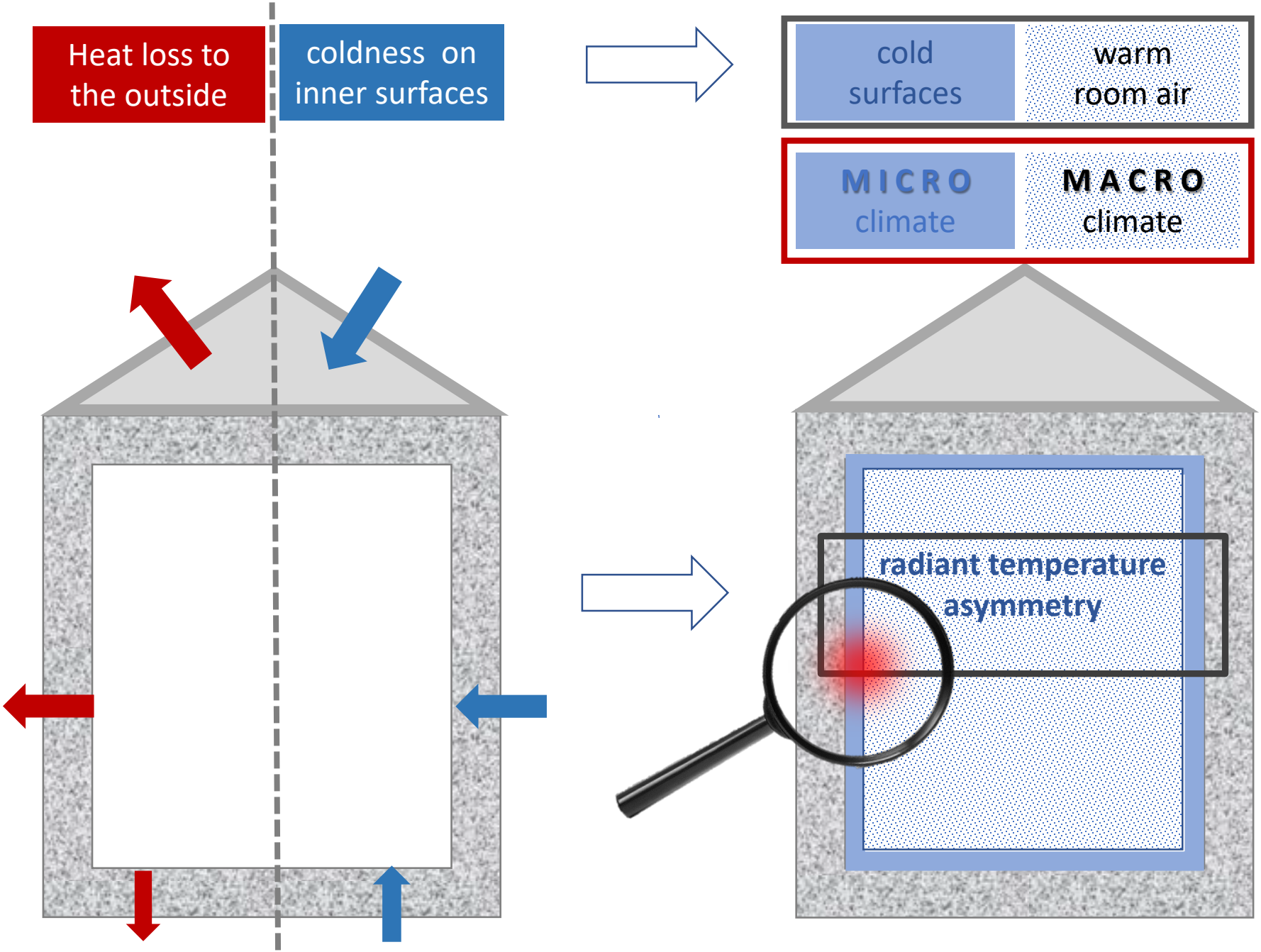
Radiant temperature asymmetry causes a split climate …



Macro- und Micro- Climate in buildings

(winter situation in temperate climate)

MACRO – CLIMATE

room air 22 °C 40 – 60 % RH

MICRO–CLIMATE boundary layer: room air - enclosing surfaces

80% RH	100% RH
WALL	WALL
$T_{surface} \leq 11/17{,}5$ °C	$T_{surface} \leq 7{,}8/13{,}9$ °C
= **critical surface temperature**	= **dew point temperature**
equilibrium humidity 80% ≈ a_w 0,8	equilibrium humidity 100%
→ **microbial growth** possible	→ **condensation** happens

OUTDOOR – CLIMATE ≈ 0 °C, 90% RH

Macro- und Micro- Climate in buildings

(winter situation in temperate climate)

MACRO – CLIMATE

room air 22 °C 40 – 60 % RH

Challenge:
Radiant temperature asymmetry
< 3 - 4 °C for mould prevention!

MICRO–CLIMATE boundary layer: room air - enclosing surfaces

80% RH

100% RH

WALL

$T_{surface} \leq 11/17{,}5$ °C

= **critical surface temperature**

equilibrium humidity 80% ≈ a_w 0,8

→ **microbial growth** possible

$T_{surface} \leq 7{,}8/13{,}9$ °C

= **dew point temperature**

equilibrium humidity 100%

→ **condensation** happens

WALL

OUTDOOR – CLIMATE ≈ 0 °C, 90% RH

Macro- und Micro- Climate in buildings

(winter situation with very cold outside temperature)

MACRO – CLIMATE in room air

22 °C, 20 % RH

Microbes (bacteria and mould) cannot extract water from air humidity, they grow even at 20% humidity !

MICRO–CLIMATE boundary layer: room air - enclosing surfaces

80% RH

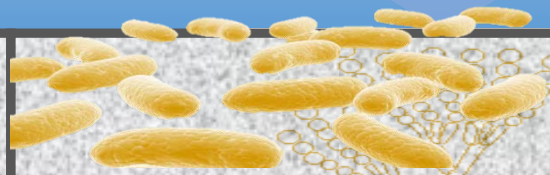
W A L L

$T_{surface} \leq 3$ °C

= critical surface temperature

equilibrium humidity 80% ≈ a_w 0,8

→ **microbial growth** possible



Mould and bacteria are dependent on liquid water and nutrients in porous materials.

W A L L

OUTDOOR – CLIMATE ≈ minus -20 °C, 70% RH

Reasons for ever lower humidity in energy efficient commercial buildings:

airtightness → **mechanical ventilation**

since demand-driven ventilation is not mandatory → over-ventilation, energy waste and increased dryness

lightweight constructions with low **mass** and **inertia**

high fluctuation of climate Parameters high radiant temperature asymmetries

different **mix of building materials**
↓bricks, concrete, stone
↑glass, steel, plastic, composites

↓ storage capacity for heat and moisture

LOWER HUMIDITY

Reasons for ever lower indoor humidity in residential buildings

4 to 6 °C higher room temperature in **all** rooms (not only in living area)

→ reduction of 10 - 15% of relative humidity

housing space per person has doubled in 50 years (central Europe)

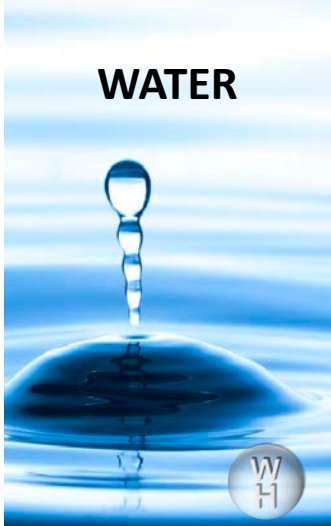
moisture input per m2 has diminished

lifestyle trends: single-households,
↓cooking (ready meals, microwaves),
↓washing habits (dryers, etc.)

reduces moisture input per person

LOWER HUMIDITY

ARE THE EFFECTS ON THE LEFT CAUSED by HUMIDITY or by WATER/DAMPNESS?



VISIBLE AND HIDDEN EFFECTS of WATER/DAMPNESS – NOT OF HUMIDITY !

MATERIAL DAMPNESS	+ MICRO-BIOLOGY	«ACTIVITIES» OF WATER	PHYSCAL PROCESSES	«INVISIBLE» VAPOR
CORROSION CONDENSATION		**CONDENSATION** (superficial water) **SORPTION** («incorporated» water)	**CONDENSATION** **SORPTION**	
		with the following proportions	according to the properties of materials	
MOULD BIOFILMS ROTTENNESS	FUNGY BACTERIA	***Unbound water*** (= water activity a_w) ***free capillary water***	**temperature** **porosity** **hygroscopicity** **wettability**	**"INVISIBLE" VAPOR BECOMES "VISIBLE" BY CONDENSATION ON CLOUD CONDENSATION NUCLEI (CCN)**
DECAY DEGRADATION		***bound capillary water*** ***water of crystallisation*** (= chemically bonded water) **CORROSION** **MATERIAL "AGING"** **CHANGING PROPERTIES**	**+** **convection** **+** **Humidity**	

All life evolved from water and all life is maintained through water!

Goethe, Faust, second part, 1832

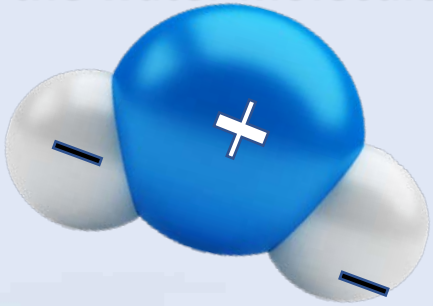
humidity
= gaseous water

evaporation

condensation

liquid water

The fascinating dipole-property of the water molecule ….



… makes it an ideal adhesive …

… and explains the huge impact of humidity on aerosol properties and air quality !

Indoor Air Quality

Indoor air quality is ultimately a question of **quantity** and **quality** of suspended solid or liquid particles – the aerosols

Indoor Air

Nitrogen	(N_2)	78 %
Oxygen	(O_2)	21 %
CO_2		0.04 %
Water vapour		0–4 vol%

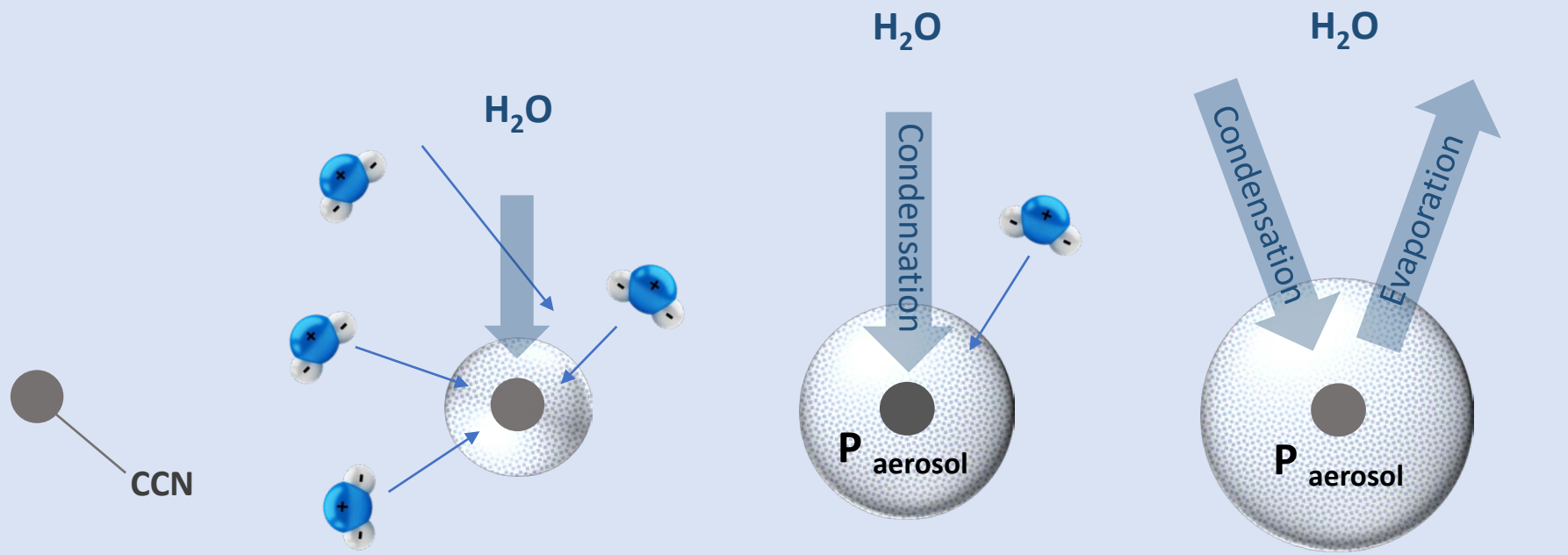
Pollution

solid and/or liquid suspended particles (aerosols)

gaseous/molecular pollution

«Hygroscopic Growth» of Aerosols by Condensation of bipolar Water Molecules in increasing Humidity (= Vapour Pressure P_{air})

P_{air} very low | P_{air} low | P_{air} medium | $P_{air} = P_{aerosol}$



hygroscopic Particles with Diameter > 0.1 µm are **Cloud Condensation Nuclei** called **CCN**

CCN covered with condensed Water Molecules

→ Condensation
→ increasing Volume
→ Settling Velocity ↑

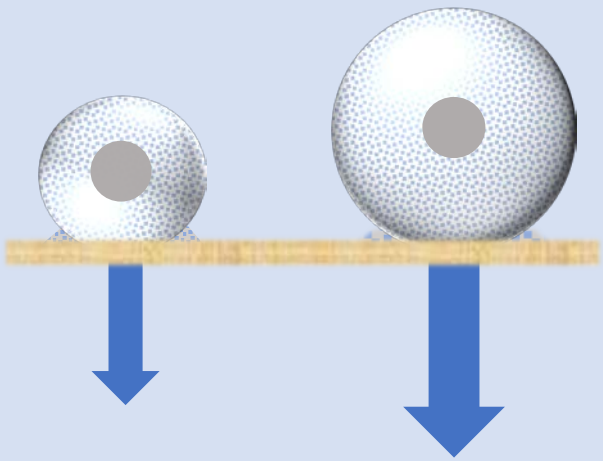
State of Equilibrium
Condensation
↕
Evaporation

Source: Willian C. Hinds, Aerosol Technology, Properties, Behavior and Measurement of Airborne Particles, John Wiley & Sons, Inc, 1999, Graph by W.Hugentobler

surface adhesion force

adhesion forces↑
with RH↑

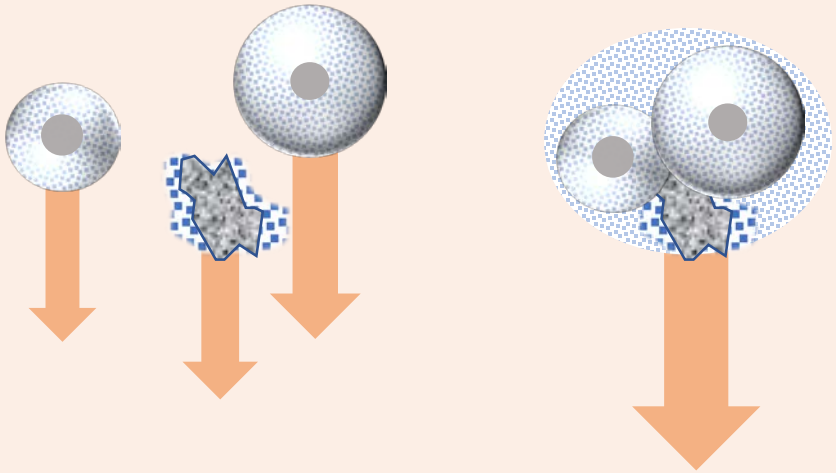
RH ① < RH ②



F ① < F ②

aggregation of wet, sticky aerosols

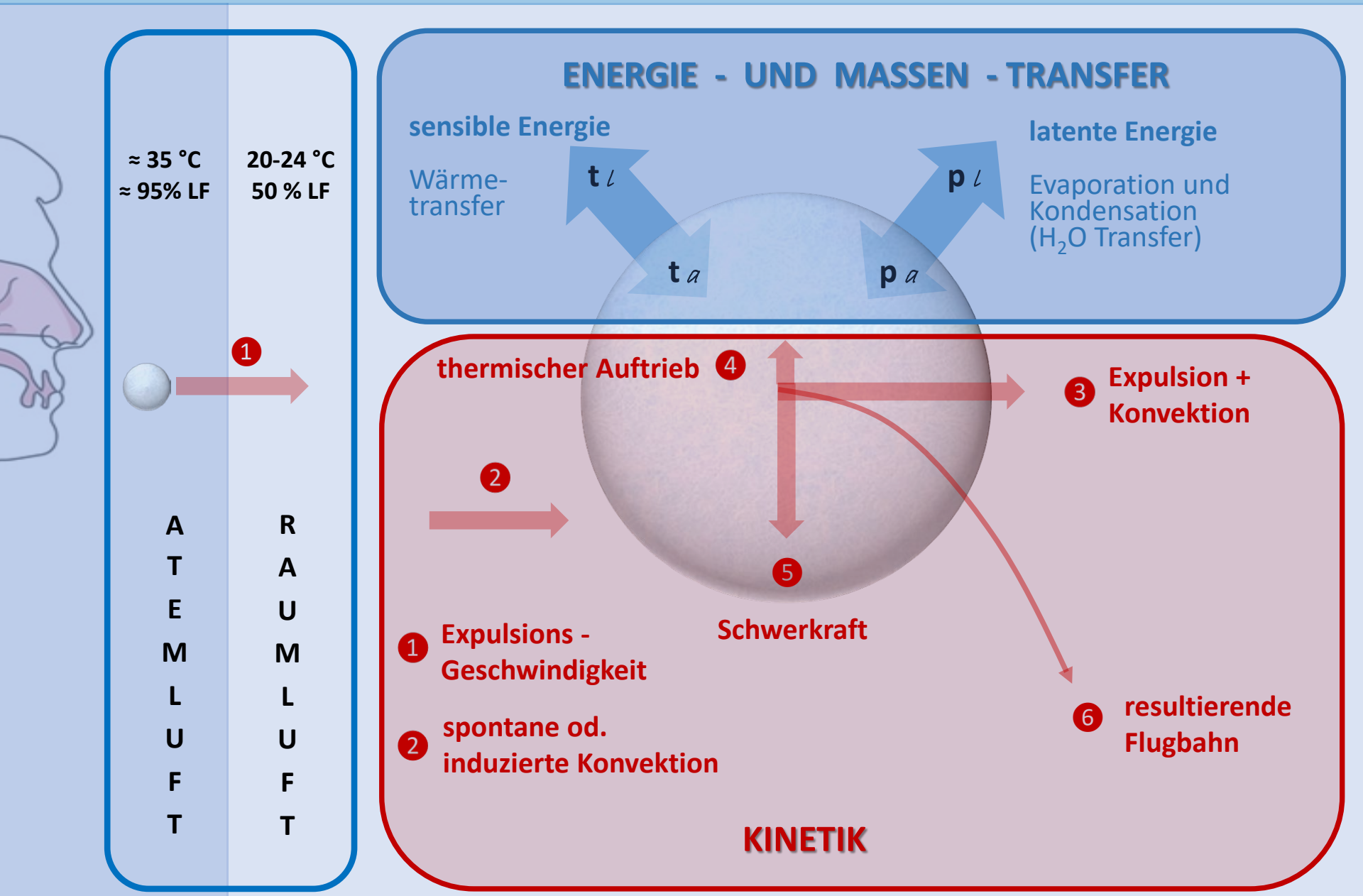
aggregation↑ with RH↑
→ settling velocity↑, floating time↓



RH ① < RH ②

V① V② V③ < V④

Physikalische Interaktionen zwischen infektiösen Aerosolen aus dem Atemtrakt und der Raumluft, Thermodynamik (Energie- und Massen-Transfer) und Kinetik

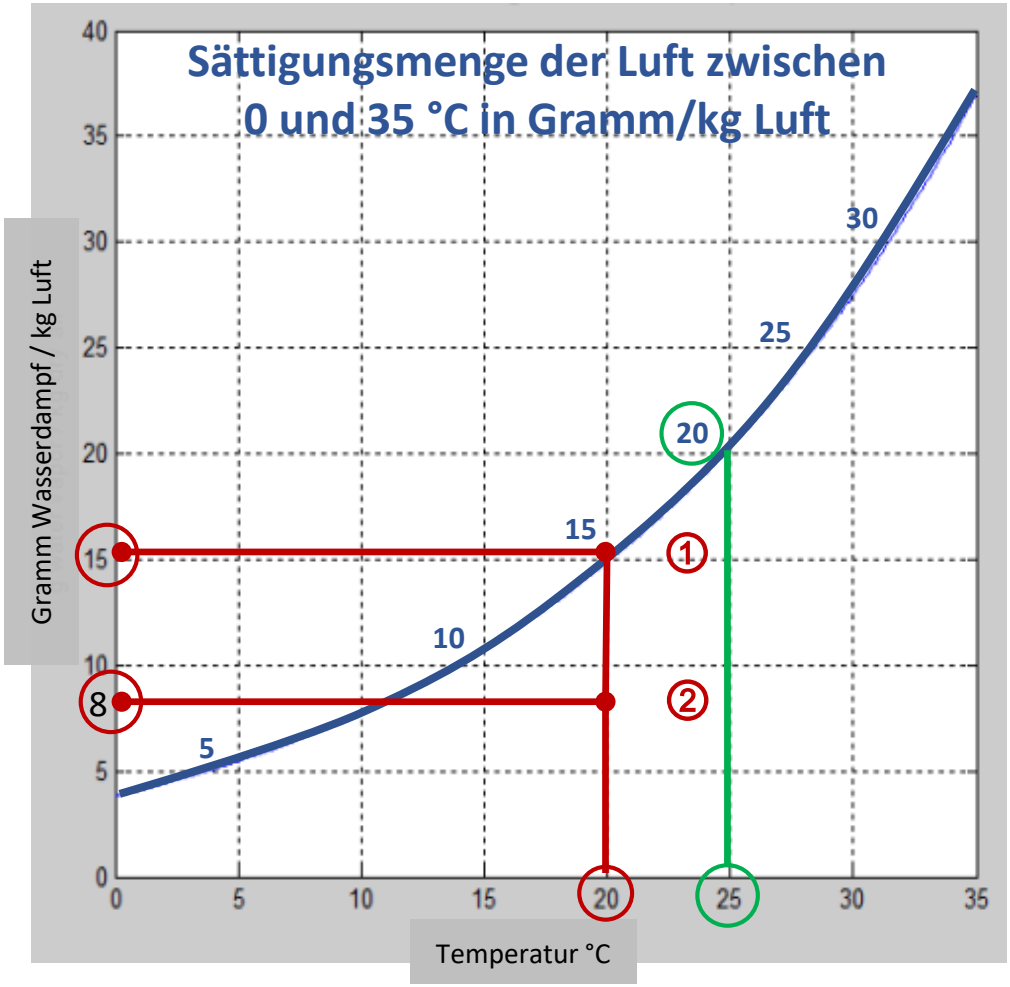


Absolute Luftfeuchtigkeit = Gramm H_2O pro Kilogramm oder Kubikmeter Luft

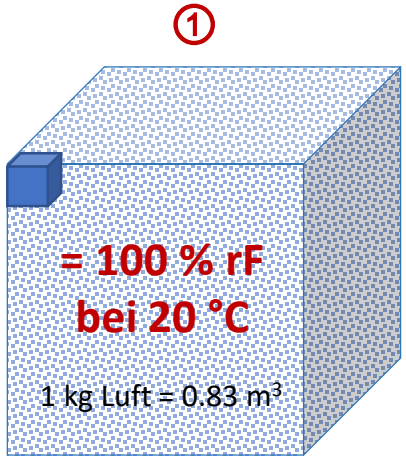
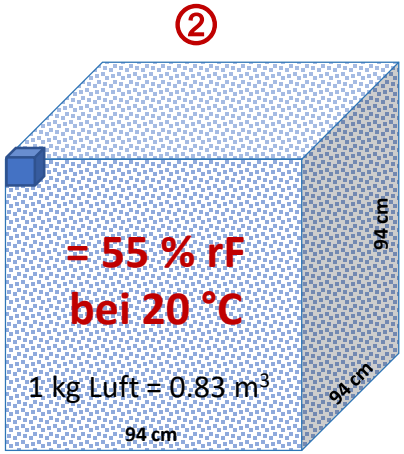
dieses Wasser ist in Form von Wasserdampf d.h. gasförmig in der Luft verteilt
der Wert ist unabhängig von der Lufttemperatur

Relative Luftfeuchtigkeit = prozentuale Wasserdampf-Sättigung der Luft

Dieser Wert ist temperaturabhängig, da die Sättigungsmenge der Luft mit steigender Temperatur zunimmt



15 g/kg



8 g/kg