Respiratory and cardiovascular adaptations to exercise

Modul BIO 406 – 17/05/2011

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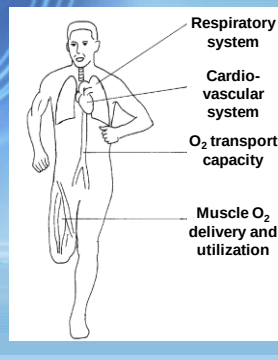
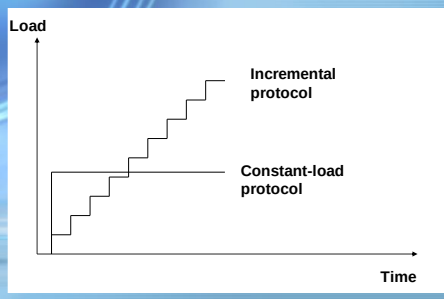
Cardiorespiratory exercise response



ERGOMETRY

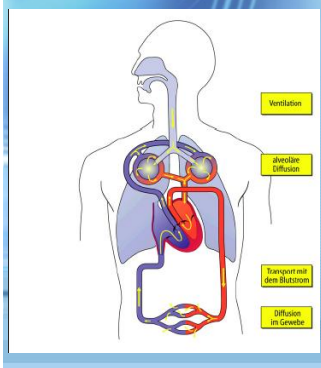
Incremental protocol / Constant-load protocol

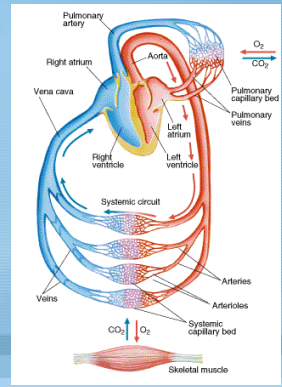


Incremental protocol / constant-load protocol

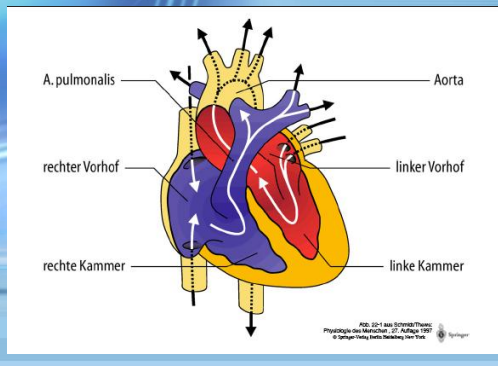
- Incremental test until exhaustion
- Constant-load test to exhaustion
- TIME TRIAL (constant distance):
  3000 m running test, 40 km cycling test
- TIME TRIAL (time constant):
  12 min Cooper Test

Heart and circulation

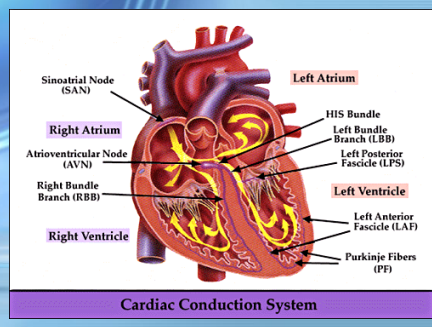




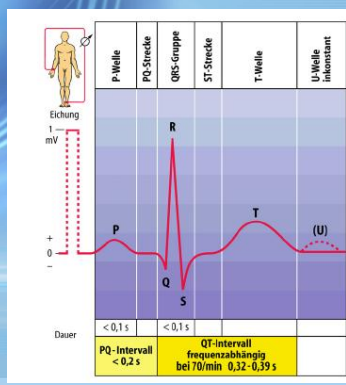
Heart



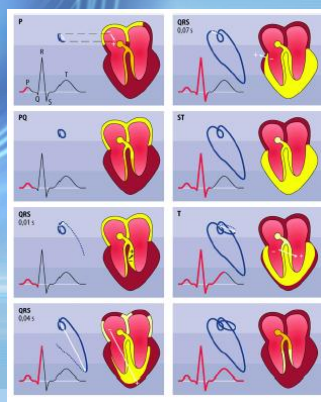
Heart



ECG



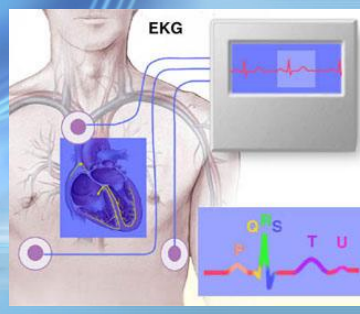
ECG



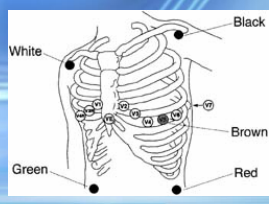
HEART RATE: MEASUREMENT

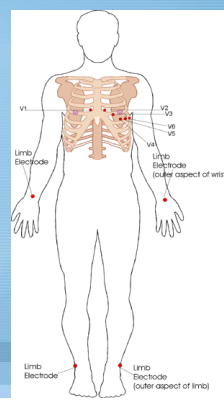
HEART RATE MONITOR

3-CHANEL ECG



12-CHANEL ECG





Heart rate abnormalities

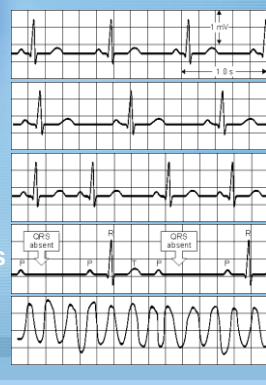
Normal Signal

Bradicardia

Tachicardia

Atrioventricular blocks

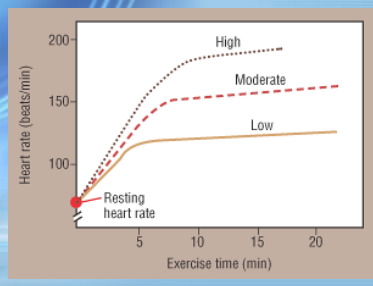
Ventricular fibrillation



Heart rate: resting values

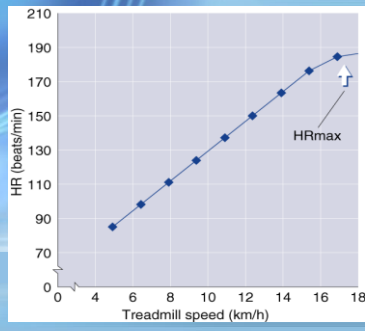
Alter oder Trainings-Status	Schläge pro Minute
Babys, bis 1 Jahr:	100 – 160
Kinder, 1 bis 10 Jahre:	60 – 140
Kinder, >10 Jahre und Erwachsene:	60 – 100
Gut trainierte Athleten:	40 – 60

Heart rate during exercise



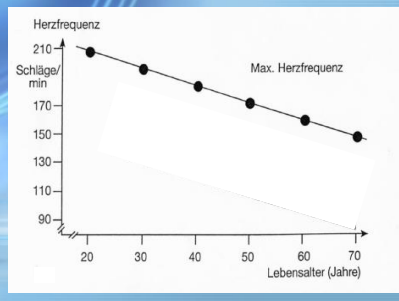
Constant load exercise
(LOW, MODERATE and HIGH INTENSITIES)

Heart rate during exercise



Incremental running test

Maximal heart rate: ageing

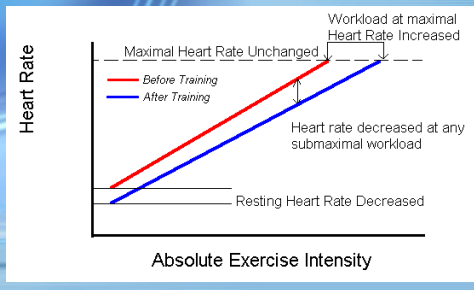


Maximal heart rate: ageing

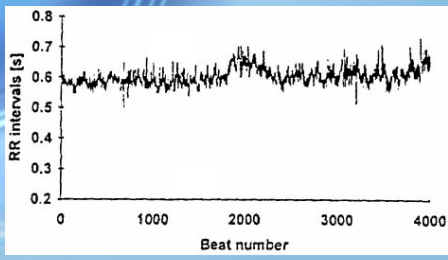
HR_{max} = 220 – AGE

HR_{max} = 208 – [0.7 × AGE]

Heart rate: effect of training

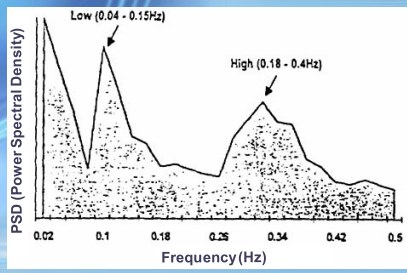


Heart rate variability



TACHOGRAM

Heart rate variability



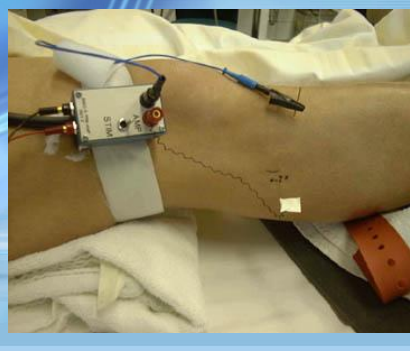
Spectral analysis of heart rate variability

Heart rate variability

Cardiovascular abnormalities

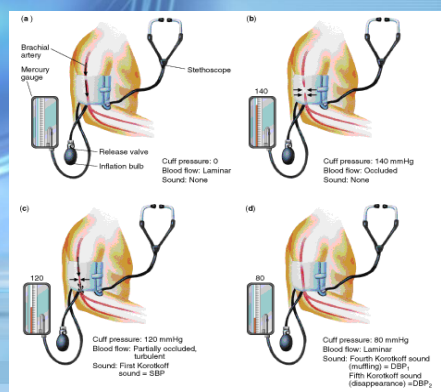
Training status

Muscle sympathetic nerve activity

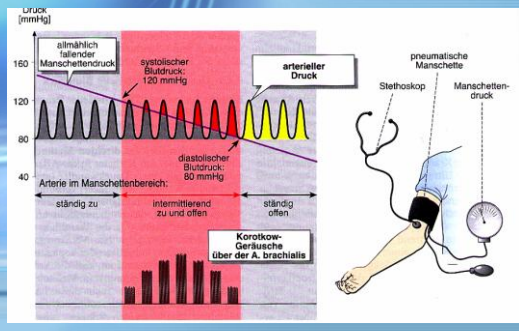


Blood pressure measurement

Blood pressure measurement

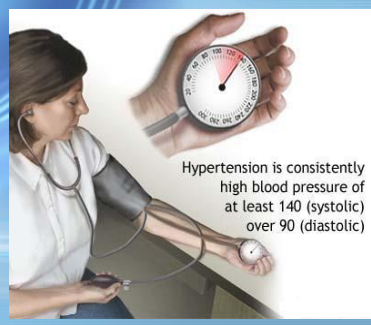


Blood pressure measurement



Blood pressure measurement

Hypertension

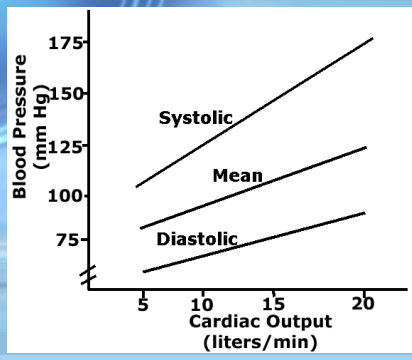


Increased blood pressure

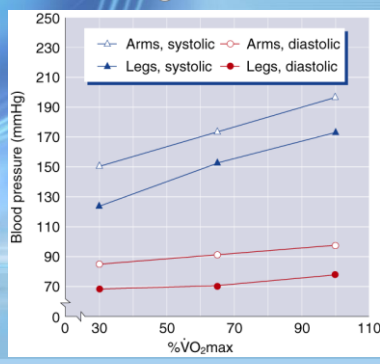
Kategorie	systolisch (mmHg)	diastolisch (mmHg)
Normal	< 120	< 80
Hochnormal	120-139	80-89
Bluthochdruck		
Stadium 1	140-159	90-99
Stadium 2	> 160	> 100

Classification for adults

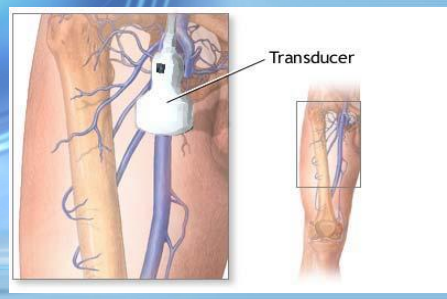
Blood pressure during exercise



Blood pressure during exercise



Blood flow measurement

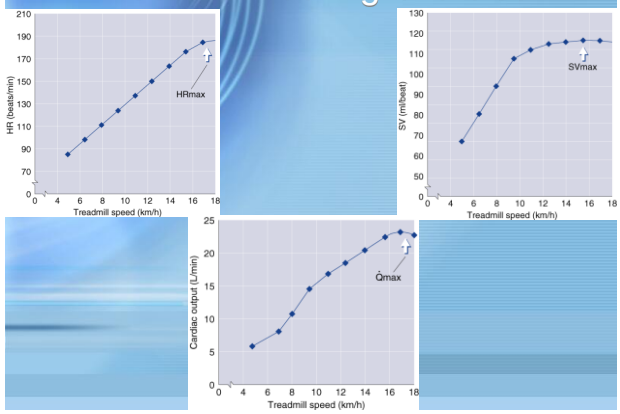


DOPPLER ULTRASOUND

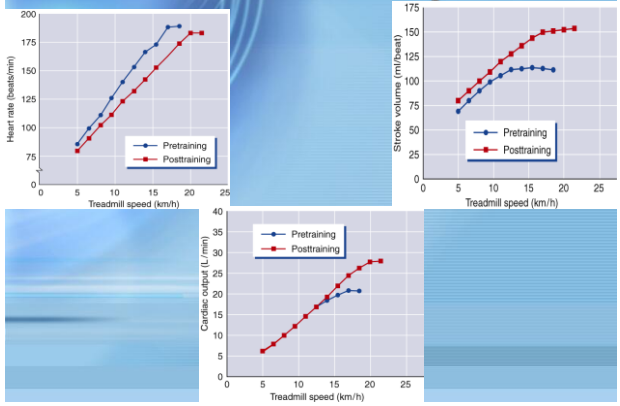
Blood flow

Cardiac output (l/min)
=
Stroke volume (l)
X
Heart rate (cycles/min)

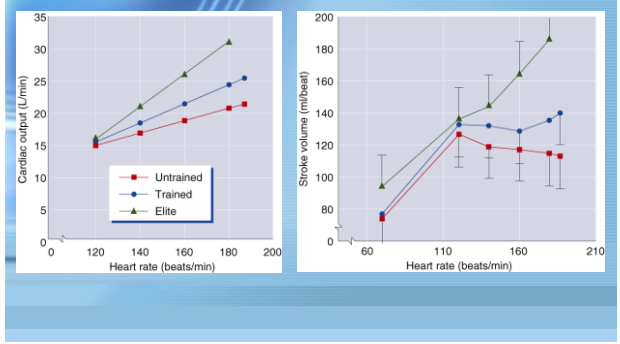
Blood flow during exercise



Blood flow and training status



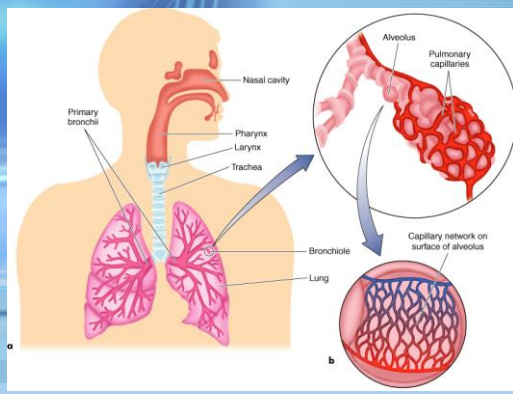
Blood flow and training status



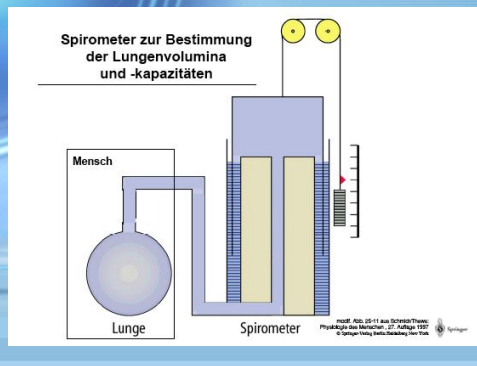
Maximal blood flow and training status

	MAXIMAL BLOOD FLOW		
	SV (ml)	HR (min)	Qc ($l \cdot min^{-1}$)
Non trained	90	200	18
Endurance trained	180	200	36

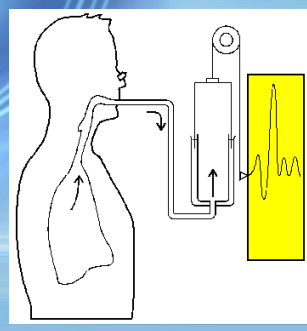
Respiratory system



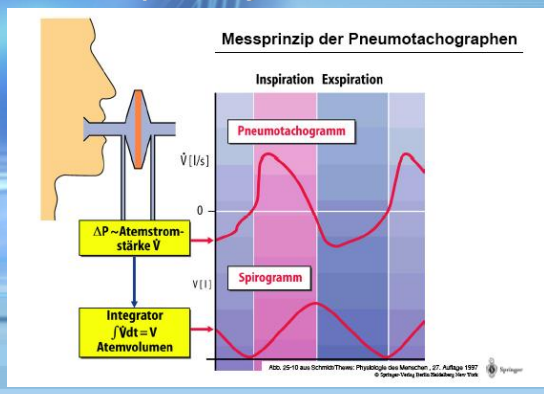
Respiratory measurement



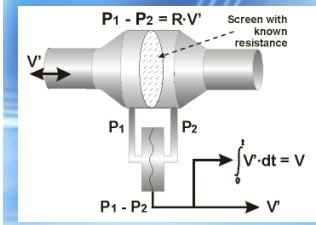
Respiratory measurement



Respiratory measurement

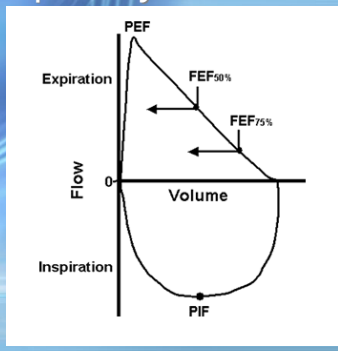


Respiratory measurement



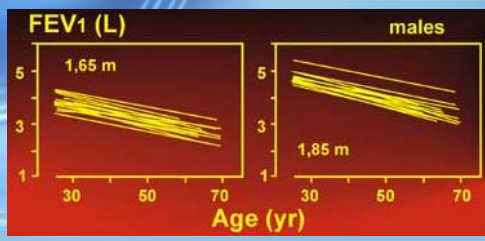
LILLY PNEUMOTACHOGRAPH

Respiratory measurement



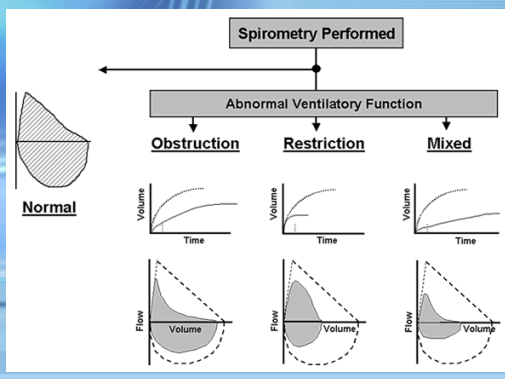
Flow volume curve

Ageing and FEV1

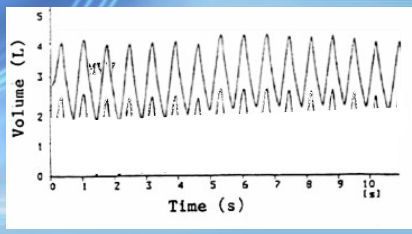


Einsekunden-Kapazität (FEV_1)

Abnormal lung function

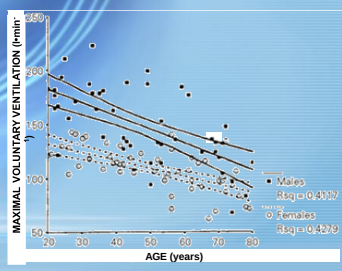


Respiratory measurement



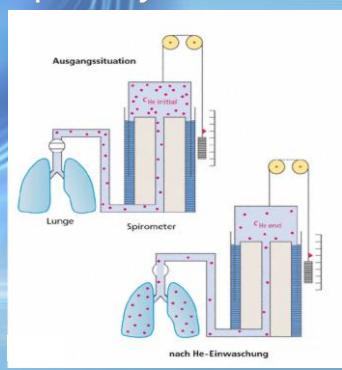
Maximal voluntary ventilation

Ageing and MVV



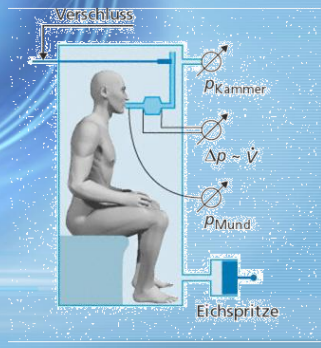
Maximal voluntary ventilation

Respiratory measurement



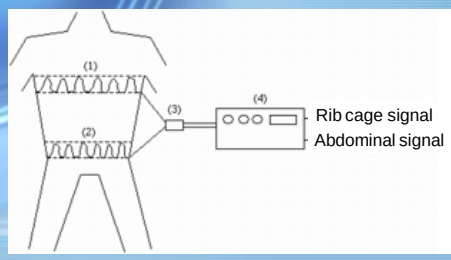
Helium dilution method

Respiratory measurement



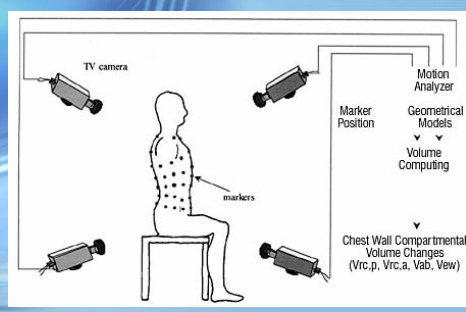
BODY PLETHYSMOGRAPHY

Respiratory measurement

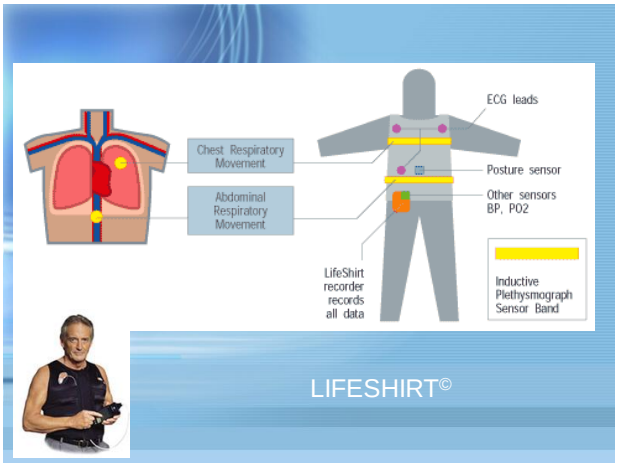


INDUCTION PLETHYSMOGRAPHY

Respiratory measurement

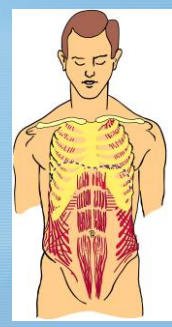


OPTOELECTRONIC PLETHYSMOGRAPHY



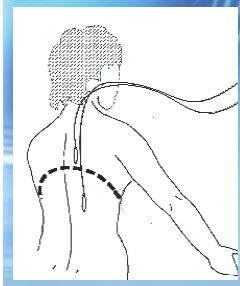
Respiratory muscles

Inspiration



Expiration

Respiratory muscle pressure measurements



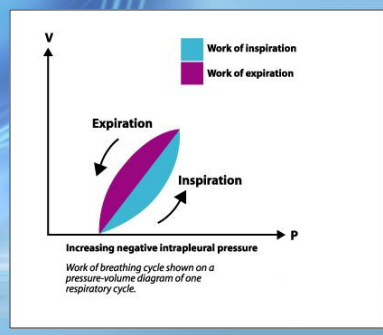
P_{es}
P_{ga}

$P_{di} = P_{ga} - P_{es}$

	Rest	
	End Exp.	End Insp.
P_{es}	-5 cmH_2O	-8 cmH_2O
P_{ga}	+8 cmH_2O	+13cmH_2O
P_{di}	+13 cmH_2O	+21 cmH_2O

Esophagus and gastric balloons

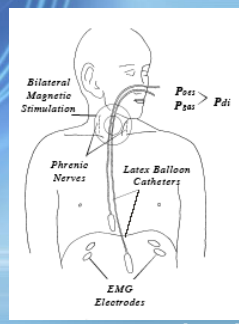
Respiratory muscle work



Work of breathing cycle shown on a pressure-volume diagram of one respiratory cycle.

$W = \Delta P \times \Delta V$

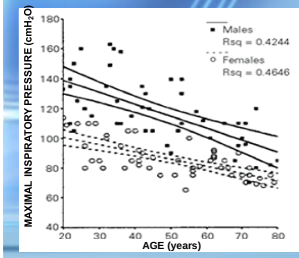
Respiratory muscle force



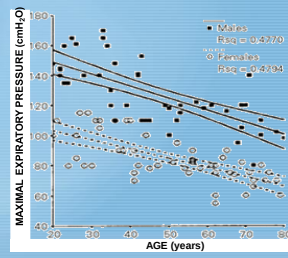
Phrenic nerve magnetic stimulation

Respiratory muscle force

Respiratory muscle force: ageing

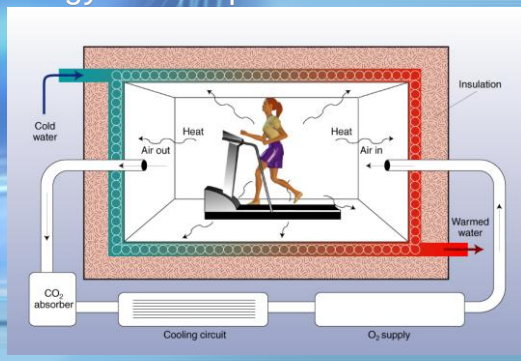


MAXIMAL INSPIRATORY PRESSURE



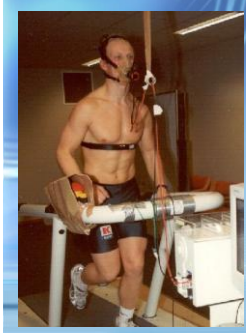
MAXIMAL EXPIRATORY PRESSURE

Energy consumption: measurements



DIRECT CALORIMETRY

Gas exchange measurements

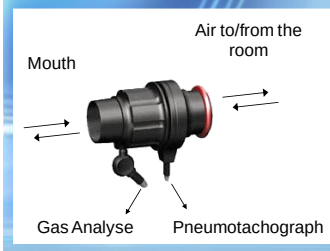


INDIRECT CALORIMETRY

Gas exchange measurements

INDIRECT CALORIMETRY

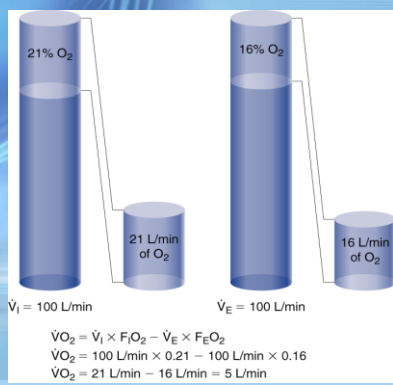
Gas exchange measurements



2-WAY VALVE

3-WAY VALVE

Gas exchange measurements



Gas exchange calculation

- Substrate energy-equivalence :
  - CHO: 4.1 kcal/g
  - Fat: 9.4 kcal/g
  - Protein: 4.1 kcal/g
- Energy per Liter of oxygen:
  - CHO: 5.0 kcal/L
  - Fat: 4.7 kcal/L
  - Protein: 4.5 kcal/L
- Example:

$\dot{V}O_2$ Rest = 0.300 L/min, 60 min/h, 24 h/d, 4.8 kcal/LO_2
Total $\dot{V}O_2$ = 432 L/d
Total energy consumption = 2074 kcal/d

Respiratory exchange ratio

$$RER = \dot{V}CO_2 / \dot{V}O_2$$

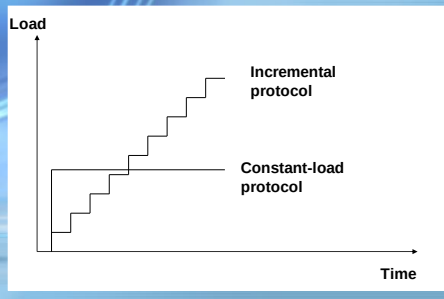
Resting value: 0.78 - 0.80

Respiratory exchange ratio

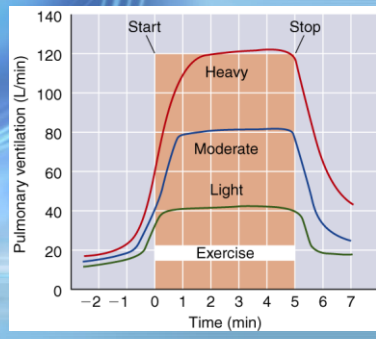
	Energy	% kcal	
RER	kcal/L O_2	Carbohydrates	Fats
0.71	4.69	0.0	100.0
0.75	4.74	15.6	84.4
0.80	4.80	33.4	66.6
0.85	4.86	50.7	49.3
0.90	4.92	67.5	32.5
0.95	4.99	84.0	16.0
1.00	5.05	100.0	0.0

Ventilation and gas exchange during exercise

Incremental protocol / Constant-load protocol



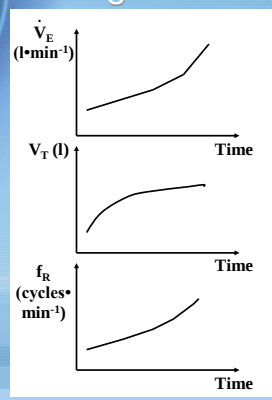
Ventilation during exercise



Ventilation during constant-load exercise

Ventilation during exercise

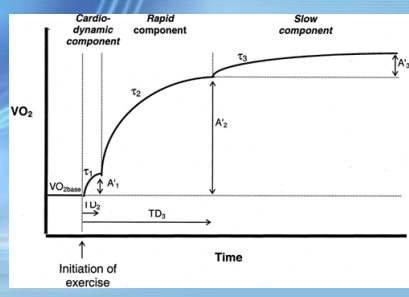
Incremental protocol



O_2 consumption: FICK Equation

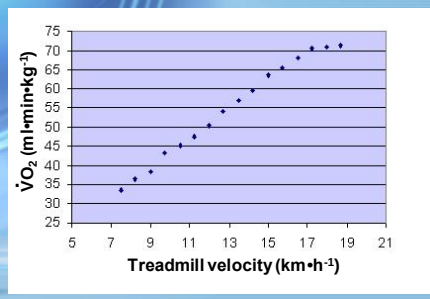
O_2 consumption ($\dot{V}O_2$)
=
Cardiac output (CO)
x
Arterio-venous O_2-Difference (Da-vO_2)

O_2 consumption during exercise



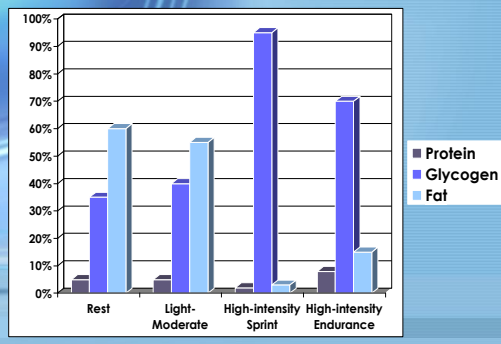
Constant load test

O_2 consumption during exercise

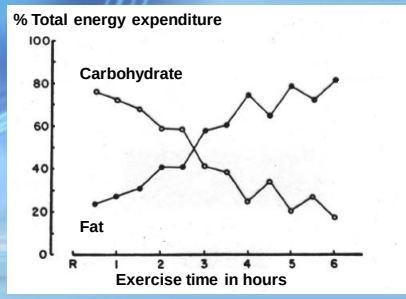


Incremental test

Substrate utilization during exercise

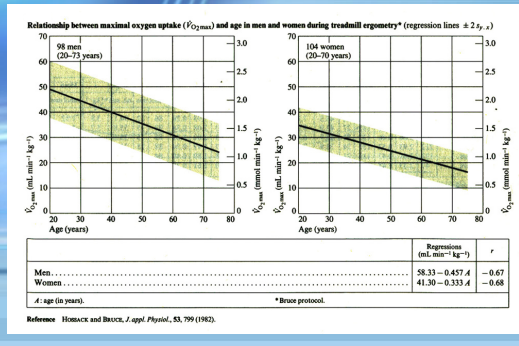


Substrate utilization during exercise



Constant-load moderate intensity

Maximal oxygen consumption: ageing



Relationship between maximal oxygen uptake ($\dot{V}_{O_2max}$) and age in men and women during treadmill ergometry* (regression lines ± 2 $s_{y.x}$)

98 men (20–73 years)

104 women (20–70 years)

$\dot{V}_{O_2max}$ (mL · min^{-1} · kg^{-1})

$\dot{V}_{O_2max}$ (mmol · min^{-1} · kg^{-1})

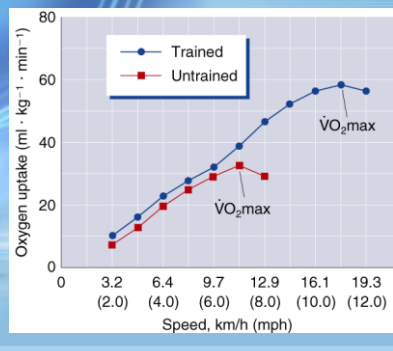
Age (years)

	Regressions (mL · min^{-1} · kg^{-1})	r
Men	58.33 − 0.457 A	−0.67
Women	41.30 − 0.333 A	−0.68

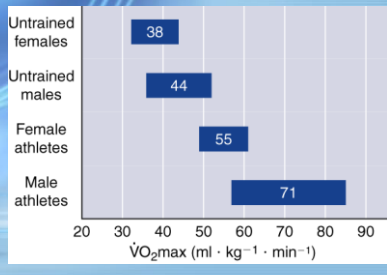
A: age (in years). * Bruce protocol.

Reference HOSKACK and BRUCE, *J. appl. Physiol.*, **53**, 799 (1982).

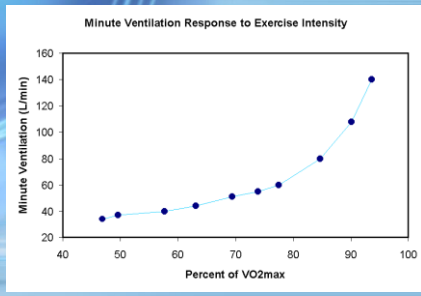
Maximal oxygen consumption: effect of training



Maximal oxygen consumption: effect of training

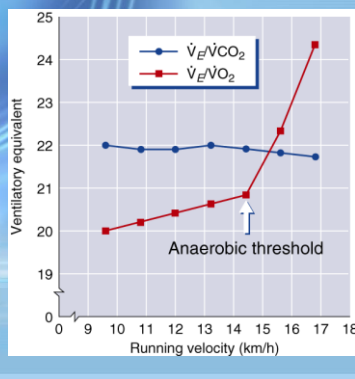


Anaerobic threshold

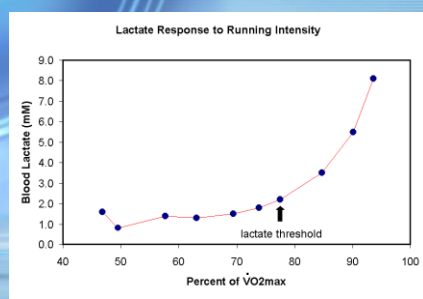


Incremental test

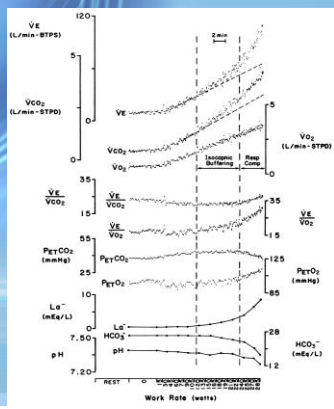
Anaerobic threshold



Anaerobic threshold



Anaerobic threshold



Anaerobic threshold: effect of training