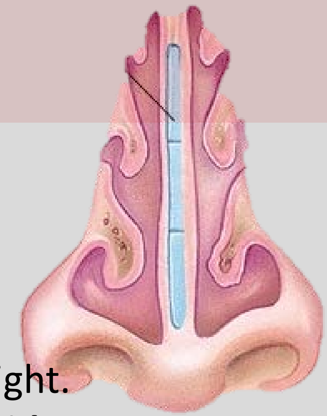
Cyclic, bi-directional load, "double block and bleed", combined Air handling unit for adiabatic humidification, heating and enthalpy recovery

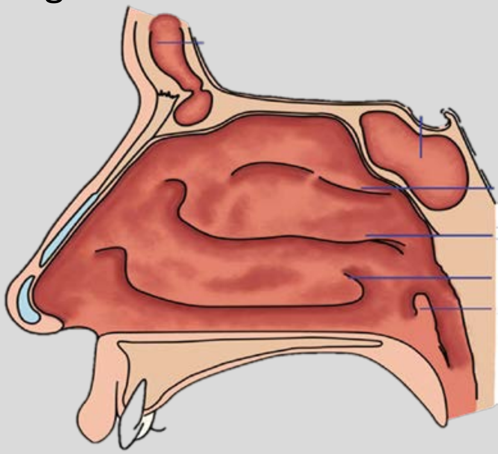
Key features:

- **Inspiration:** **air - conditioning** (moistening and heating)
  filtering and **clearance of** air pollutants
- **Expiration:** **enthalpy-recovery (latent and sensible energy)**
- **Smelling**



Nasal-cycle:

- ≈ 80 % of people have a rhythmic cycle of several minutes to hours where **congestion** and **decongestion** of mucous membranes alternates between left and right. This enables the **narrowed side** to have optimal filtration and clearance while the **wider side** has higher air-flow, providing ideal physical requirements for air conditioning.



Description:

- length: 8-10 cm, surface area 150 – 200 cm^2
- inner lining: mucous membrane with cilia (10^9 /cm^2) and goblet cells
- sticky surface layer = **A**irways **S**urface **L**iquid: velocity 0-22 mm/min., direction larynx, propagated by cilia beating, frequency (5-20 Hz)
- mucous production: ≈ 1-2 l per day (depending on irritation, infection)
- three turbinate's increase the surface area and affect the flow-profile.

Nasal cycling enables the partition of **«two jobs»** and **«work and recovery»** [1,2]

«recovery time» → optimal filtering + clearing

nose **narrow (congested)**
- low air-flow
- → optimal filtering
- → fast clearance
- **→ good hydration**

narrow   wide

«work time» → optimal conditioning (heating and hydration)

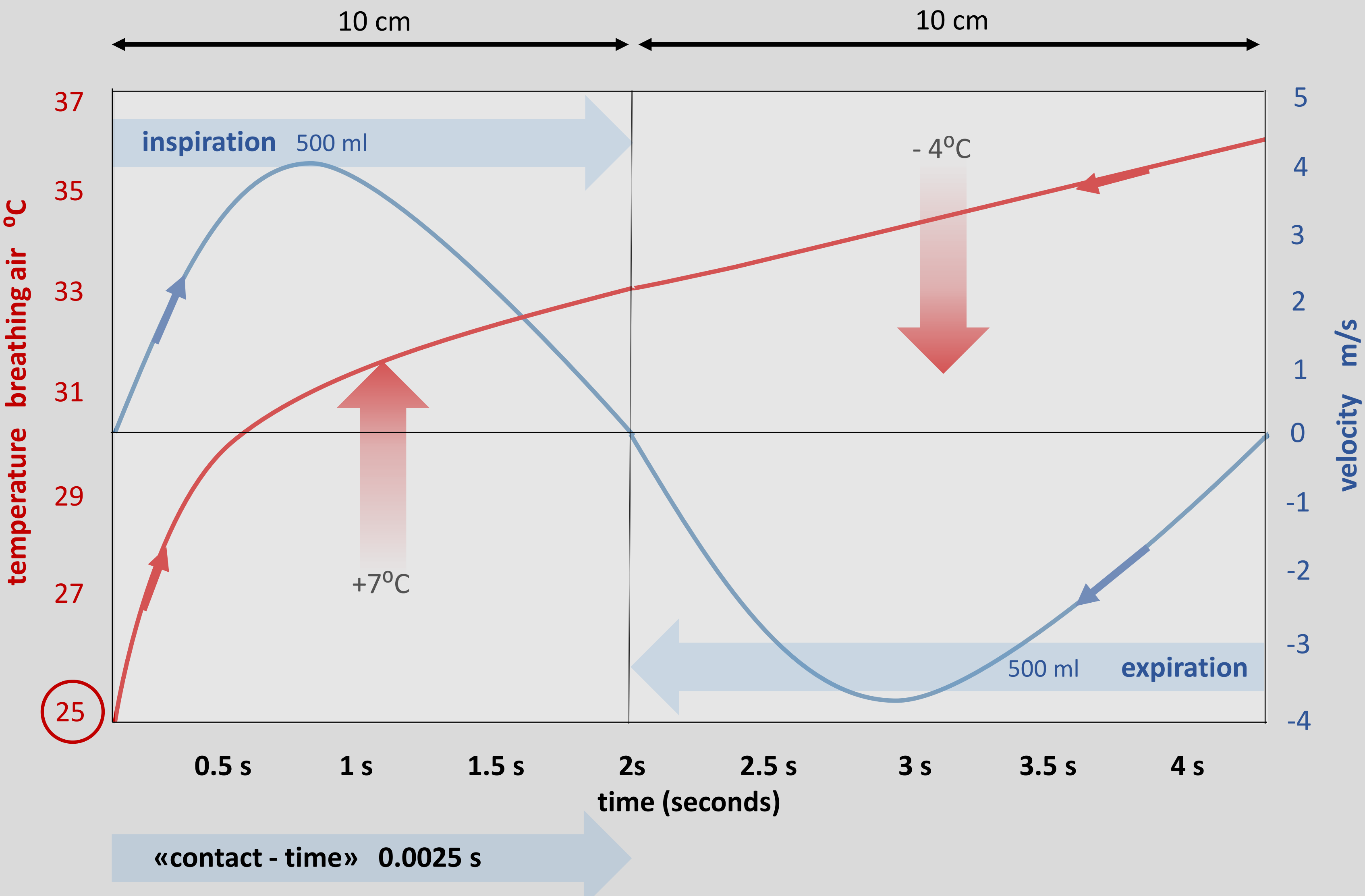
nose **wide (decongested)**
- high air-flow
- → optimal conditioning
- → low mucociliary flow
- **→ increasing dehydration**

[1] **Soane RJ** et al, The effect of nasal cycle on mucociliary clearance, Clin. Otolaryngol. **2001**, 26

[2] **White DE, Bartley J, Nates RJ**, Model demonstrates functional purpose of the nasal cycle, BioMedical Engineering, 2015

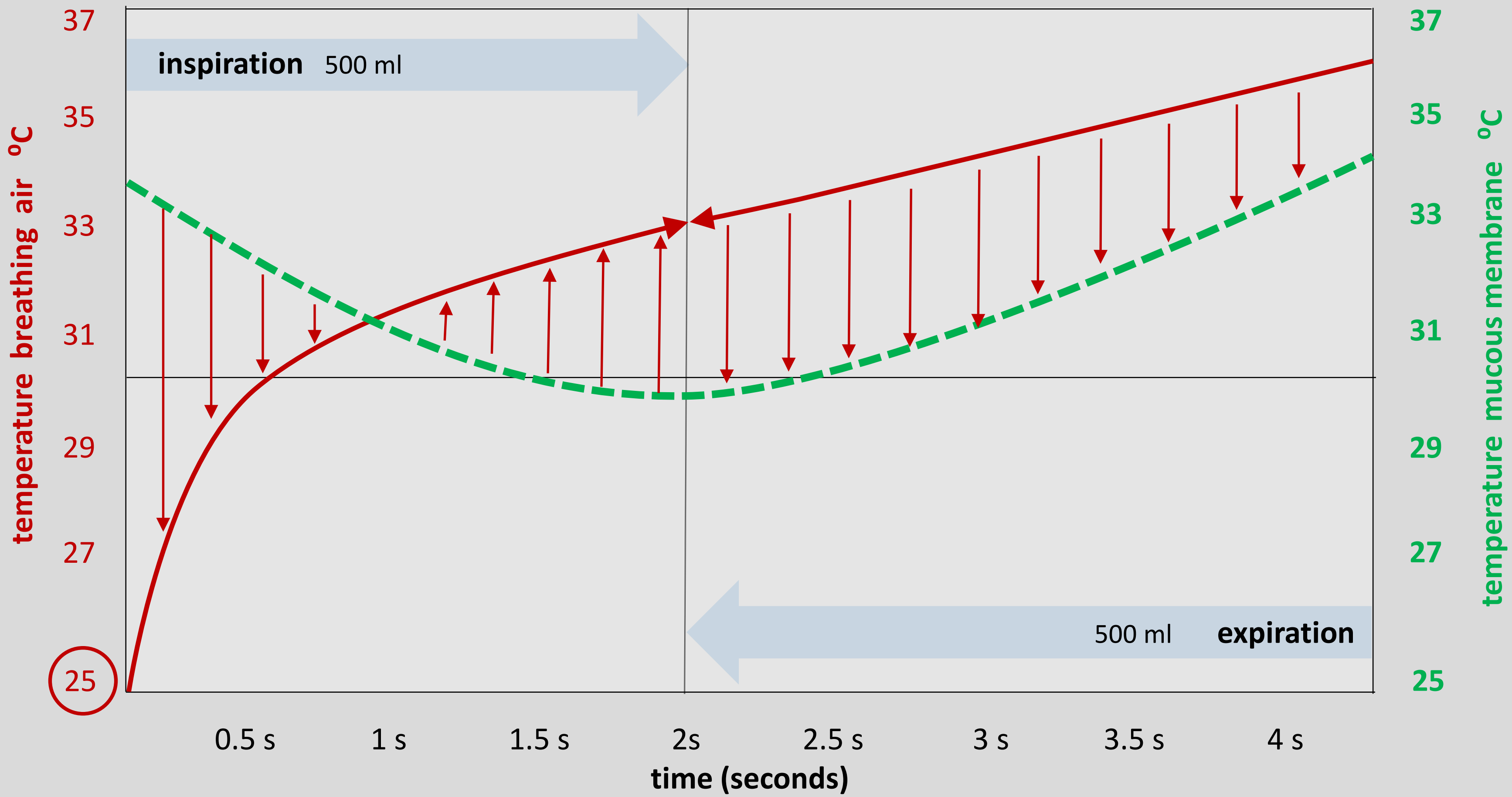
Dynamic changes of **inhaled air** and **mucus membranes** during a respiratory cycle

- **flow-velocity during in- and expiration (extremely short contact-time)**
- **heating of breathing air during inspiration and heat recovery during expiration**



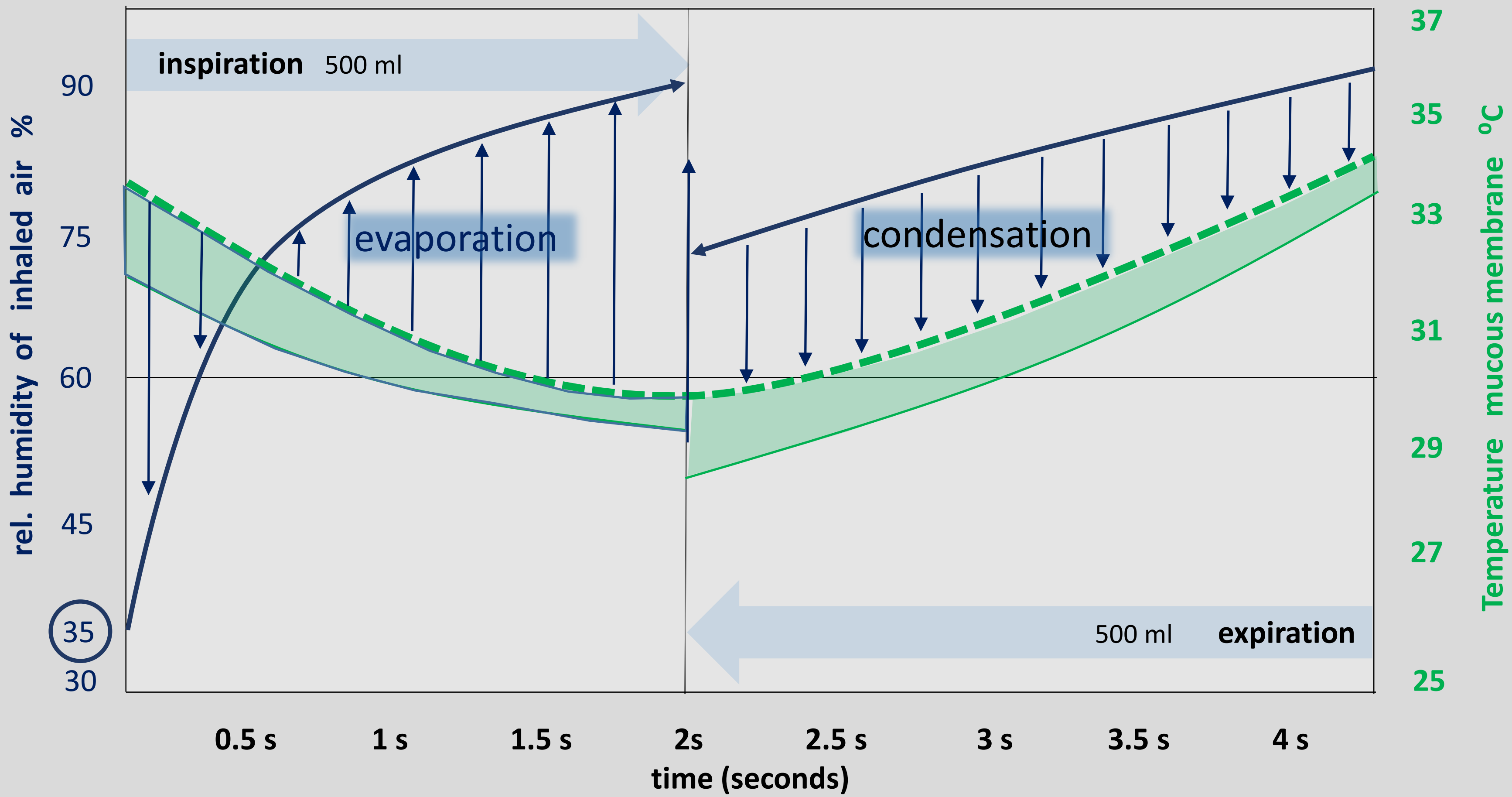
Dynamic changes of **inhaled air** and **mucus membranes** during a respiratory cycle

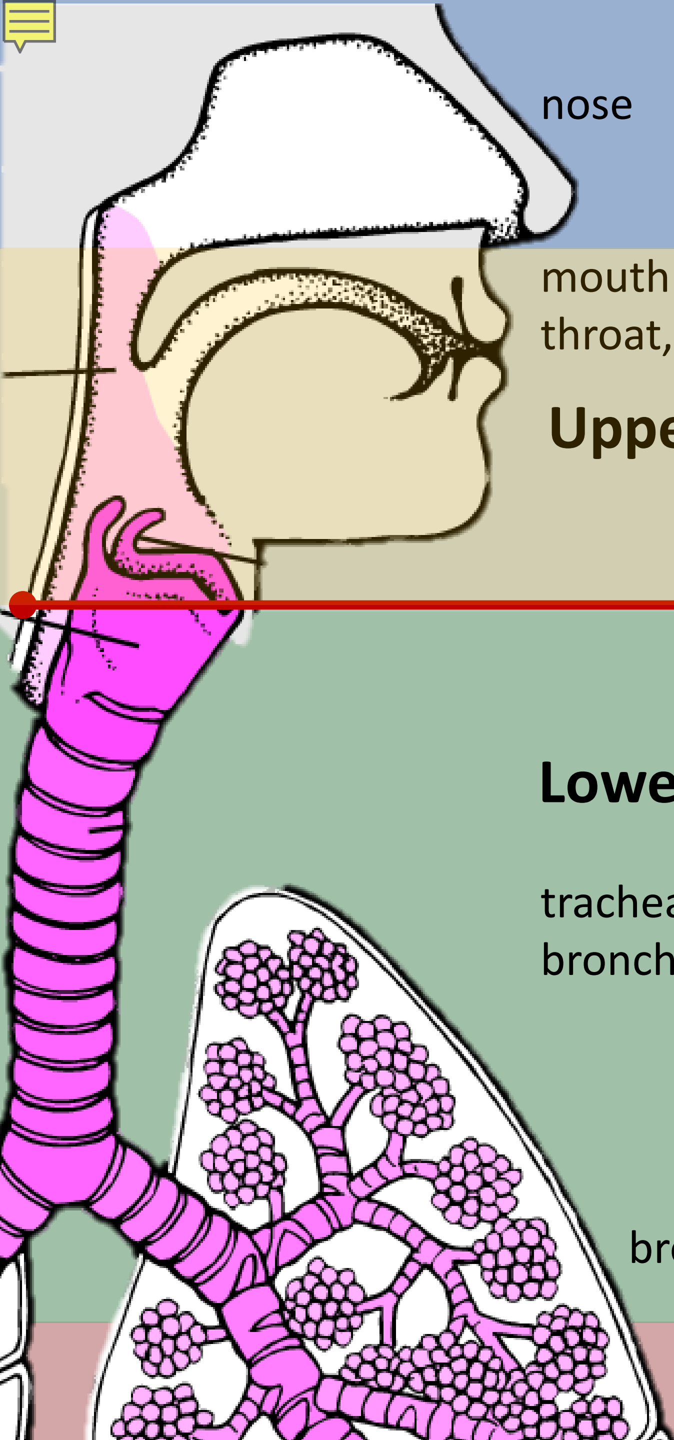
- **heat flux from mucus membrane → to breathing air during inspiration**
- **heat influx to mucus membrane ← from breathing air during expiration**
- driving force: temperature difference air – mucus membrane, perfusion plays decisive part



Dynamic changes of **inhaled air** and **mucus membranes** during a respiratory cycle

- **humidification of air: evaporation from mucous membranes driven by gradient of vapour**
- **water-recovery: condensation on the cooler mucous membrane**
- **height of mucus membrane is equivalent to water mass transfer**





nose

specialised in air–conditioning
filtration
clearance

mouth
throat, larynx

Upper Airways

- eating and speech
- pathway for breathing air
- minimal involved in filtration and air-conditioning

Lower Airways

specialised in filtration
clearance

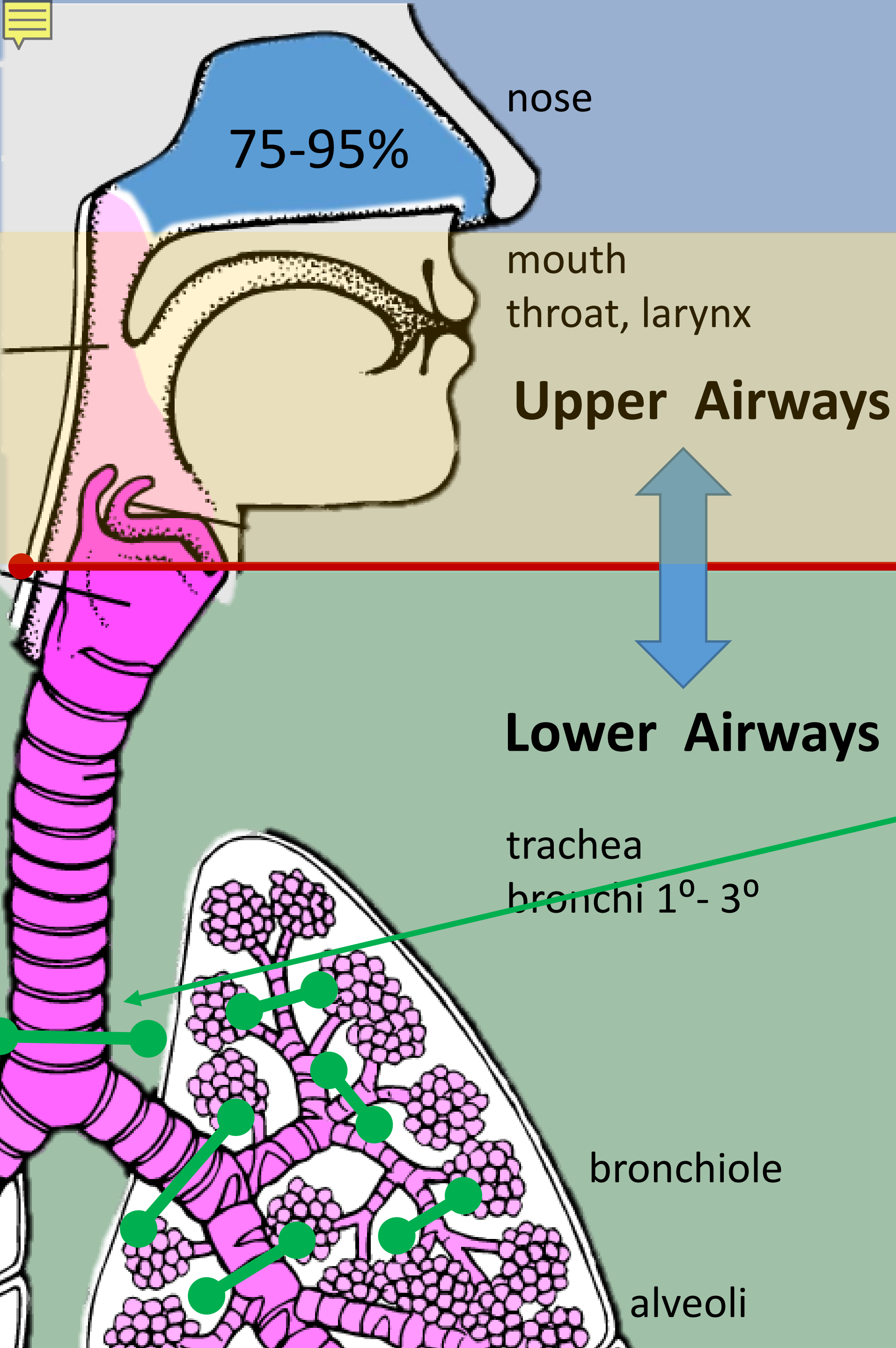
trachea
bronchi 1^{o}- 3^{o}

Lower Airways take over air-conditioning, when nose is blocked or high ventilation rate requires mouth breathing

bronchiole

alveoli

specialised in gas exchange



normal nose breathing

75-95 % of air conditioning

> 50 % of filtration 1-100 µm

mouth breathing

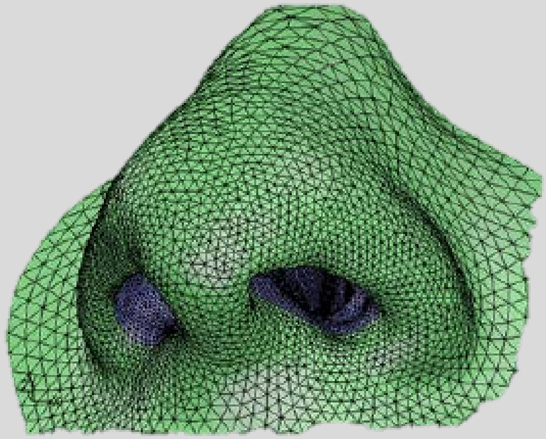
consequences for Lower Airways

no pre-filtering by nose

isothermal saturation boundary moves deeper into bronchi

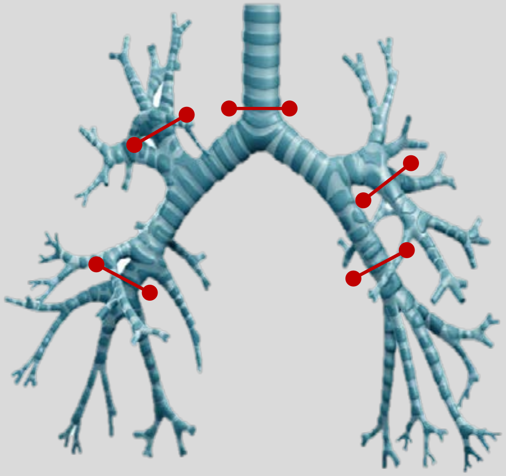
dehydration- and thermal stress → lung periphery → inflammation and tissue damage [1]

[1] **Karjalainen EM et al**, Evidence of Airway Inflammation and Remodelling in Ski Athletes with and without Bronchial Hyperresponsiveness, Am J Respir Crit Care Med Vol 161. pp 2086–2091, **2000**

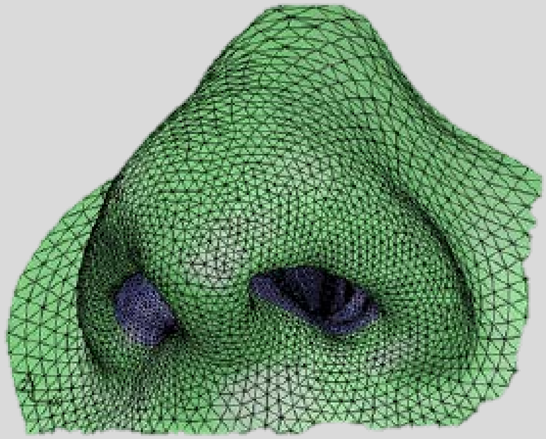


All noses which are not optimal in function and shape need help from lower airways for the conditioning of breathing air!

As a consequence, the isothermal saturation boundary moves deeper into the bronchi ....



.... leading to dehydration and cold - stress which ultimately causes **inflammation** and **tissue damage** to mucous membranes.



Noses do not function properly when:

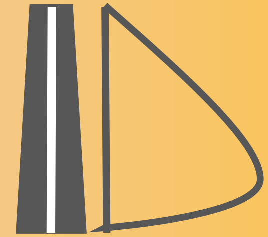
- «blocked», impermeable for air
- asthmatic and allergic persons
- acute and recurrent infections of upper airways (paranasal sinuses)
- COPD patients
- smoker's
- seniors
- children with large adenoids

When lungs are stressed by the task of conditioning they react with:

- asthma symptoms («cold-asthma»)
- inflammation
- decelerated clearing (MCC)
- thickening of Airway Surface Layer, COPD
- increased susceptibility to infections

desert climate
Hot and dry
high pollution (dust)

big noses
narrow, tight
prominent



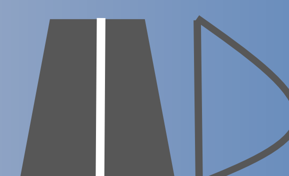
front- /
side-
view nose

tropical climate
humid and warm
little air pollution

small noses
median wide
little prominent

arctic climate
cold and dry
minor air pollution

big noses
wide, broad
prominent



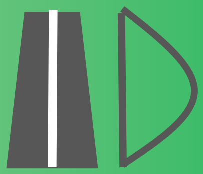
dominant tasks:
filtration + clearing of dust+ pollution
moistening, little need for heating

big noses
narrow, tight
prominent

front- / side- view nose

dominant task:
no urgent needs!
easy job

small noses
median wide
little prominent



dominant tasks:
moistening + heating = conditioning
little need for filtering + clearing

big noses
wide, broad
prominent