ESCOLA SUPERIOR
DE SAÚDE DO ALCOITÃO

SANTA CASA da Misericórdia de Lisboa

Oxygen transport: a physiologically-based conceptual framework for the promotion of Funcionality

António Alves Lopes
Portugal >> Groninger | 2015


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1277


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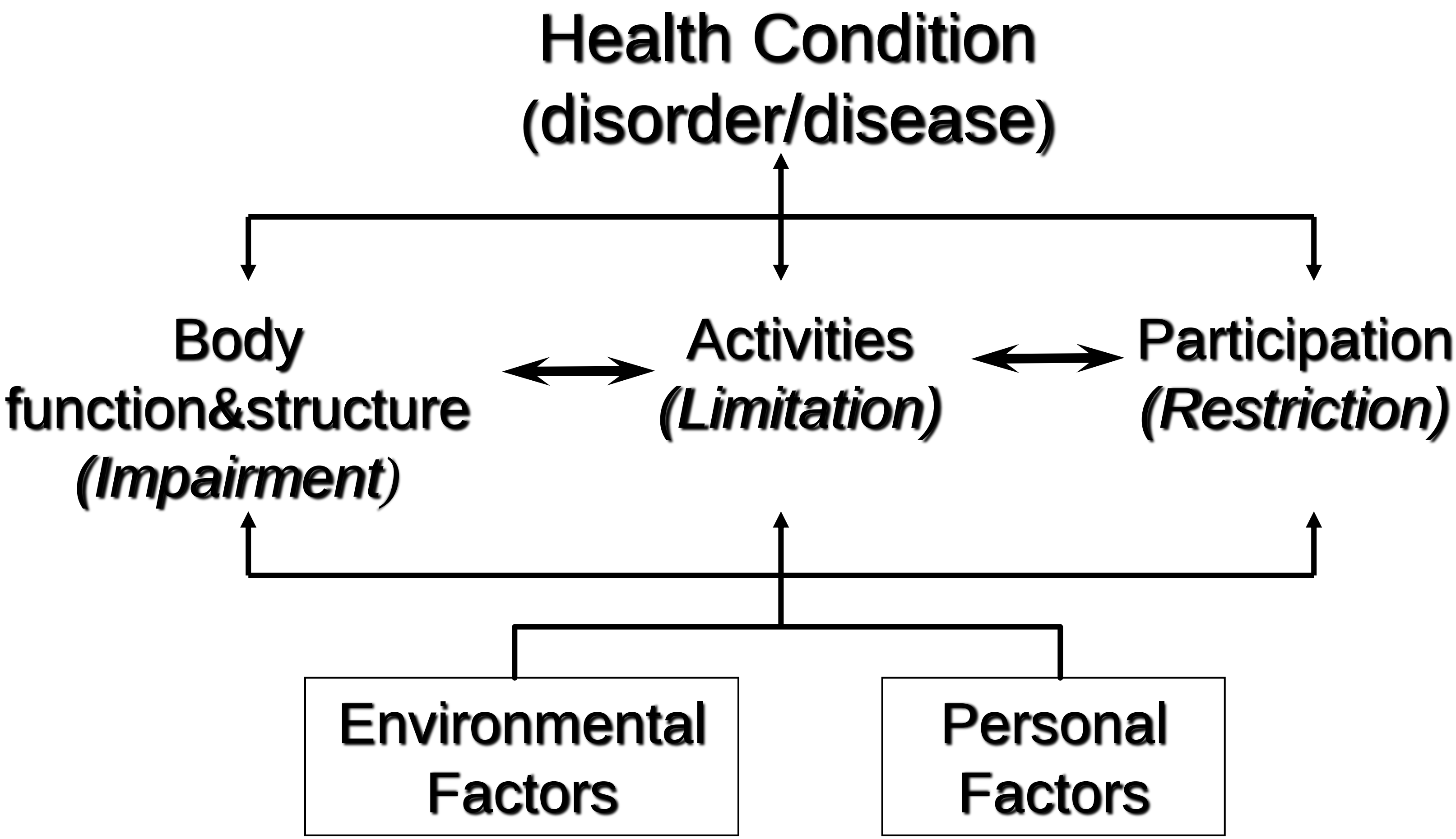
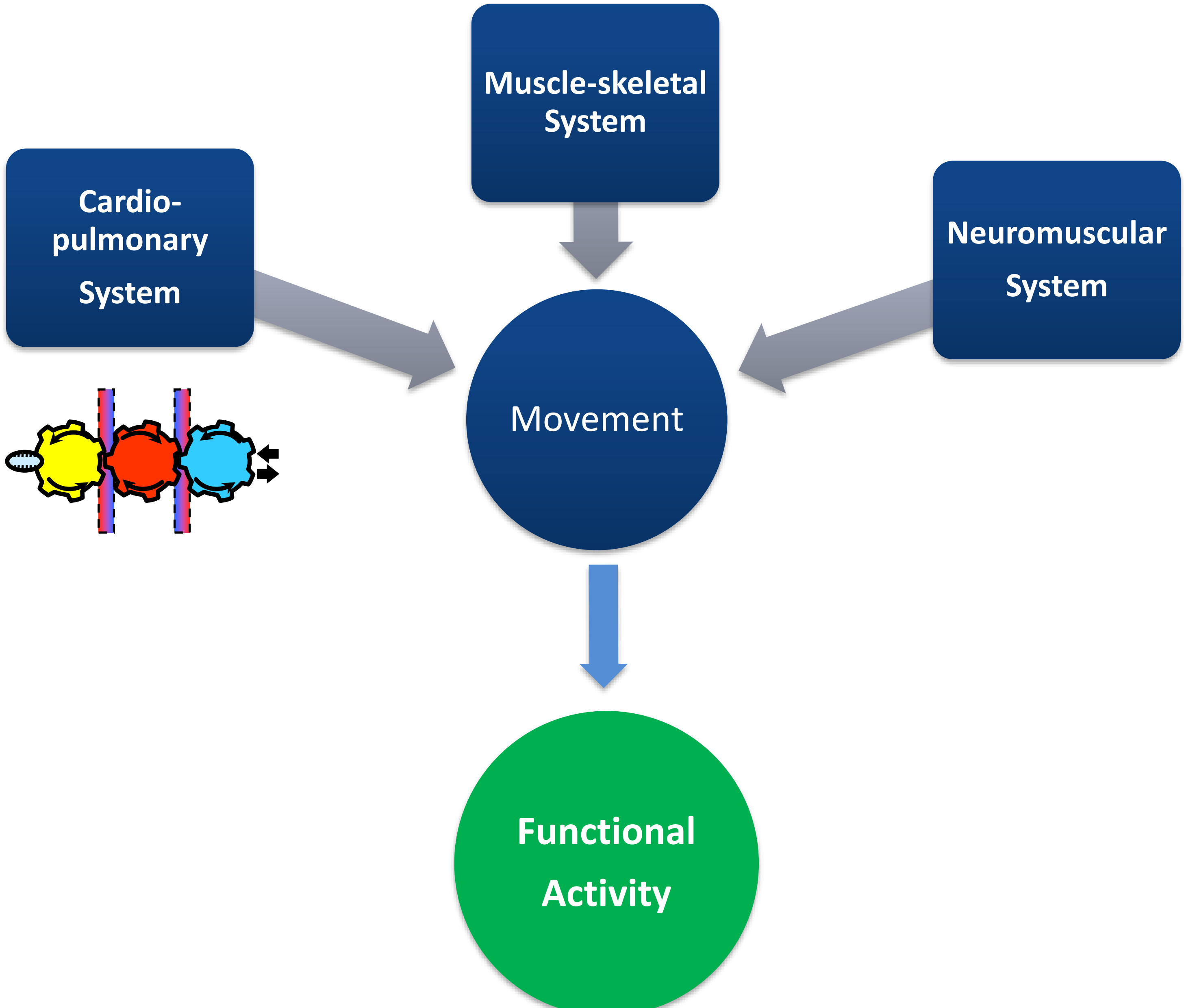
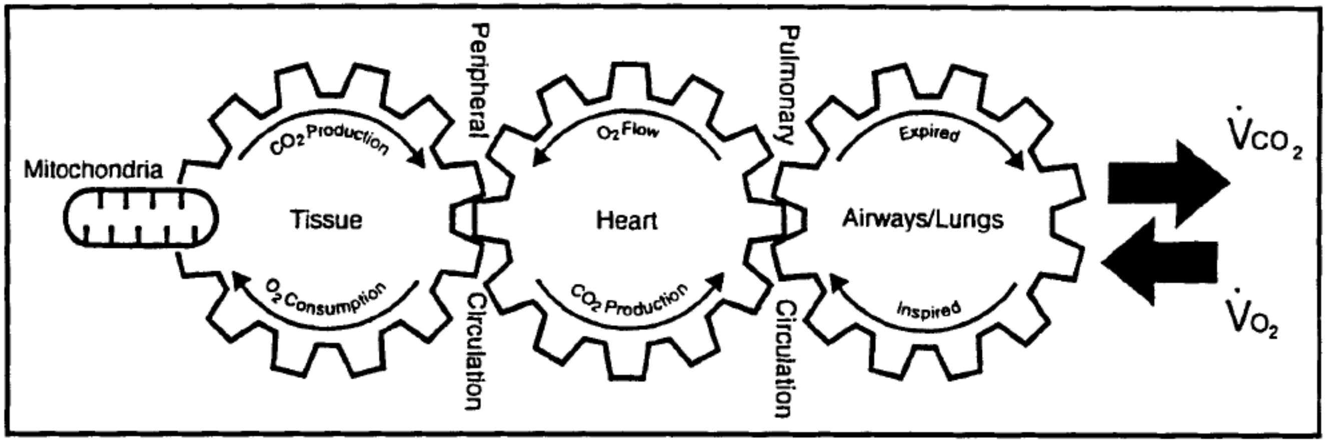
Interaction of Concepts ICF 2001




Muscle-skeletal System
Cardio-pulmonary System
Neuromuscular System
Movement
Functional Activity

Oxygen Transport System

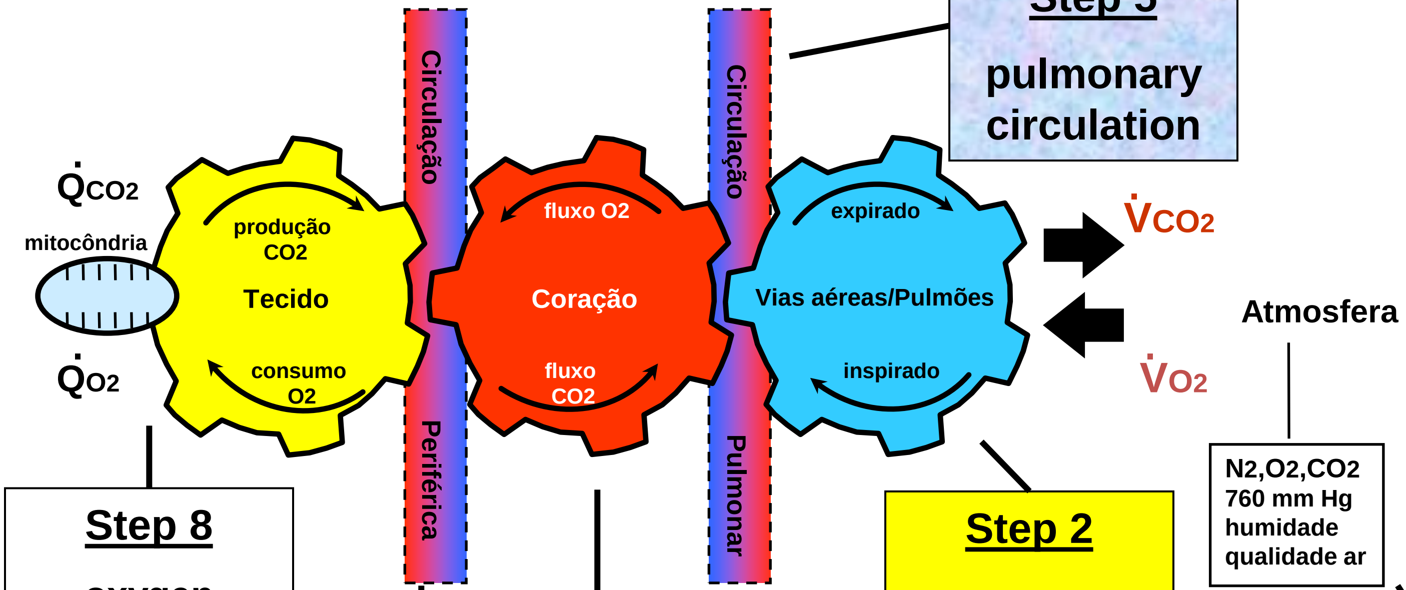


Delivery or supply of **fully oxygenated blood** to peripheral tissues, the cellular uptake of oxygen, the utilization of oxygen in the tissue, and the return of **partially desaturated blood** to the lungs.

The steps in this system include:

Step 9

Return of CO_2 and partially desaturated blood to the lungs



Step 5

pulmonary circulation

Step 8

oxygen extraction and utilization in the muscle and tissues

Step 6

Cardiac Function

Step 2

Airways

Step 3

Lungs

Step 1

the quality of inspired gas

Step 7

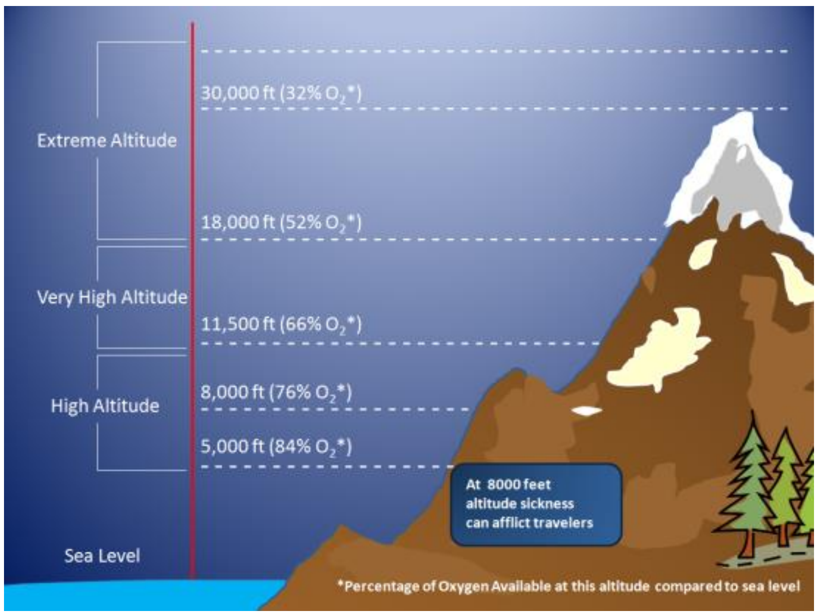
Peripheral circulation

Step 4

diffusion

Step 1: Inspired Oxygen and Quality of the Ambient Air

Atmospheric air consists of 79% nitrogen, 20.97% oxygen, and 0.03% carbon dioxide



- altitude,
- geographical area,
- season,
- population density,
- home and work environment,
- level of ventilation,
- …

Step 2: Airways

Airway structure and function

Airway obstruction and increased resistance to airflow, is caused by multiple factors:

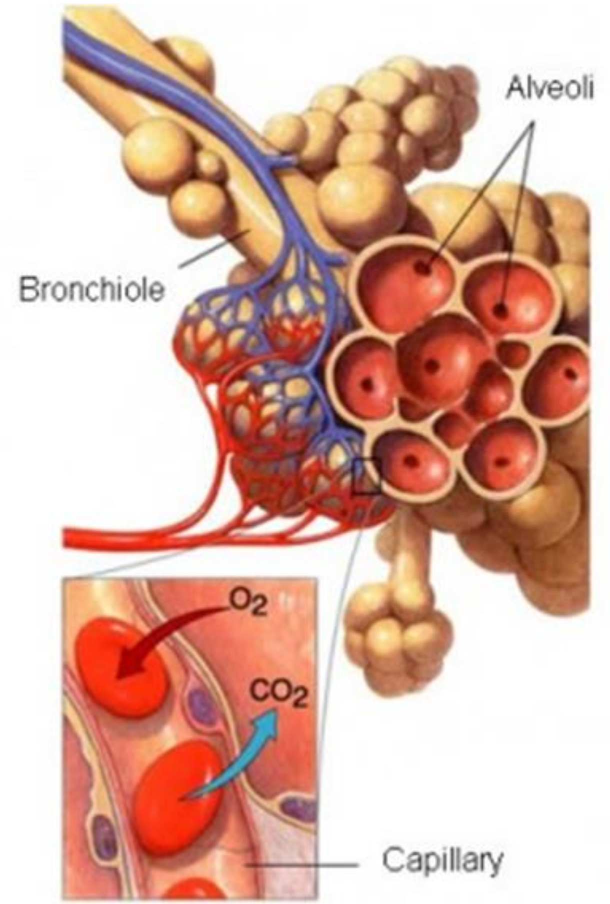
- edema, mucus, foreign objects, calcification, particulate matter, space-occupying lesions, and hyper-reactivity of bronchial smooth muscle.

Step 3: Lungs and Chest Wall

Air entry to the lungs depends on the integrity of :

- Respiratory drive (CNS)
- Respiratory muscles, in particular the diaphragm
- Chest wall (mobility and protection)
- Pleural (negative intrapleural pressure gradient)
- Parenchyma (compliance and elastic recoil)

Step 4: Diffusion



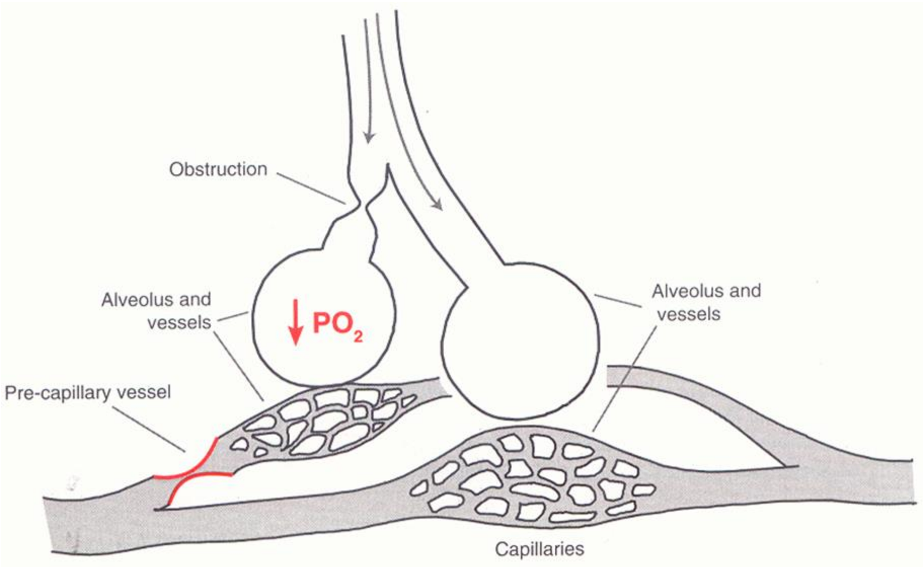
Diffusion of oxygen from the alveolar sacs to the pulmonary arterial circulation depends on:

- area of the alveolar capillary membrane,
- diffusing capacity of the alveolar capillary membrane,
- pulmonary capillary blood volume,
- ventilation-perfusion ratio

(Ganong, 2003).

Step 5: Perfusion

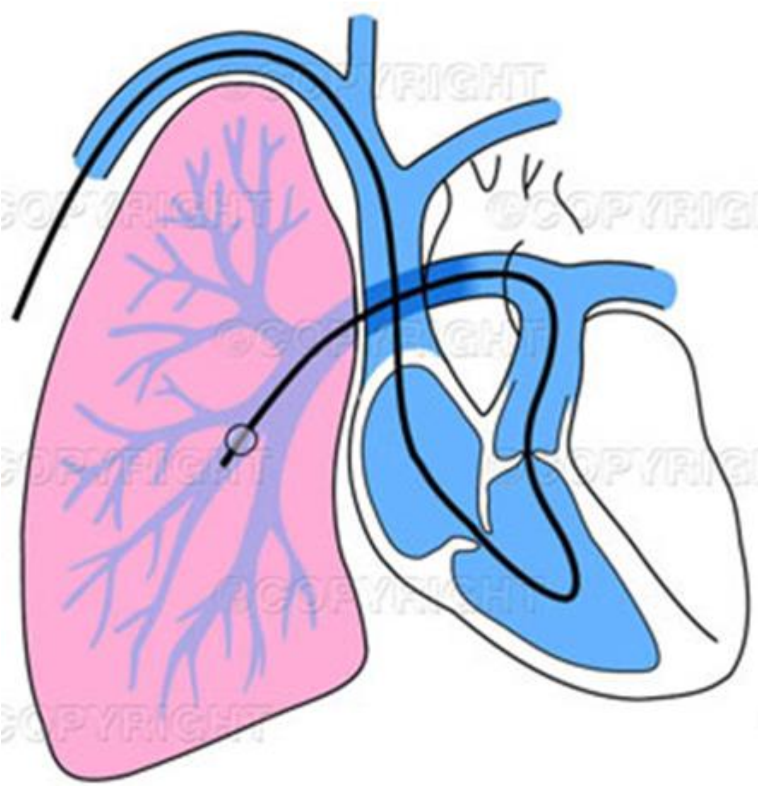
The distribution of blood perfusing the lungs is primarily gravity dependent:



- In the upright lung the bases are better perfused than the apices.
- Ventilation and perfusion matching is optimal in the midzones of the lungs when a person is upright (West, 1985).

Step 6: Myocardial Function

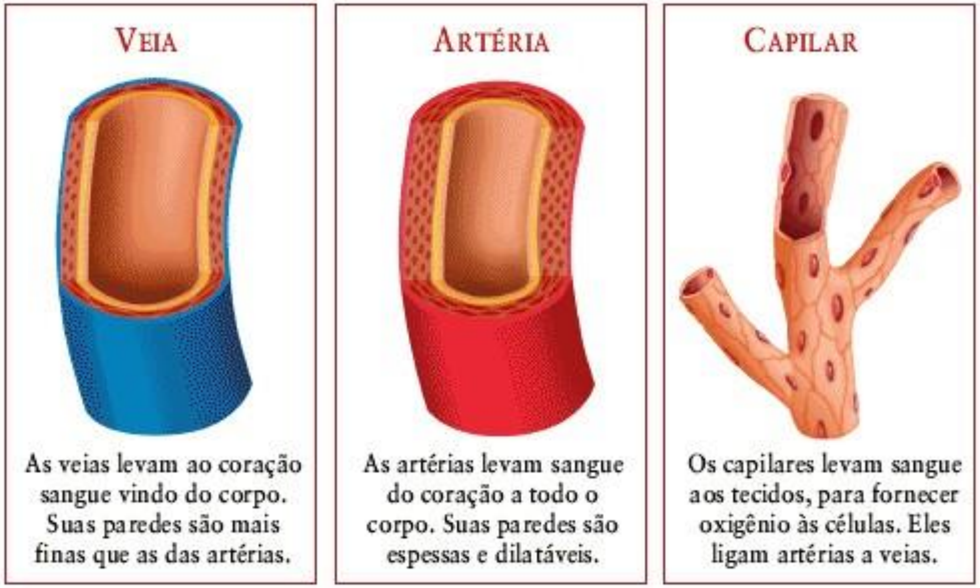
Optimal myocardial function and cardiac output depend on:



- Synchronized coupling of electrical excitation of the heart and mechanical contraction
- The distensibility of the ventricles
- Contractility of the myocardial muscle

Step 7: Peripheral Circulation

Once oxygenated blood is ejected from the heart, the peripheral circulation provides a conduit for supplying this blood to metabolically active tissue

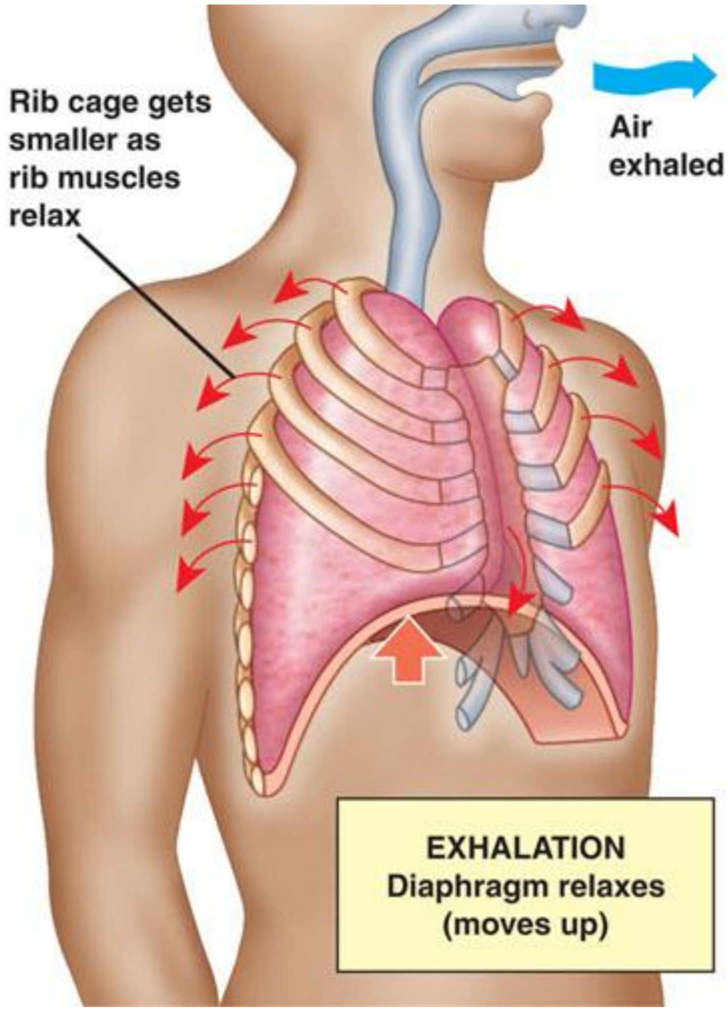


Step 8: Tissue Extraction and Utilization of Oxygen

All cells in the body continually use oxygen, which rapidly diffuses out of the circulation and through cell membranes to meet metabolic needs:

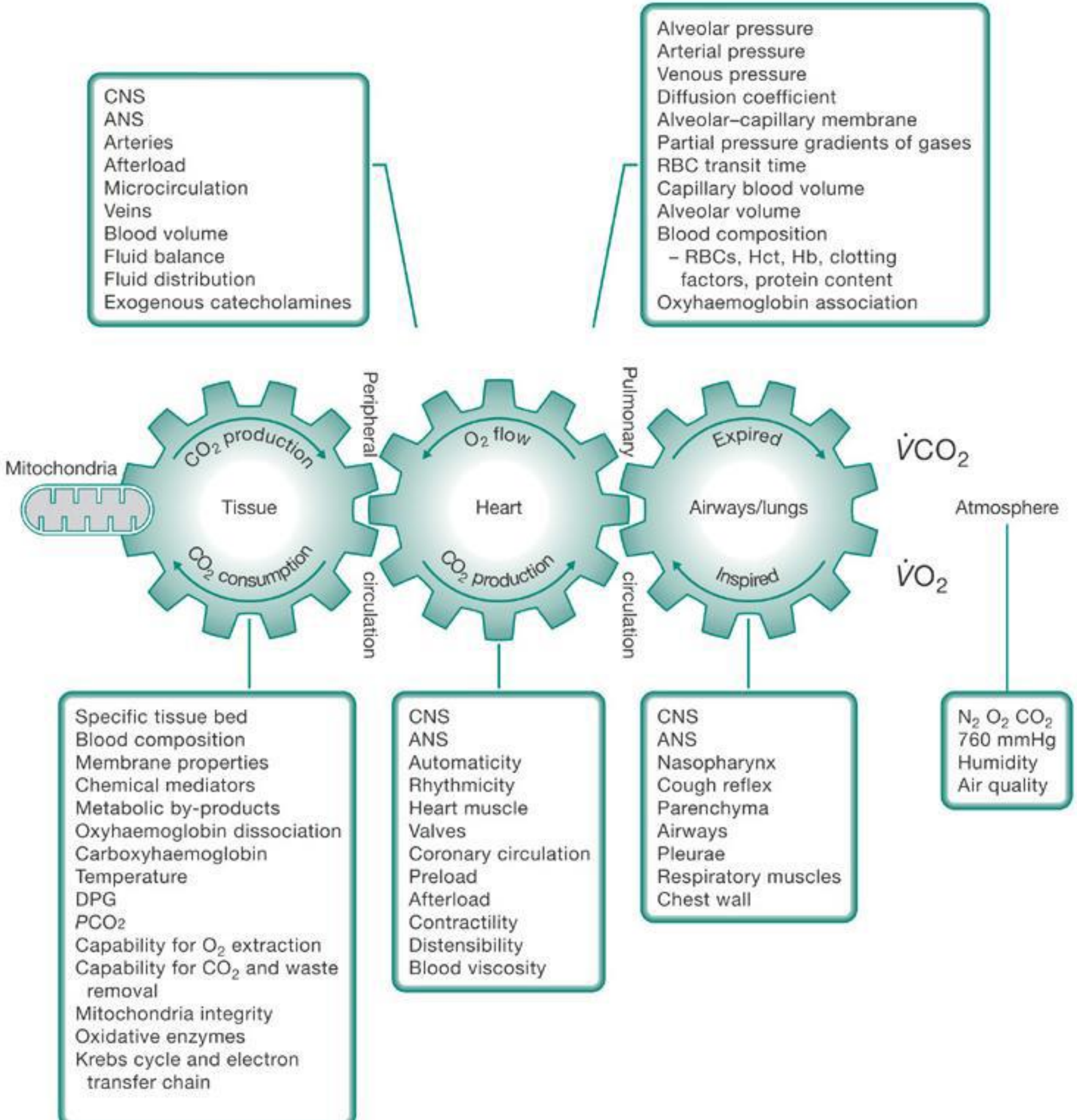
- Distance between the capillaries and the cells is variable
- Oxygen pressure (PaO2)
- Rate of oxygen extraction by the cells is regulated by their oxygen demand

Step 9: Return of Partially Desaturated Blood and Carbon Dioxide to the Lungs

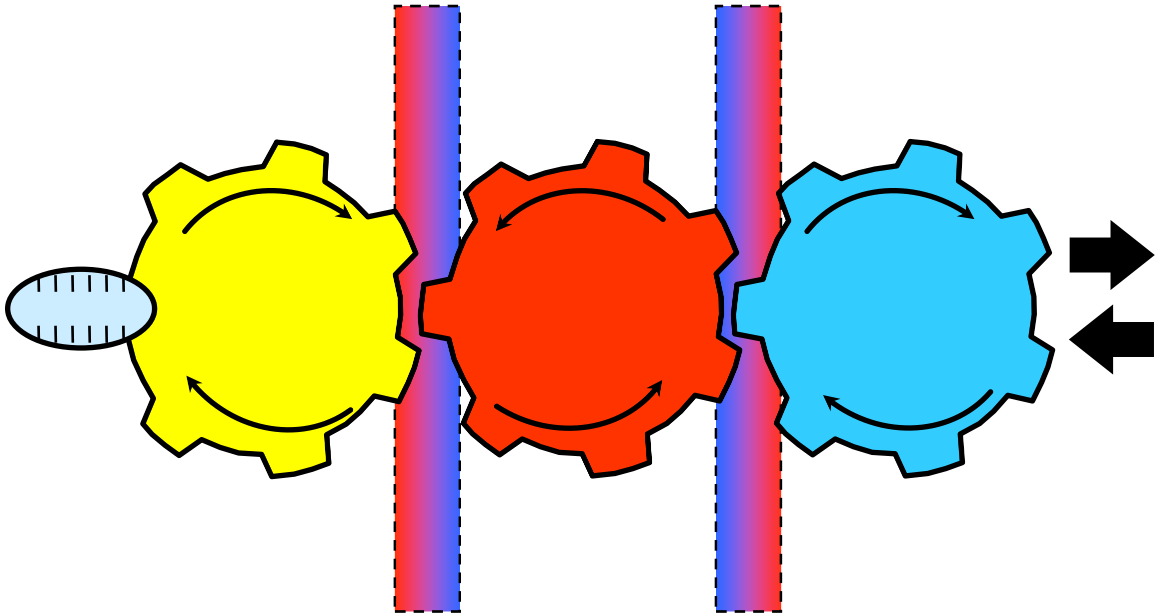


- Partially desaturated blood and carbon dioxide are removed from the cells via the venous circulation to the right side of the heart and lungs;

- Carbon dioxide diffuses across the alveolar capillary membrane and is eliminated from the body via the respiratory system, and the deoxygenated venous blood is reoxygenated;



(Modified from Wasserman et al 1987)



- **No one step is rate limiting; rather each step can individually alter oxygen transport to organ tissues.**
- The system attempts to compensate for limitations at any step.
- In healthy person, this system is acutely responsive to changes in oxygen demand, and changes oxygen delivery correspondingly.

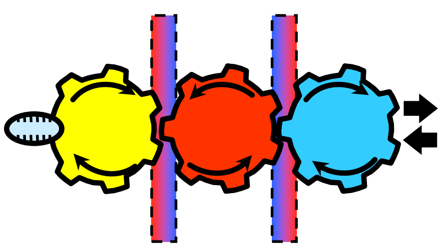
WHY???

WHY GOD WHY!!!

Interaction of Concepts

Health Condition
(disorder/disease)

Body function&structure ***(Impairment)*** ↔ **Activities** ***(Limitation)*** ↔ **Participation** ***(Restriction)***



Impact during the Life Span

Respiratory System: Functional Divisions and Changes with Aging

Functional Division	Components	Function	Change(s) with Aging
Conducting airways	All airways not involved in gas exchange (mouth to terminal bronchioles)	Gas movement between environment and alveolar space	Slight changes in size; calcification; glandular hypertrophy
Lung parenchyma	Gas-exchanging airways and vessels; connective tissue framework	Gas exchange between alveolar space and capillary blood	Enlarged terminal airspaces; ventilation/perfusion mismatching
Bellows apparatus	Chest wall and muscles of respiration	Provide mechanical forces for ventilation	Increased rigidity of chest wall; decreased respiratory muscle strength
Ventilatory control	Respiratory control center (pons and medulla); carotid and aortic bodies	Maintaining homeostasis by altering ventilation to match metabolic needs	Markedly decreased responses to hypercapnia and hypoxemia
Cardiovascular system	Heart and systemic vasculature	Blood transport and tissue exchange of respiratory gases	Decreased maximal heart rate and cardiac output; decreased responsiveness to hypoxemia

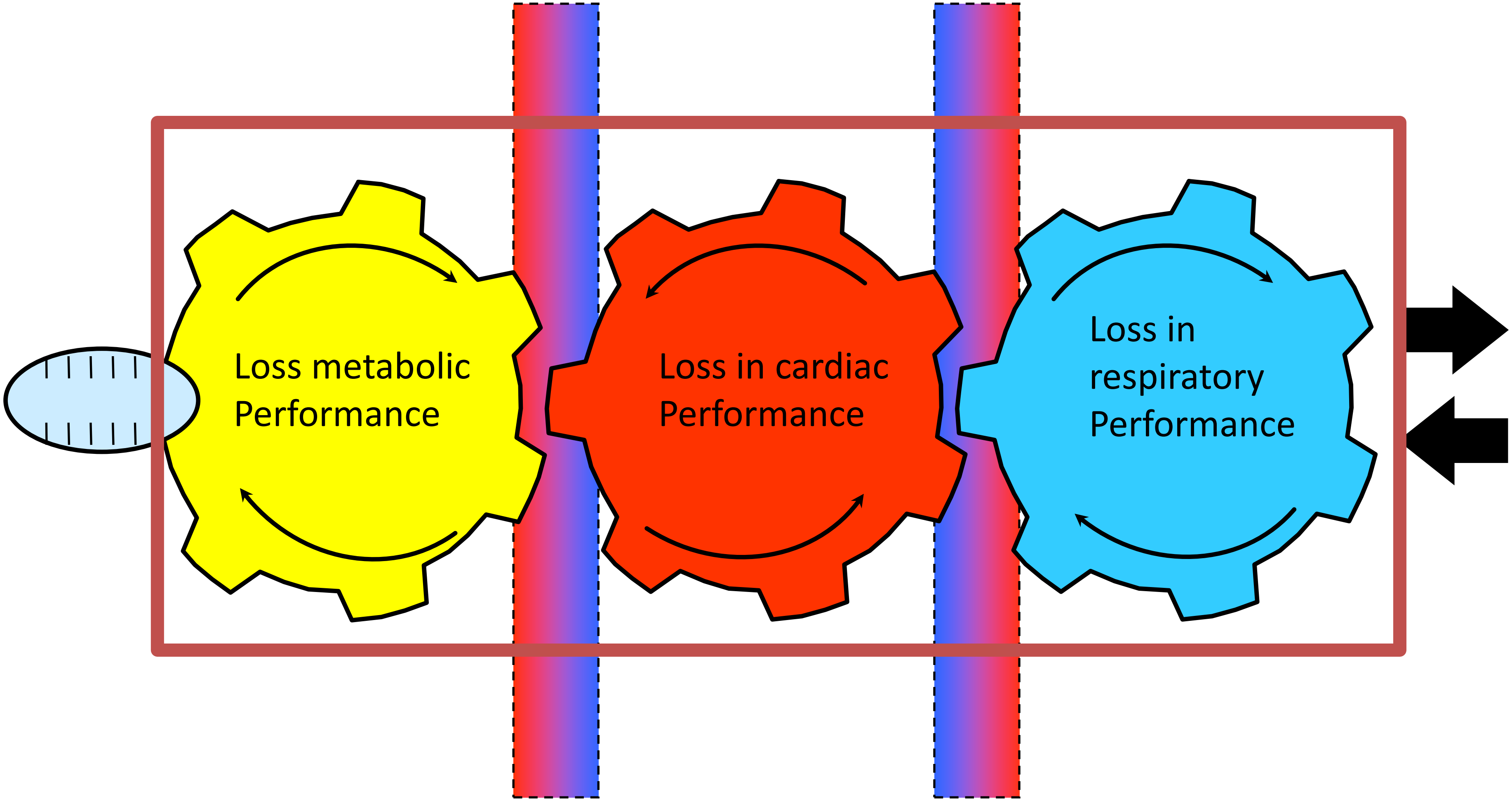
Fishman's Pulmonary Diseases and Disorders (2008)

Impact during the Life Span

Variables Associated with a Decline in Exercise Capacity with Age	
Variable	**Comment**
Decreased muscle mass	These changes especially affect $\dot{V}O_2$ calculated per kg of body weight
Increased fat mass	
Decreased cardiac output oxygen	As a result of the decreased cardiac output and maximal $C(a-\bar{v})O_2$, delivery and extraction are reduced; decreased cardiac output is a major contributor to the age-related decline in exercise capacity
Decreased maximal stroke volume	
Decreased maximal heart rate	
Decreased maximal $C(a-\bar{v})O_2$ difference	
Decreased maximum voluntary ventilation	
Increased ventilation at each workload	At each workload, older individuals breathe more and work harder for each breath than younger persons; however, the effect is small and contributes little to the decline in exercise capacity with aging
Increased oxygen cost of breathing	
Sedentary life-style	Life-style issues play a large role in the rate at which exercise capacity is lost with age; the good news is that, like other deconditioned groups, the elderly respond very well to exercise training
Decreased training intensity in active persons	
Decreased willingness to work to maximal level during tests	

Fishman's Pulmonary Diseases and Disorders (2008)

Impact on the Oxygen Transport System

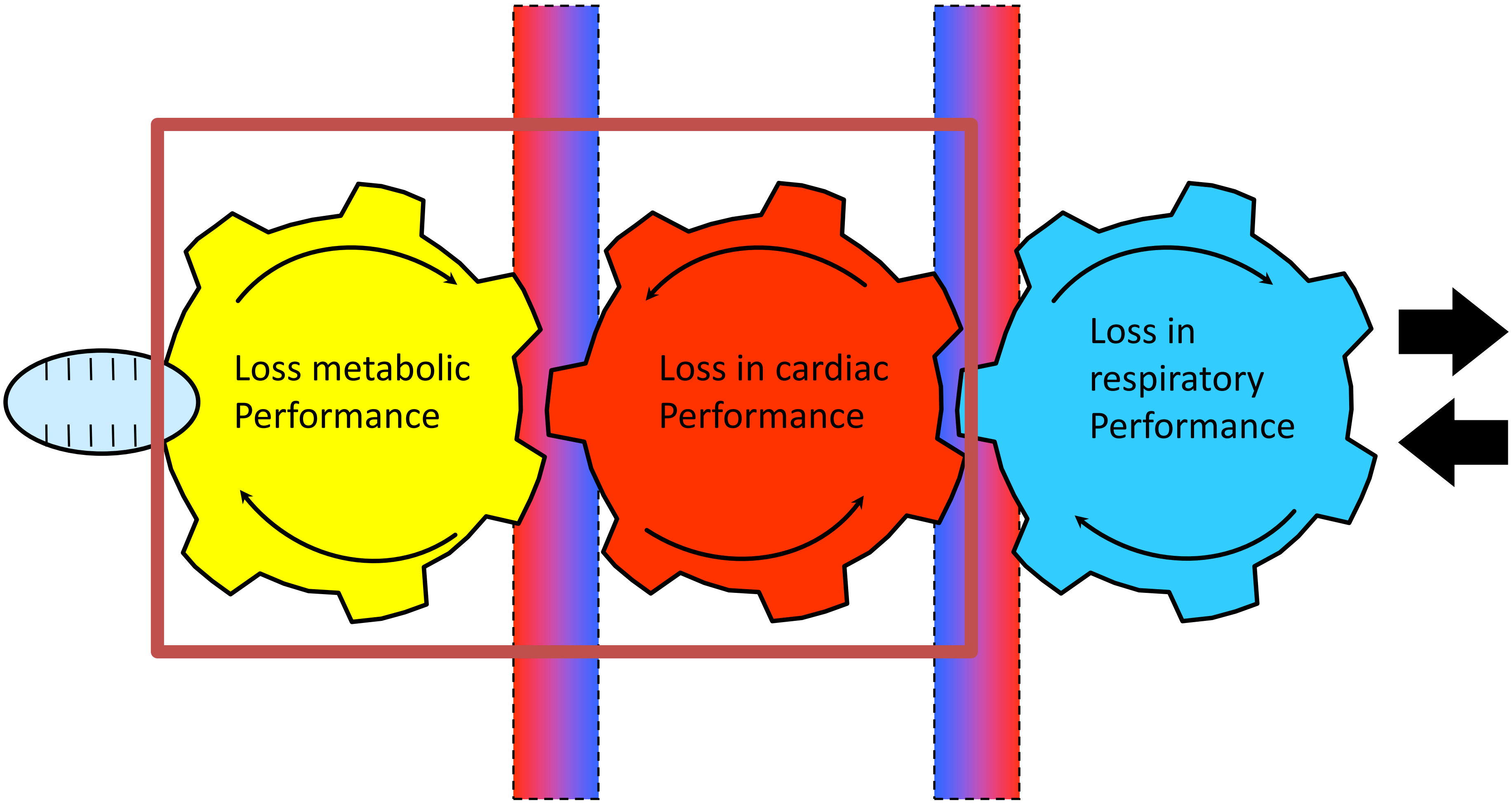


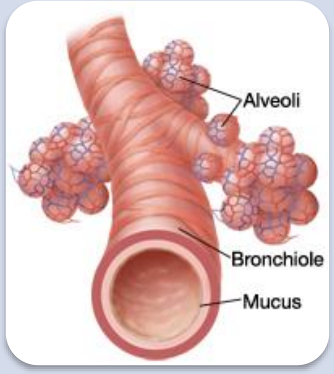
What are common health consequences of overweight and obesity?

Raised BMI is a major risk factor for noncommunicable diseases such as:

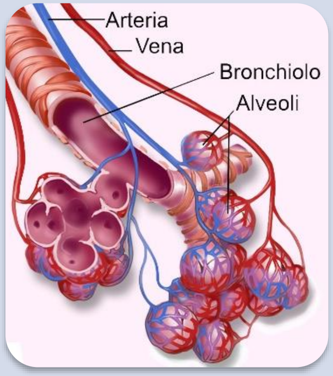
- cardiovascular diseases (mainly heart disease and stroke), which were the leading cause of death in 2012;
- diabetes;
- musculoskeletal disorders (especially osteoarthritis - a highly disabling degenerative disease of the joints);
- some cancers (endometrial, breast, and colon).

Impact on the Oxygen Transport System

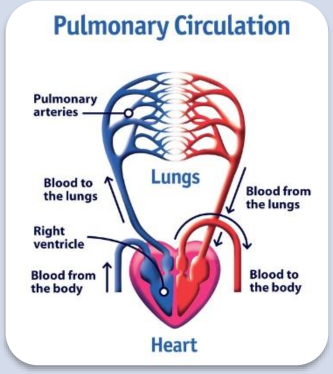




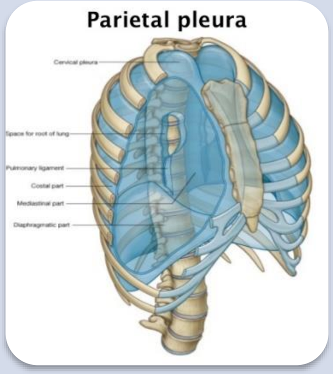
Lung Diseases Affecting the Airways



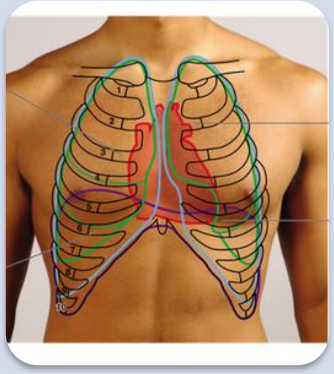
Lung Diseases Affecting the Air Sacs (Alveoli)



Lung Diseases Affecting Blood Vessels



Lung Diseases Affecting the Pleura



Lung Diseases Affecting the Chest Wall

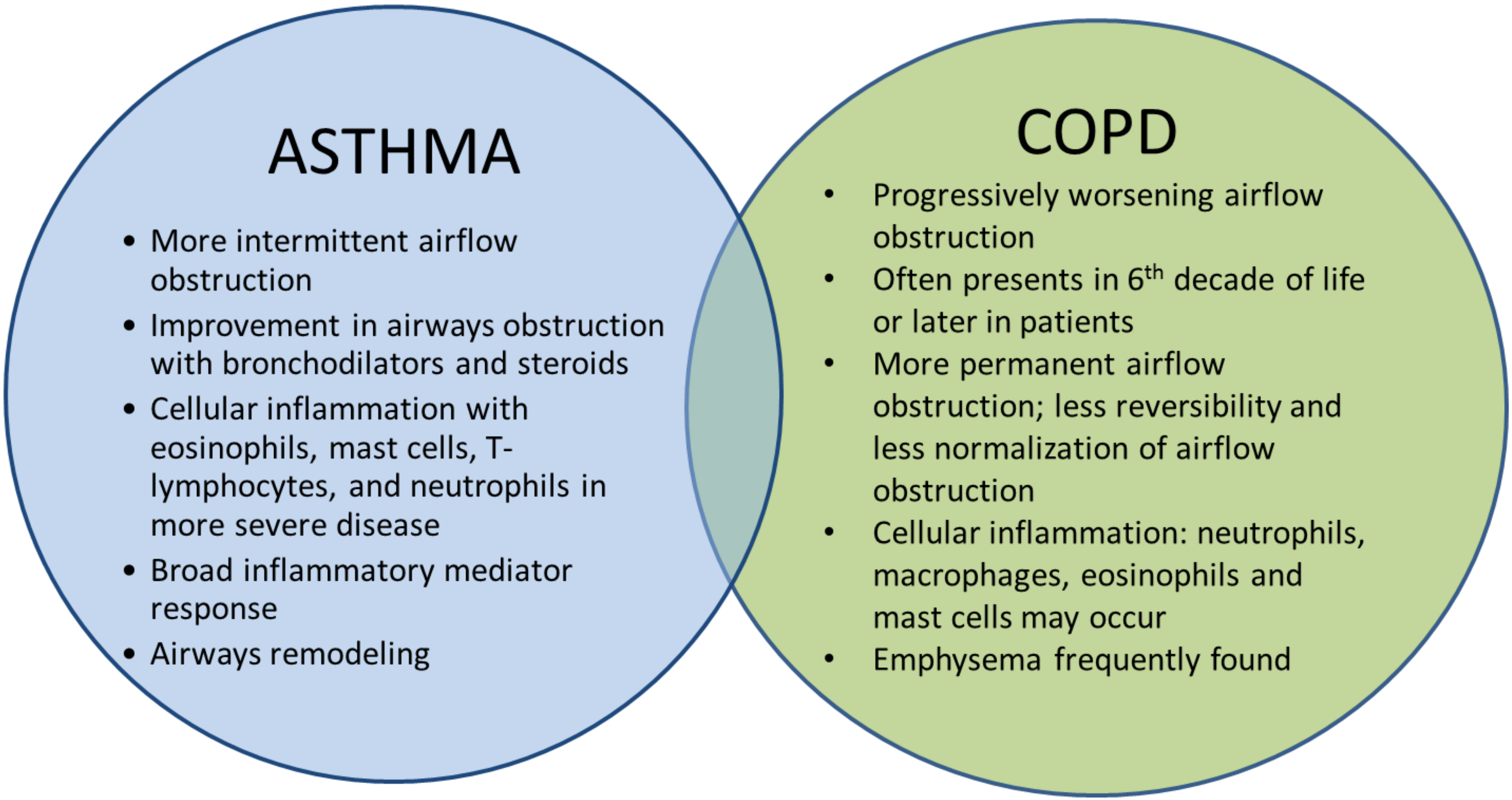
Consequences

Obstrutive

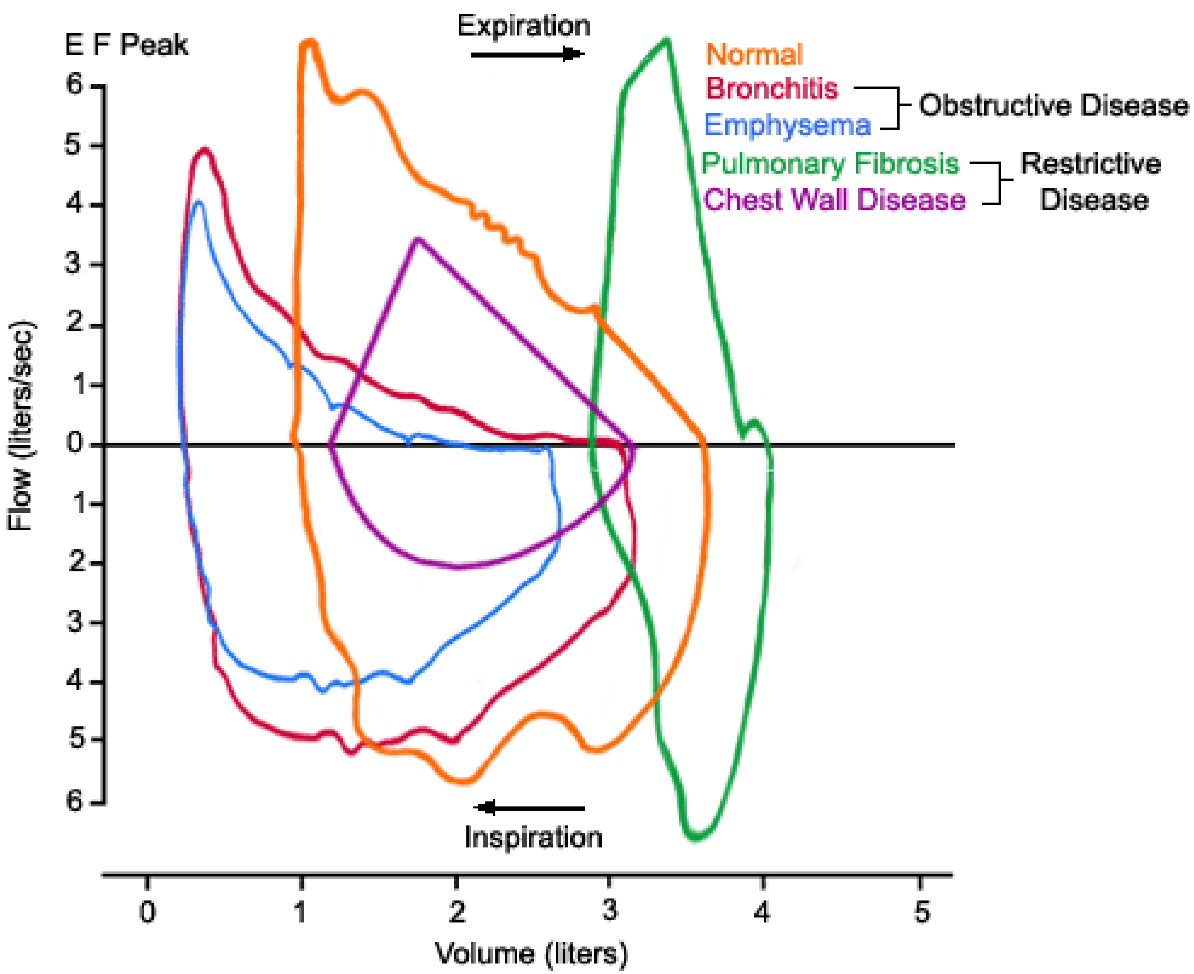
People with obstructive lung disease have shortness of breath due to difficulty exhaling all the air from the lungs.
Because of damage to the lungs or narrowing of the airways inside the lungs, exhaled air comes out more slowly than normal.

Restrictive

People with restrictive lung disease cannot fully fill their lungs with air. Their lungs are restricted from fully expanding.
Often results from a condition causing stiffness in the lungs or stiffness of the chest wall, weak muscles, or damaged nerves

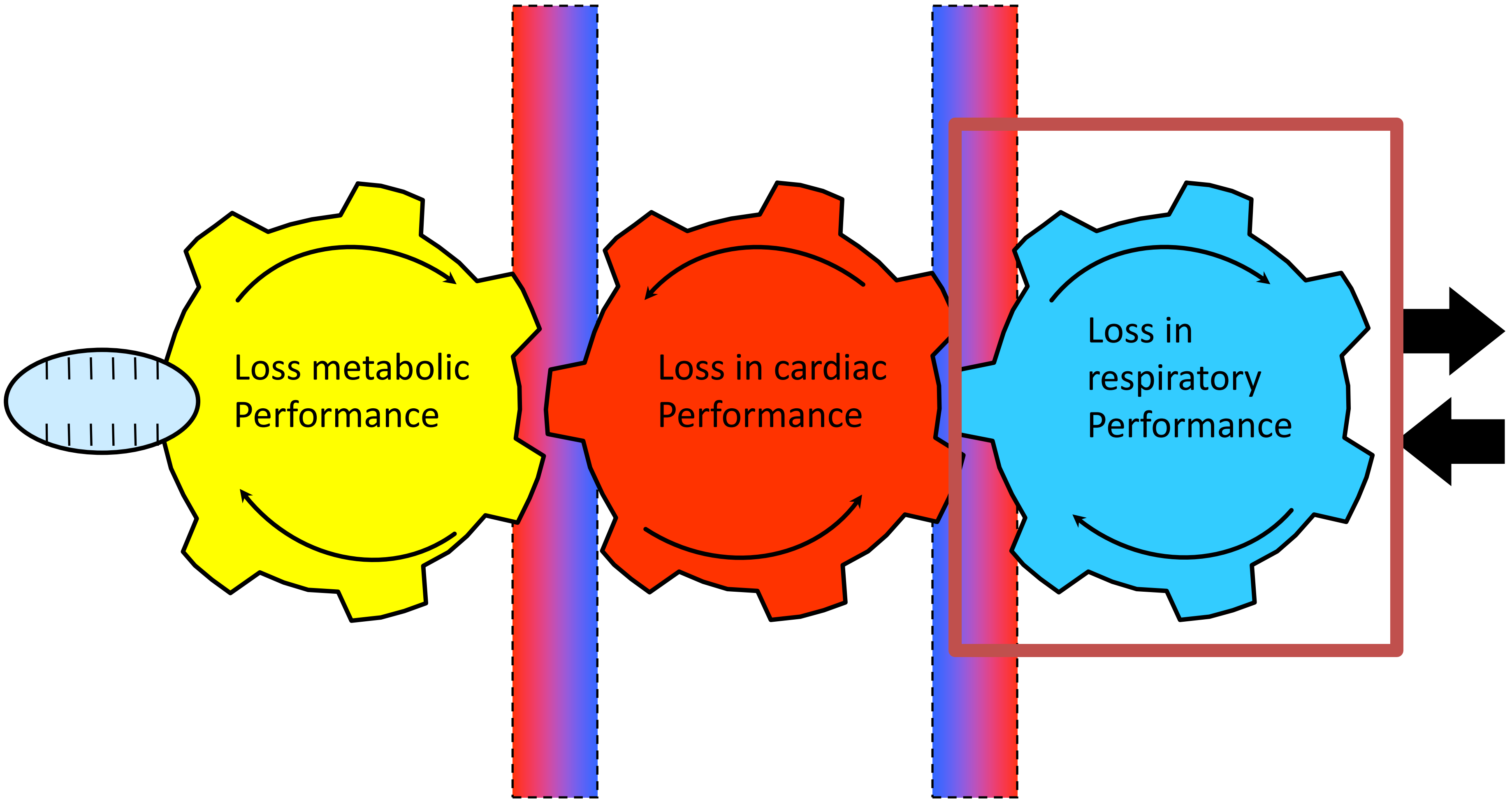

ASTHMA
• More intermittent airflow obstruction
• Improvement in airways obstruction with bronchodilators and steroids
• Cellular inflammation with eosinophils, mast cells, T-lymphocytes, and neutrophils in more severe disease
• Broad inflammatory mediator response
• Airways remodeling
COPD
• Progressively worsening airflow obstruction
• Often presents in 6th decade of life or later in patients
• More permanent airflow obstruction; less reversibility and less normalization of airflow obstruction
• Cellular inflammation: neutrophils, macrophages, eosinophils and mast cells may occur
• Emphysema frequently found

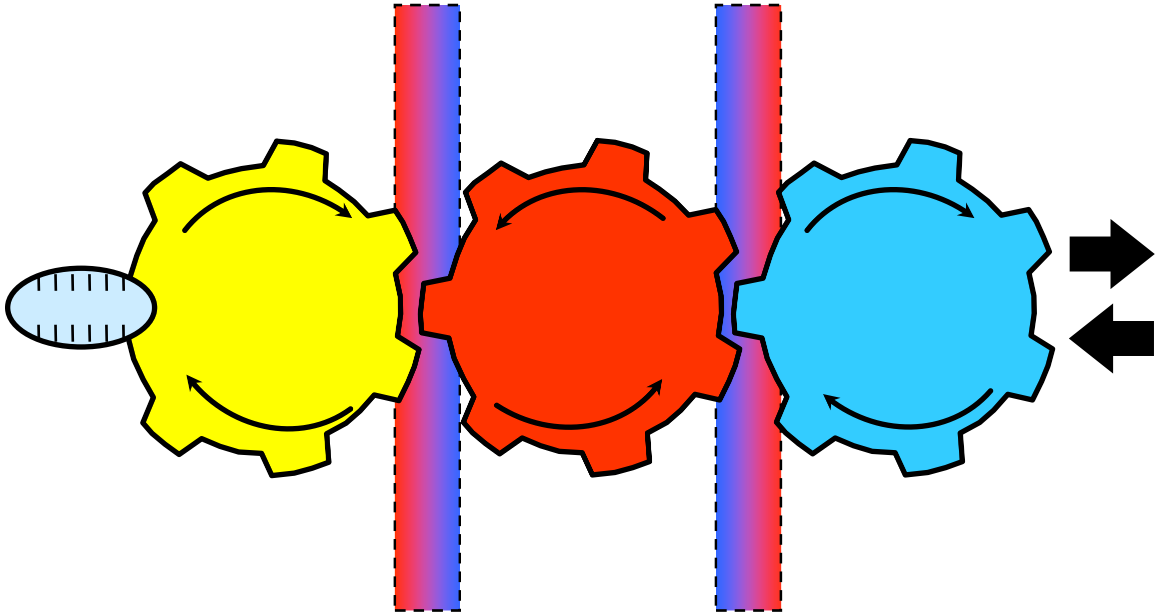
Pulmonary Function output



- Normal
- Bronchitis
- Emphysema
- Pulmonary Fibrosis
- Chest Wall Disease
- Overview

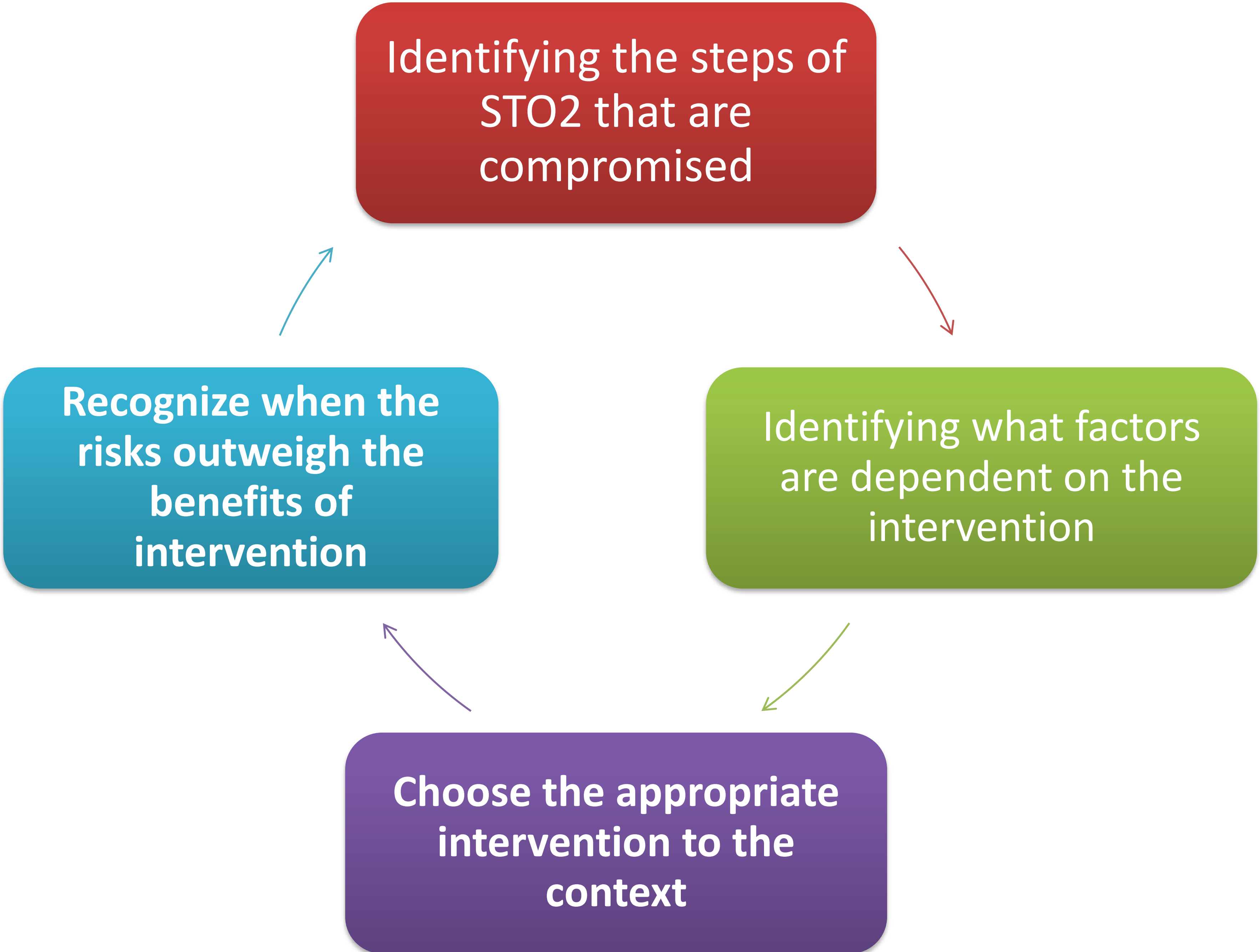
Impact on the Oxygen Transport System





An ability to analyze the contribution or threat of these factors to oxygen transport will ensure that strategies are directed at the underlying limitations, promoting a maximally beneficial and cost effective intervention.

Dean & Frownfelter (2006)



Dean & Frownfelter (2006)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minions
PRIVATE STRUCTURE
Kalenji

So… what is the best intervention to optimize the Oxygen Transport System?

1 º Premise

The position of optimal physiological function is being upright and moving

2 º Premise

Enhances the oxygen-carrying capacity + Produces the greatest adjustment = Optimal Stimulus

"The best stimulation is one that enhances the oxygen-carrying capacity of the individual and produces the greatest adjustment without causing damage."

Dean (2012)

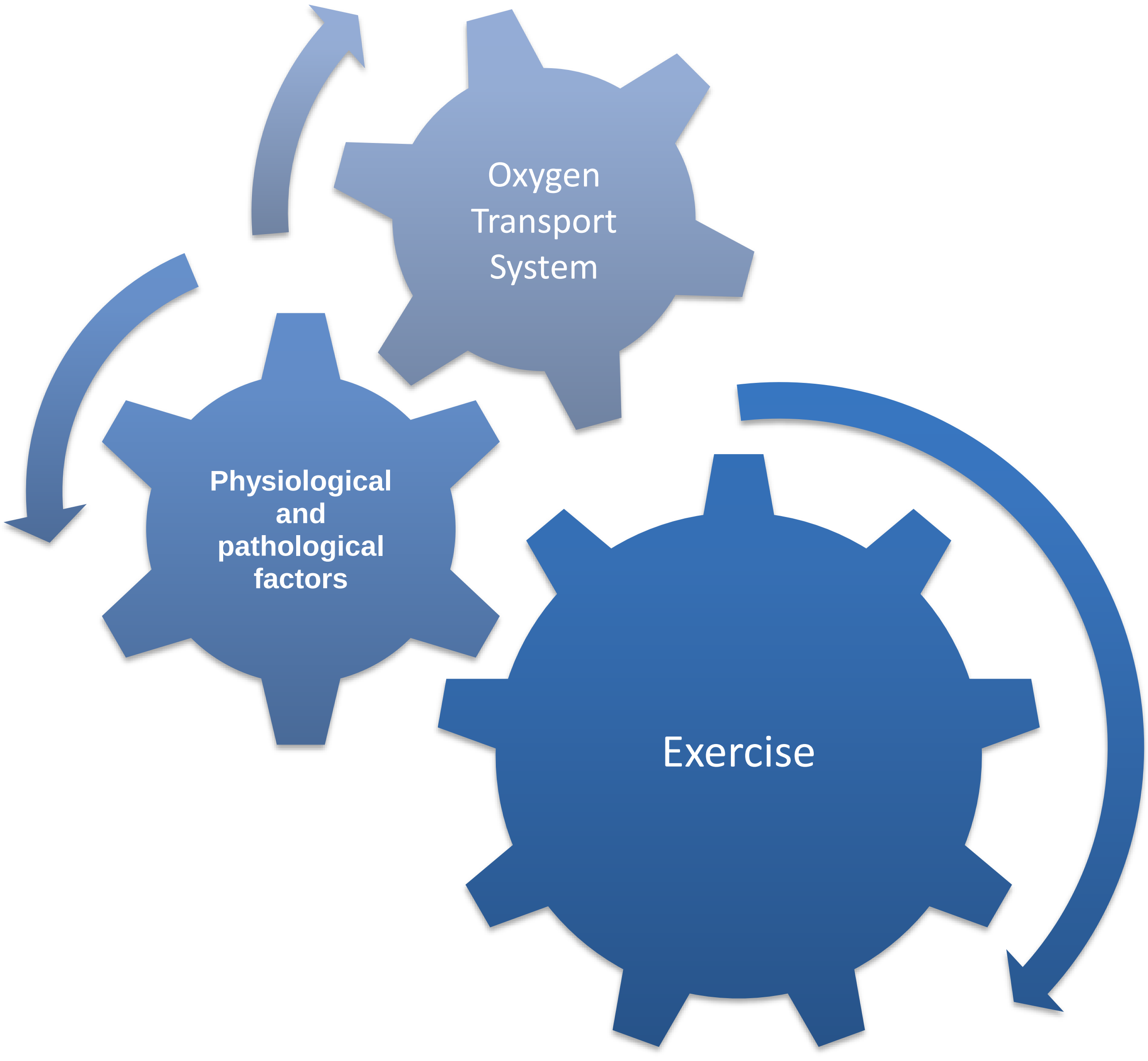
What is the evidence of these interventions?

Evidence on the effects of exercise therapy in the treatment of chronic disease (2010)

Table 1 Results of selected meta-analyses of randomised controlled trials on the benefits of exercise therapy in the treatment of patients with specific diseases

Study, year	Disease	Outcome measure	No. studies (no. participants)	Effect size of exercise compared to controls, pooled statistics (95% CI)*
Fransen *et al*, 2008[3]	Osteoarthritis	Self-reported pain	32 (3616)	Standardised mean difference −0.40 (−0.50 to −0.30)
Fransen *et al*, 2008[3]	Osteoarthritis	Self-reported physical function limitations	31 (3719)	Standardised mean difference −0.37 (−0.49 to −0.25)
Hernandez-Molina *et al*, 2008[6]	Hip osteoarthritis	Self-reported pain	8 (493)	Standardised mean difference −0.46 (−0.64 to −0.28)
Hayden *et al*, 2005[12]	Non-specific chronic (> 12 weeks) low back pain	Pain, visual analogue scale (scaled to 0 to 100 points)	8 (370)	Weighted mean difference −10.20 points (−19.09 to −1.31)
Hayden *et al*, 2005[12]	Non-specific chronic (> 12 weeks) low back pain	Condition-specific functioning limitations (scaled to 0 to 100 points)	7 (337)	Weighted mean difference −2.97 points (−6.48 to 0.53)
Busch *et al*, 2007[14]	Fibromyalgia	Pain	4 (223)	Standardised mean difference −0.81 (−1.47 to −0.15)
Busch *et al*, 2007[14]	Fibromyalgia	Tender points	6 (349)	Standardised mean difference −0.76 (−1.53 to 0.01)
Busch *et al*, 2007[14]	Fibromyalgia	Global well-being	4 (269)	Standardised mean difference 0.49 (0.23 to 0.75)
Busch *et al*, 2007[14]	Fibromyalgia	Physical function	4 (253)	Standardised mean difference 0.66 (0.41 to 0.92)
Jolliffe *et al*, 2001[15]	Coronary heart disease	All cause mortality	12 (2582)	Odds ratio 0.73 (0.54 to 0.98)
Jolliffe *et al*, 2001[15]	Coronary heart disease	Cardiac mortality	8 (2312)	Odds ratio 0.69 (0.51 to 0.94)
Jolliffe *et al*, 2001[15]	Coronary heart disease	Non-fatal myocardial infarction	9 (2104)	Odds ratio 0.96 (0.69 to 1.35)
Nolan *et al*, 2008[17]	Coronary heart disease	Heart rate variability	16 (631)	Standardised mean difference 0.36 (0.18 to 0.55)
Rees *et al*, 2004[19]	Heart failure	Maximal oxygen uptake	24 (848)	Weighted mean difference 2.16 ml/kg/min (1.49 to 2.82)
Rees *et al*, 2004[19]	Heart failure	Distance on 6-min walk	8 (282)	Weighted mean difference 41 m (17 to 65)
Smart and Marwick, 2004[20]	Heart failure	Mortality	30 (1197)	Odds ratio 0.71 (0.37, 1.02)
Watson *et al*, 2008[21]	Intermittent claudication	Maximal walking time	7 (255)	Weighted mean difference 5.12 min (4.51 to 7.52)
van de Port *et al*, 2007[23]	Stroke	Maximum walking speed	12 (501)	Standardised effect size 0.45 (0.27 to 0.63)
van de Port *et al*, 2007[23]	Stroke	Walking distance	9 (451)	Standardised effect size 0.62 (0.30 to 0.95)
Cornelissen and Fagard, 2005[24]	Hypertension	Systolic blood pressure	30 (492)	Mean net change −6.9 mm Hg (−9.1 to −4.6)
Cornelissen and Fagard, 2005[24]	Hypertension	Diastolic blood pressure	30 (492)	Mean net change −4.9 mm Hg (−6.5 to −3.3)
Kelley *et al*, 2006[26]	Cardiovascular disease	HDL cholesterol	6 (637)	Weighted mean difference 3.7 mg/dl (1.2 to 6.1)
Kelley *et al*, 2006[26]	Cardiovascular disease	Triglycerides	9 (1172)	Weighted mean difference −19.3 mg/dl (−30.1 to −8.5)
Thomas *et al*, 2006[27]	Type 2 diabetes	Glycated haemoglobin percentage (HbA_{1c})	13 (361)	Weighted mean difference −0.62% (−0.91% to −0.33%)
Boyle *et al*, 2003[28]	Type 2 diabetes	Maximal oxygen uptake	9 (266)	Standardised mean difference 0.53 (0.18 to 0.88)
Kelley and Kelley, 2007[31]	Type 2 diabetes	LDL cholesterol	4 (156)	Weighted mean difference −6.4 mg/dl (−11.8 to −1.1)
Ram *et al*, 2005[32]	Asthma	Resting lung function (FEV1)	5 (129)	Weighted mean difference 0.01 litres (−0.14 to 0.16)
Ram *et al*, 2005[32]	Asthma	Maximal ventilation (VE_{max})	4 (111)	Weighted mean difference 6.00 litres/min (1.57 to 10.43)
Ram *et al*, 2005[32]	Asthma	Maximal oxygen uptake	7 (175)	Weighted mean difference 5.4 ml/kg/min (4.2 to 6.6)
Salman *et al*, 2003[33]	COPD	Walking distance	20 (979)	Standardised effect size 0.71 (0.43 to 0.99)
Salman *et al*, 2003[33]	COPD	Shortness of breath by Chronic Respiratory Disease Questionnaire	12 (723)	Standardised effect size −0.62 (−0.91 to −0.26)
Goodwin *et al*, 2008[36]	Parkinson disease	Physical functioning limitations	7 (360)	Standardised mean difference −0.47 (−0.82 to −0.12)
Goodwin *et al*, 2008[36]	Parkinson disease	Health-related quality of life limitations	4 (292)	Standardised mean difference −0.27 (−0.51 to −0.04)
Heyn *et al*, 2004[38]	Cognitive impairment	Cardiovascular fitness	18 (1059)	Standardised effect size 0.62 (0.45 to 0.78)
Heyn *et al* 2004[38]	Cognitive impairment	Cognitive outcomes	12 (820)	Standardised effect size 0.57 (0.38 to 0.75)
Mead *et al*, 2008[39]	Depression	Depression symptoms	23 (907)	Standardised mean difference −0.82 (−1.12 to −0.51)
Edmonds *et al*, 2004[40]	Chronic fatigue syndrome	Chalder fatigue scale	5 (286)	Standardised mean difference −0.77 (−1.26 to −0.28)
Edmonds *et al*, 2004[40]	Chronic fatigue syndrome	Quality of life limitations, SF-36 physical functioning subscale	3 (162)	Standardised mean difference −0.64 (−0.96 to −0.33)
Shamliyan *et al*, 2008[41]	Urinary incontinence	Contingence rate	4 (647)	Pooled risk difference 0.13 (0.07 to 0.20)
Markes *et al*, 2006[42]	Breast cancer	Cardiorespiratory fitness	5 (207)	Standardised mean difference 0.66 (0.20 to 1.12)
Cramp and Daniel, 2008[43]	Cancer	Fatigue	30 (1662)	Standardised mean difference −0.23 (−0.33 to −0.13)

*All estimates reported in this table favour exercise groups; effect sizes as reported by the authors of original meta-analyses.
COPD, chronic obstructive pulmonary disease; HDL, high-density lipoprotein; FEV1, forced expiratory volume in 1 s; LDL, low-density lipoprotein, SF-36, Short Form 36


Oxygen Transport System
Physiological and pathological factors
Exercise

ESCOLA SUPERIOR DE SAÚDE DO ALCOITÃO

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Frownfelter D; Dean E - *Principles and Practice of Cardiopulmonary Physical Therapy. 5rd ed., St.* Louis, Mosby-Year Book, 2012.