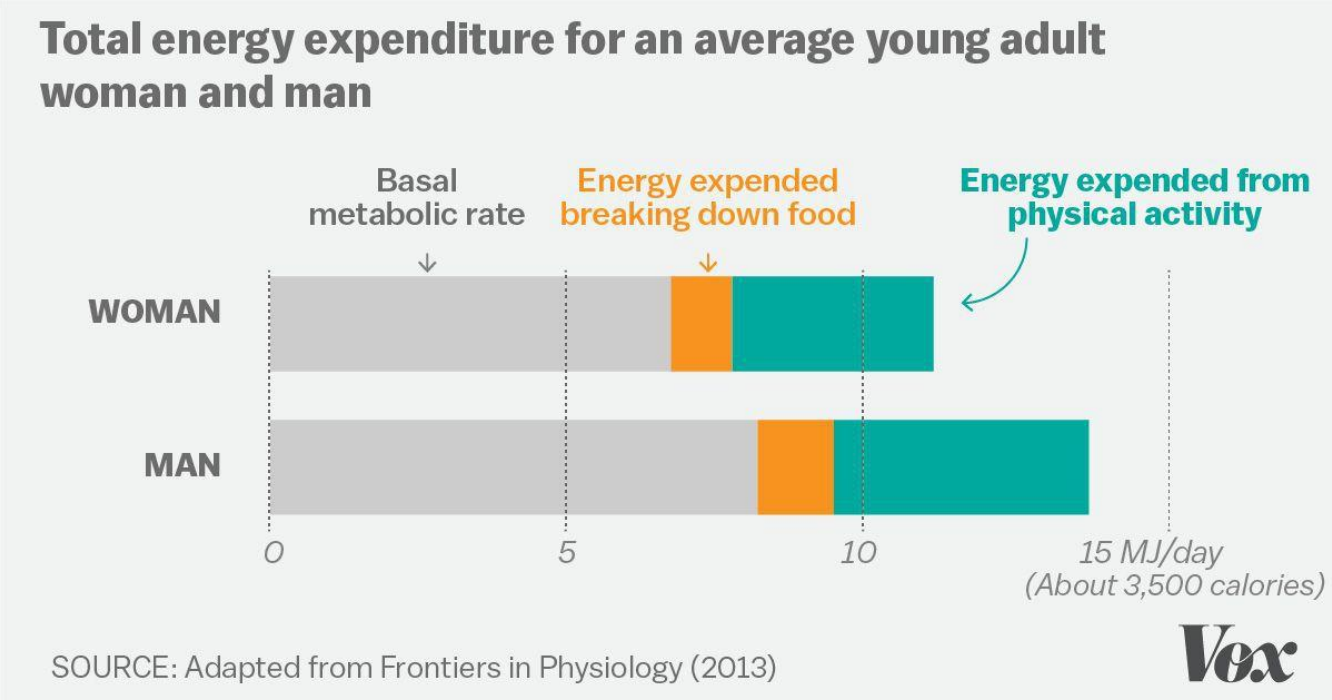
Metabolism from the perspective of physiology

- **total metabolism** = basal metabolism + activity + temperature influence of the environment
- **basal metabolism** = the smallest amount of energy necessary to ensure the basic functions of the organism under defined (basal) conditions:
  - the person is in absolute mental and physical rest
  - measurement in the thermoneutral zone (for a naked person 27 °C; for a dressed person 20 °C)
  - the last food intake was at least 12 hours ago and protein intake was limited for 3 days



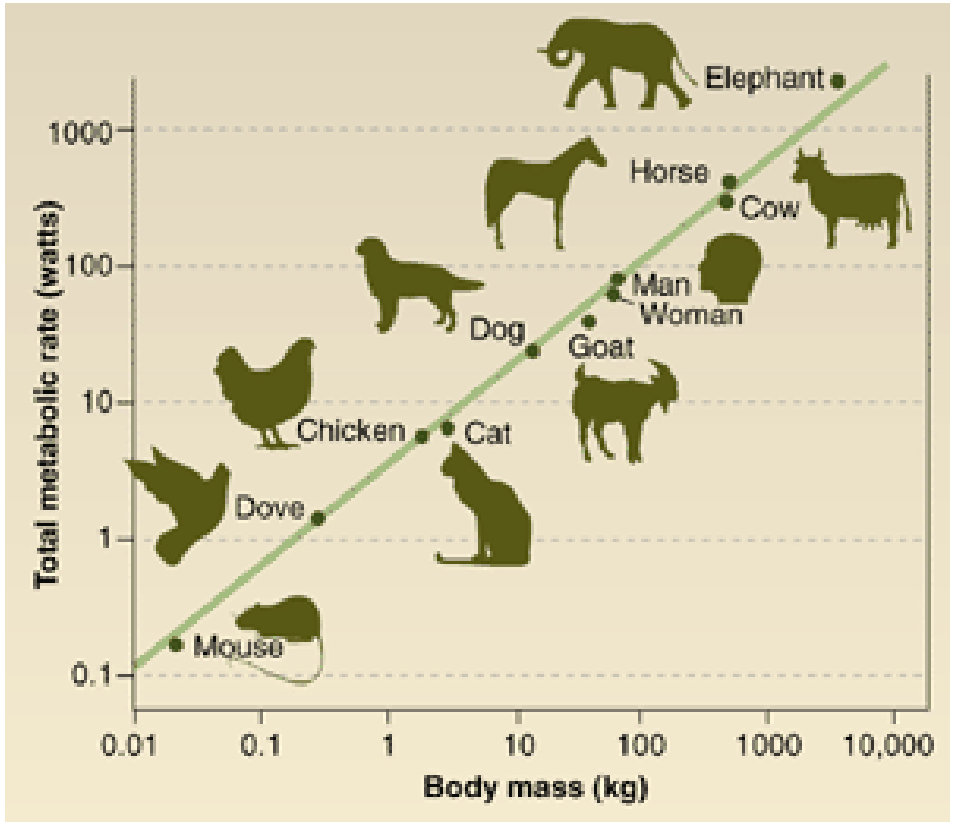
Factors affecting metabolism

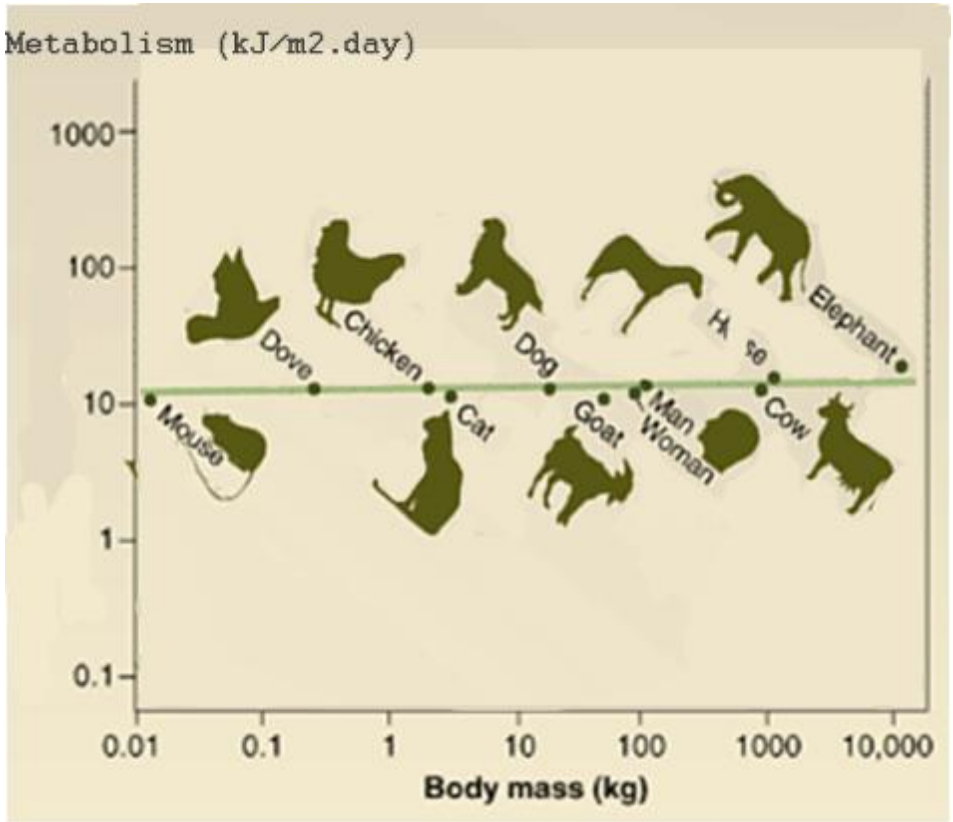
- genetic predisposition, gender, age and body constitution (e.g. muscle mass)
- diet (calorie intake)
- physical activity
- body and ambient temperature (e.g. climatic influences)



Factors affecting metabolism - Surface hypothesis

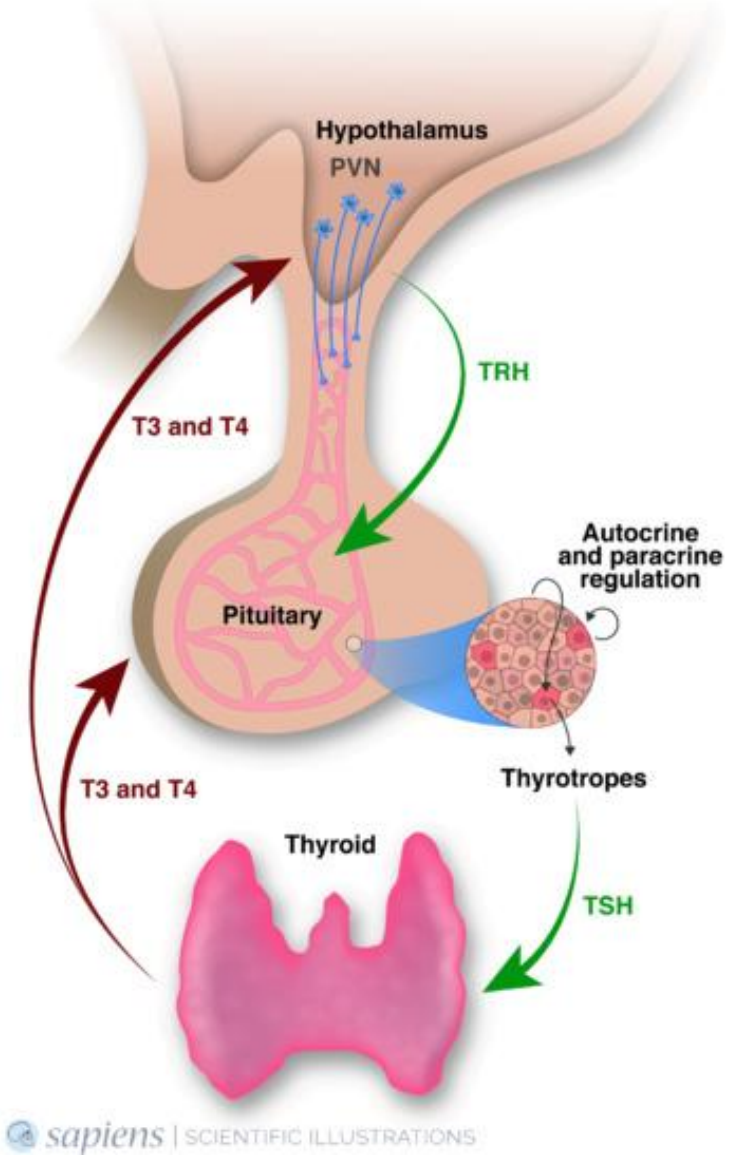
- Max Rubner (1854 - 1932)
- the metabolic rate of birds and mammals that maintain a steady body temperature is roughly proportional to their body surface area





Metabolism regulation

- nutrient/enzymatic control
- nervous control (autonomic nerve system)
- hormonal control:
  - **TRH** (thyrotropin-releasing hormone) from the hypothalamus stimulates the pituitary gland to release **TSH** (thyroid-stimulating hormone), which in turn stimulates the thyroid gland to produce **thyroxine (T4) and triiodothyronine (T3)**
  - thyroid hormones increase the basal metabolic rate
  - negative feedback loops
  - half-life
  - hyperthyroidism and hypothyroidism



How high is the human **basal** metabolic rate?

- **calorie** units (cal; the amount of energy required to raise the temperature of 1 g of water from 15 °C to 16 °C)
- 1 cal = 4.18 J; because metabolism is measured in higher units, we often see **1 kcal = 1000 cal = 4.18 kJ**
- metabolism is expressed per unit of time, unit of mass, or unit of body surface area
- Mifflin-St Jeor equation (1900), calculating basal metabolic rate:

Women: BMR (kcal/day) = 10 × weight (kg) + 6.25 × height (cm) − 5 × age (years) − 161

Men: BMR (kcal/day) = 10 × weight (kg) + 6.25 × height (cm) − 5 × age (years) + 5

To convert to kJ/day, multiply by × 4.18.

- average for women: 1300–1500 kcal/day, i.e. 5.4–6.3 MJ/day
- average for men: 1700–1900 kcal/day, i.e. 7.1–8.0 MJ/day

How high is the human **total** metabolism?

- total daily energy expenditure
- from basal metabolism can be estimated by multiplying using the coefficient:

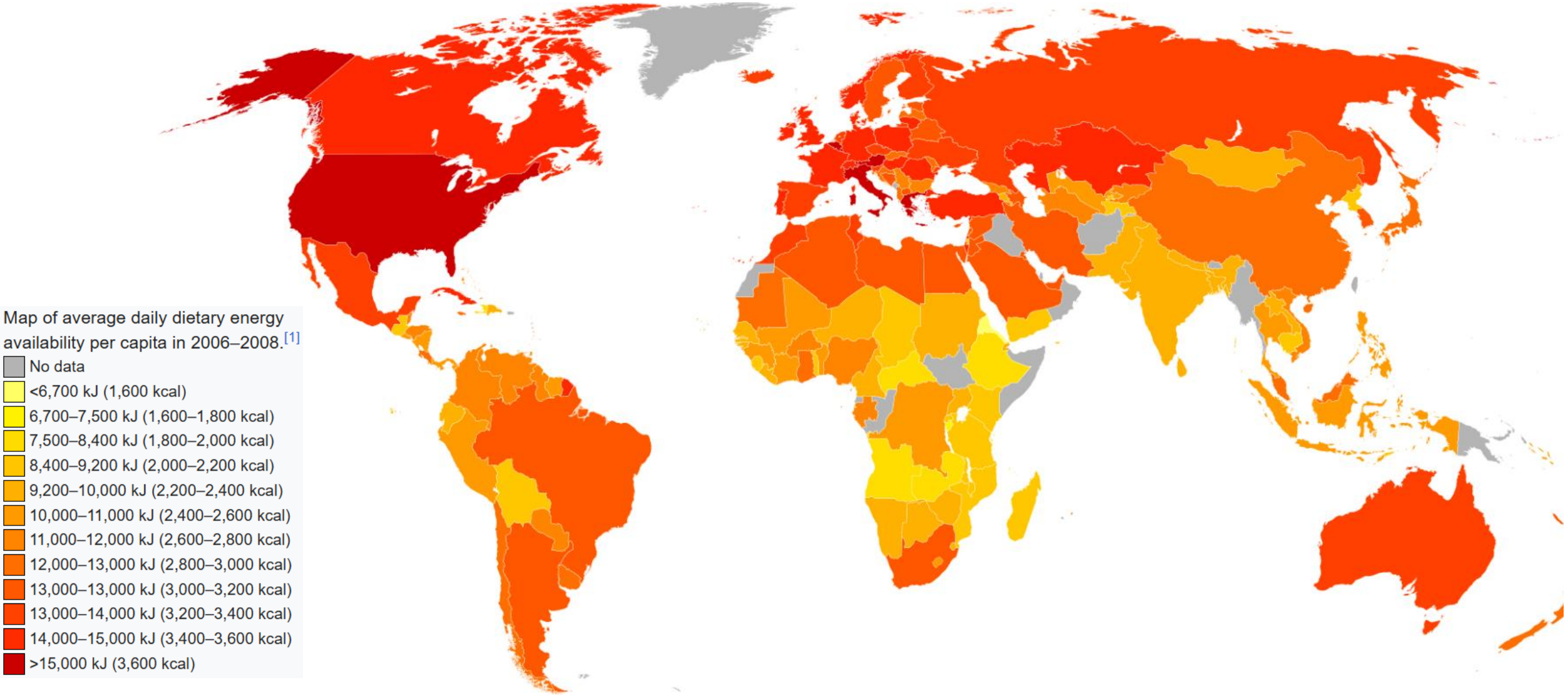
Sedentary lifestyle	× 1.2
Light activity	× 1.375
Moderate activity	× 1.55
High activity	× 1.725
Very high activity	× 1.9

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

Total metabolism vs. actual caloric intake



"FAO Food Consumption Nutrients spreadsheet - 2008". Food and Agriculture Organization of the United Nations. Retrieved February 18, 2009.

Calorific value, energy equivalent and RQ

- **energy equivalent (EE)** is the amount of energy released from the substrate when 1 liter of O_2 is used (average 20.18 kJ)
- **respiration coefficient (RQ)** is used to more accurately determine the composition of the combustion mixture; depends on the specific-dynamic effect of nutrients

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

$$\underset{\text{Glucose}}{C_6H_{12}O_6} + 6O_2 \longrightarrow 6CO_2 \uparrow + 6H_2O + \text{Energy}$$

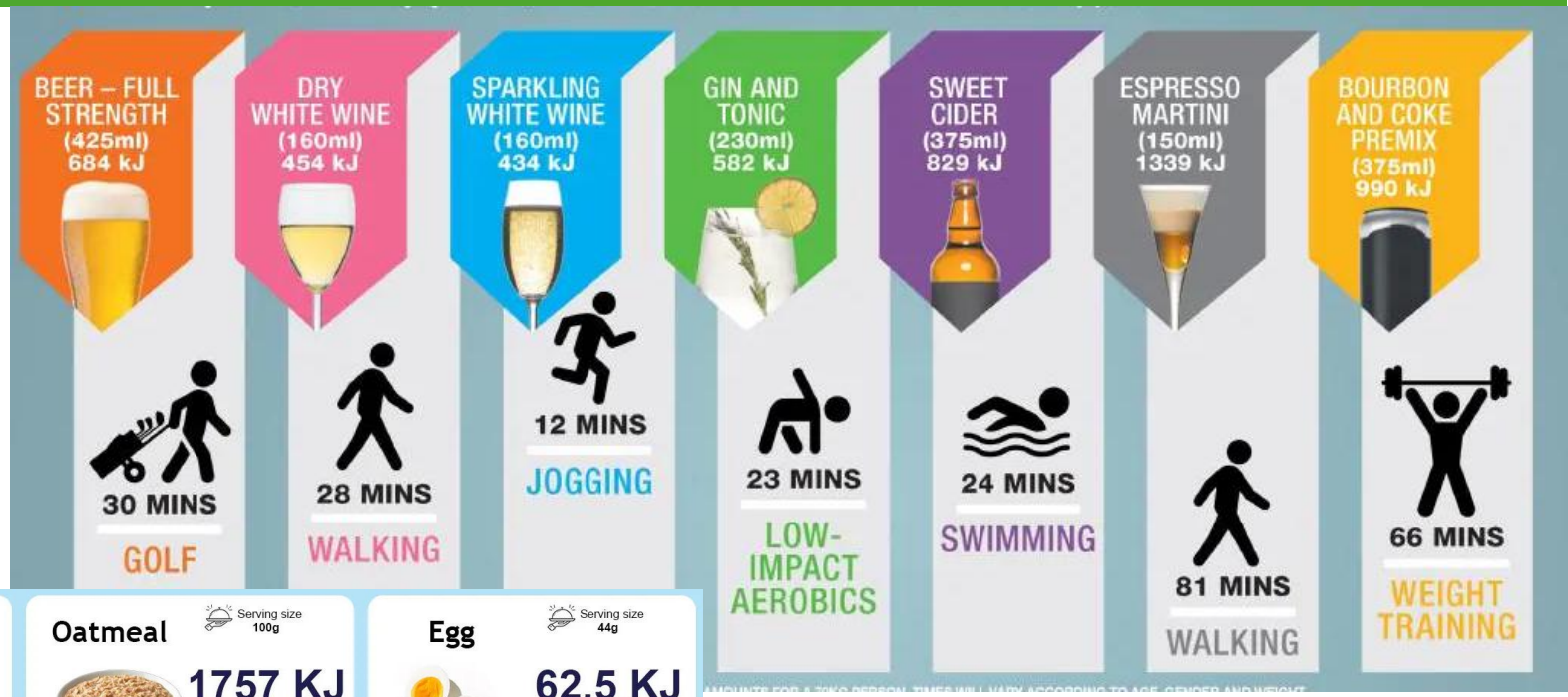
$$\text{RQ of glucose} = \frac{6 \text{ molecules of } CO_2}{6 \text{ molecules of } O_2}$$

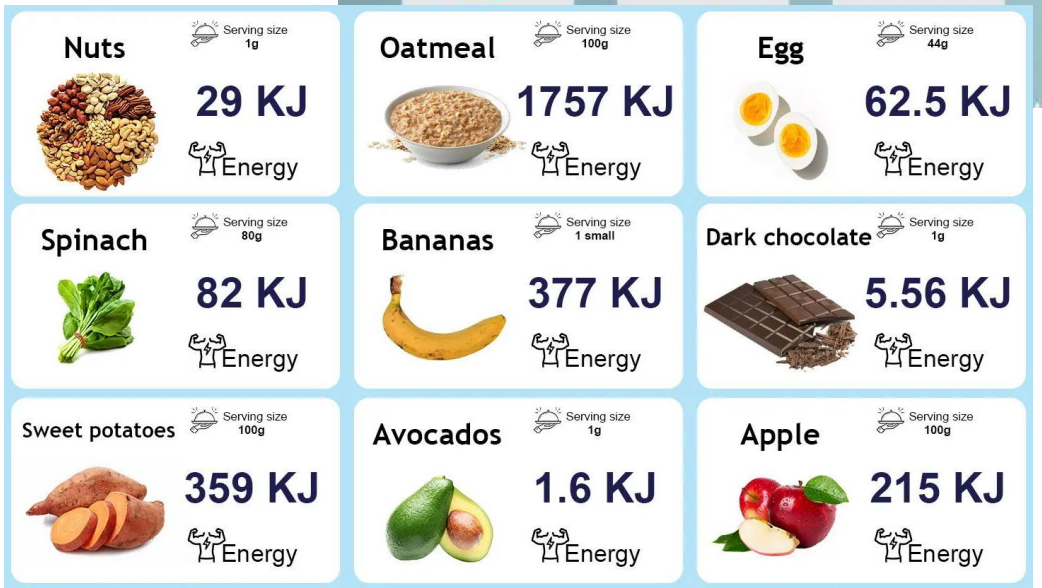
$$= 1 \text{ (unity)}$$

saccharides > RQ = 1
proteins > RQ = 0,8
lipids > RQ = 0,7
in average > RQ = 0,85

Nutritional and energy value of food

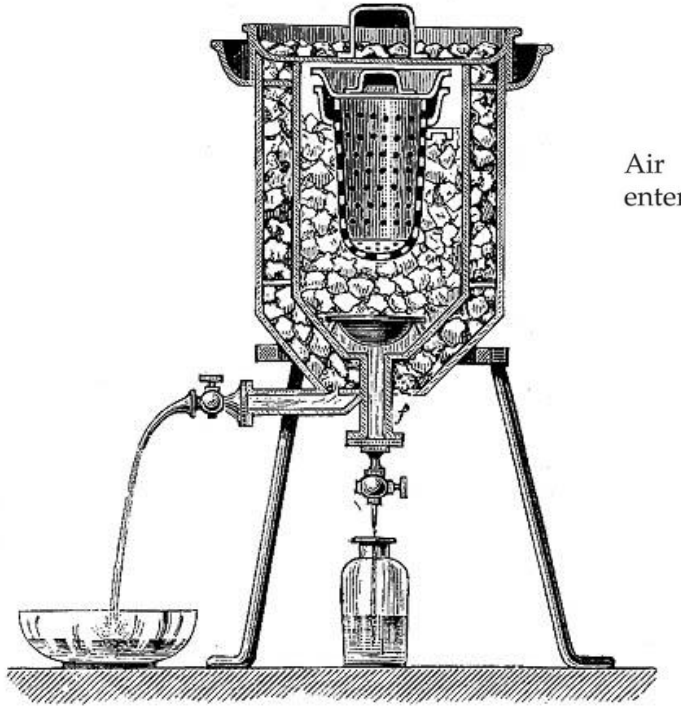
- nutritional and energy content are interconnected but different parameters
- balance between energy intake and expediture
- calorie calculators

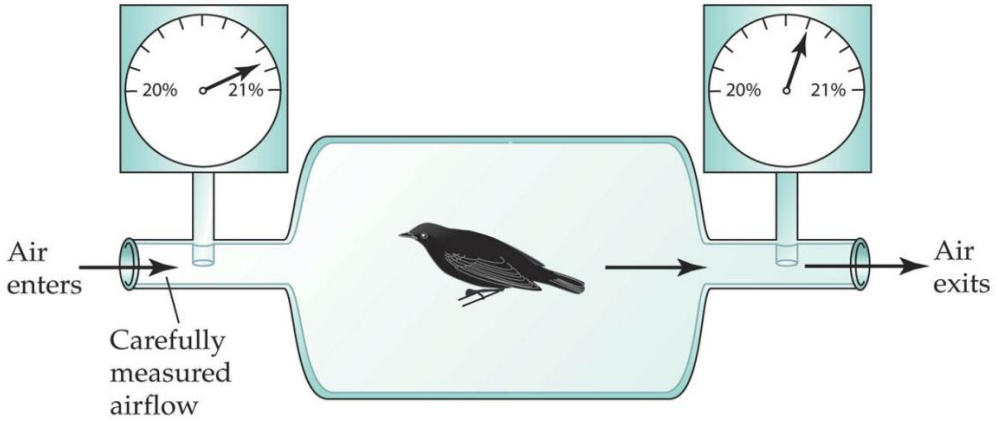




Measurement of metabolism

- **direct and indirect calorimetry** (closed and flow systems)
- metabolism is based on the combustion of nutrients > heat production (direct calorimetry) > we need oxygen for combustion (indirect calorimetry, respirometry)
- relationship between consumed O_2, emitted CO_2 and metabolic rate





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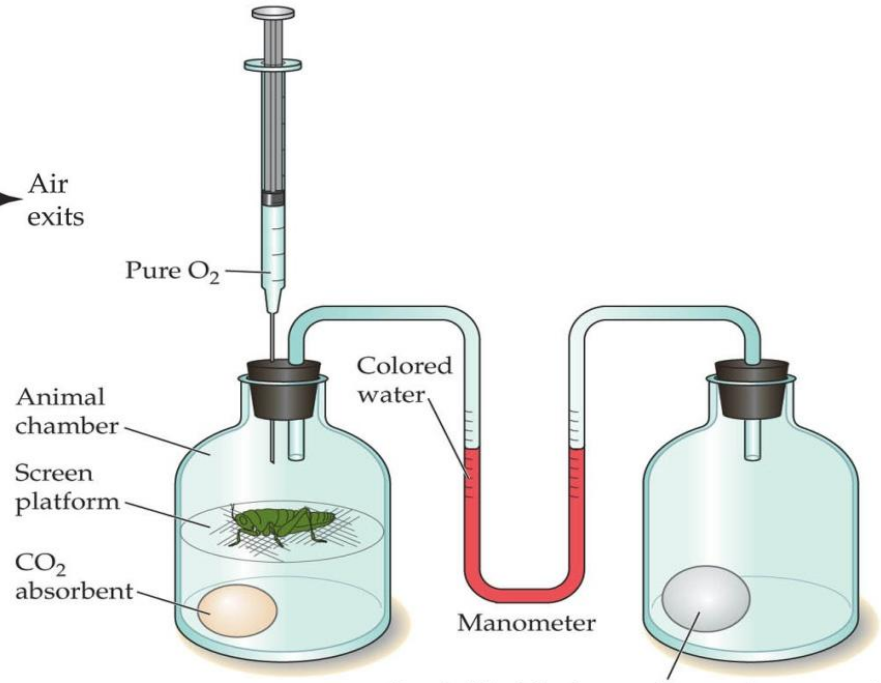


ANIMAL PHYSIOLOGY, Box 5.4, Figure A © 2004 Sinauer Associates, Inc.

Inert object that occupies a volume equal to the volume occupied by the insect and the CO_2 absorbent in the animal chamber

Practical part – Measuring **total** insect metabolism

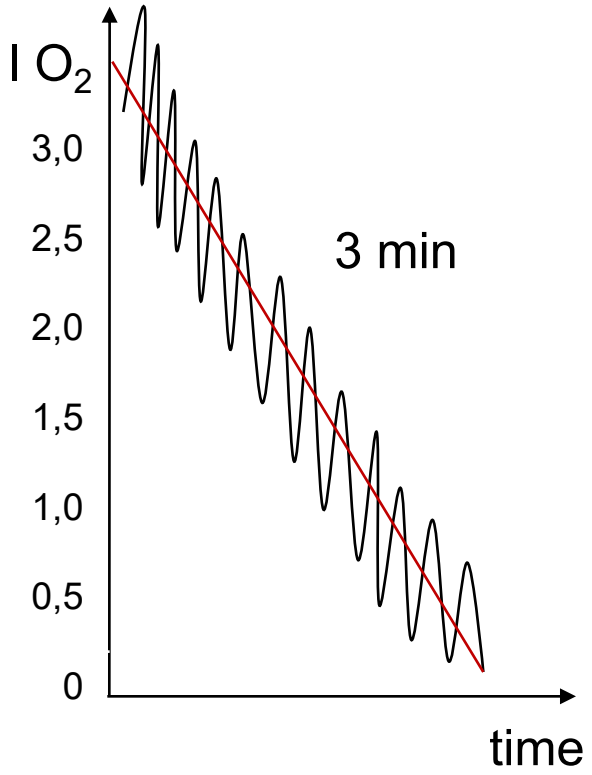
- modified Barcroft chamber
- model organism waxmoth (*Galleria mellonella*)
- sorbent: NaOH + $CaCl_2$ (absorption of CO_2 and H_2O)

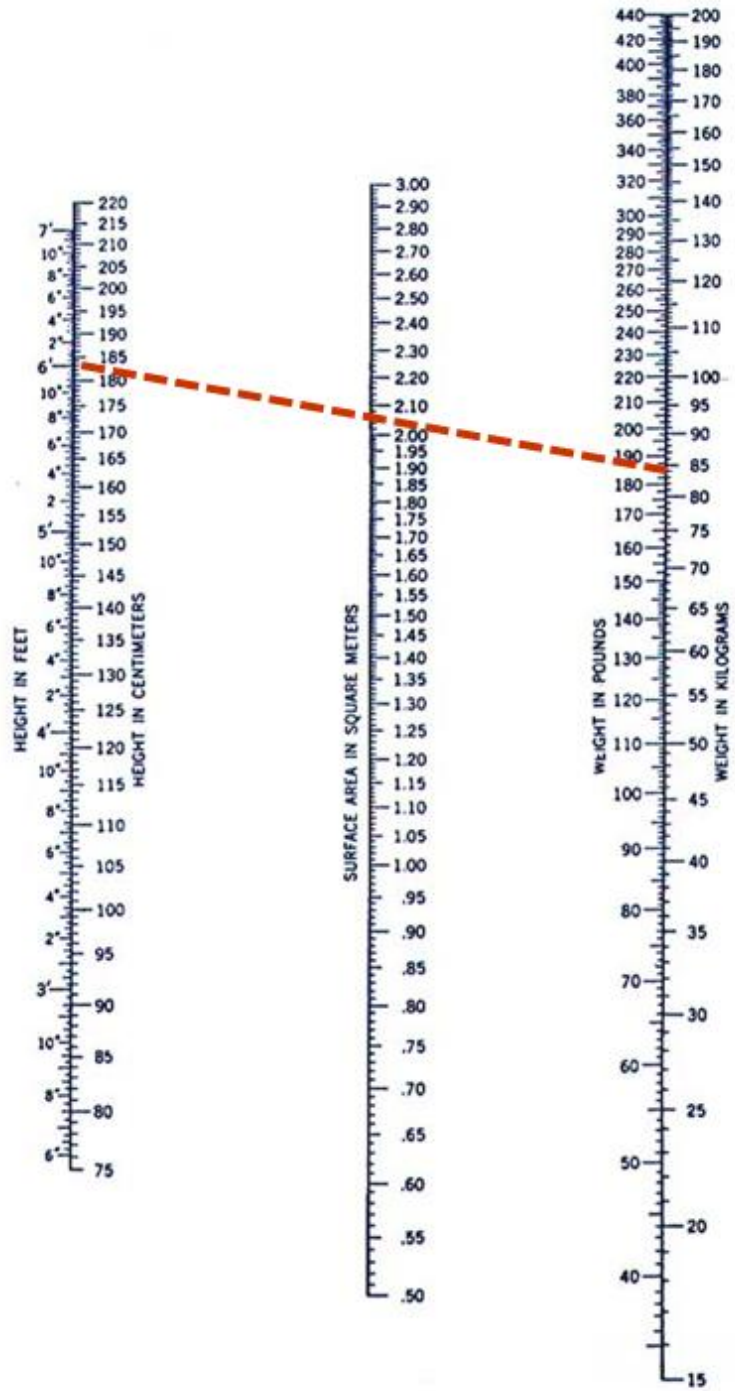
1. Prepare the measuring chamber
2. Insert a test tube with sorbent into both parts
3. Insert five larvae into one part
4. Close the large and then the small openings with plugs
5. Equalize the water level in the tubes in the middle (use the syringe above empty part of the chamber)
6. Measure the change in pressure (air volume) in the chamber for 10 min
7. Determine the total weight of the measured larvae
8. Convert the change in volume (consumed O_2) to energy
   (ml O_2/10 min > l O_2/10 min > x EE = kJ/10 min > convert to units **kJ/h/kg**)

Practical part – Measuring **total** human metabolism

- spirometry according to Krogh
- sorbent: NaOH + $CaCl_2$ (absorption of CO_2 and H_2O)
- **basal** human metabolism: men 171 kJ/h/m^2
  women 151 kJ/h/m^2

1. Measure the decrease in oxygen volume per 3 min
2. Calculate change in oxygen volume per minute (l O_2/min)
3. Use EE to transfer oxygen volume to energy (kJ/min)
4. Calculate the metabolism in **kJ/h/m²** and compare to reference value of basal metabolism above
5. Calculate the metabolism in **kJ/h/kg** and compare to insect metabolism




HEIGHT IN FEET
HEIGHT IN CENTIMETERS
SURFACE AREA IN SQUARE METERS
WEIGHT IN POUNDS
WEIGHT IN KILOGRAMS