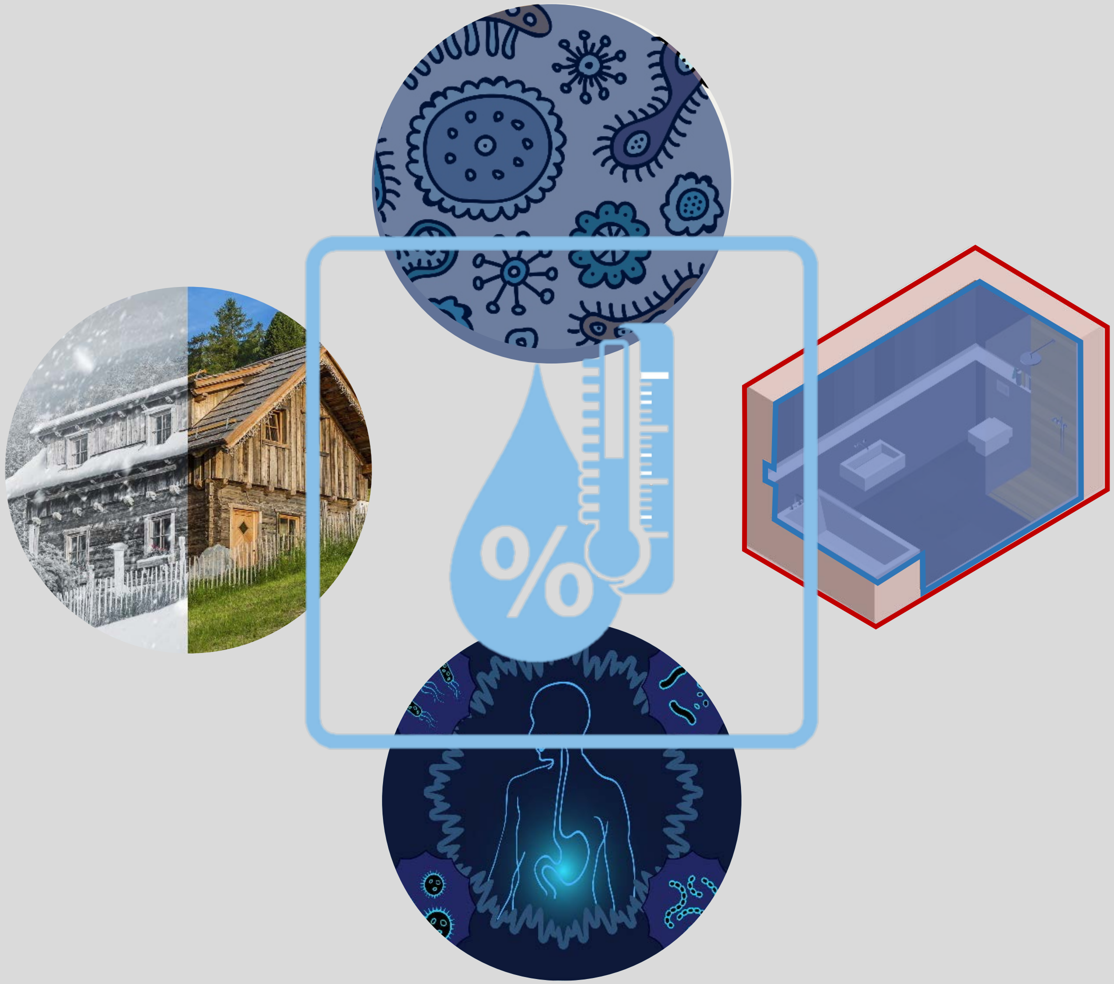
BUILDING CLIMATE AND HEALTH

CRUCIAL ROLE OF AIR HUMIDITY



STRUKTON MEETING AMSTERDAM Feb. 15th, 2017

MD Walter Hugentobler, Medical Advisor Condair AG

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General and Internal Medicine

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THE PHYSIOLOGICAL BASIS
OF HEALTH STANDARDS
FOR DWELLINGS

The modern home should not only provide protection from unfavourable atmospheric conditions, but also prevent the spread of contagious disease and ensure physical and mental comfort, rest or activity and the maintenance of human health in the wider sense.

WORLD HEALTH ORGANIZATION

GENEVA

1968

SHARED RESPONSIBILITY …

ARCHITECTS
BUILDER

BUILDING
ENGINEERS

INSTALLERS
FITTERS

OCCUPANT'S HEALTH AND WELLBEING

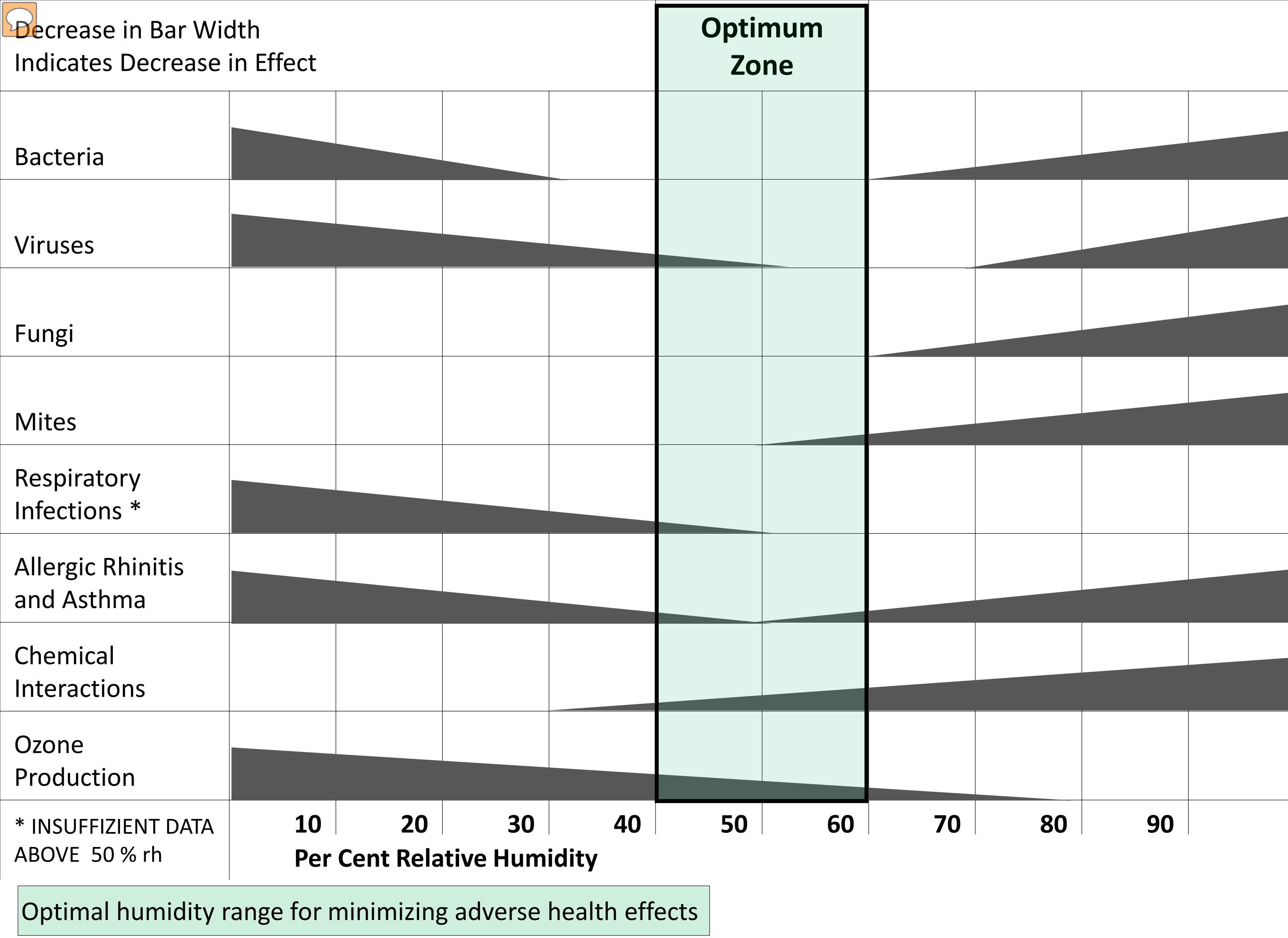
FACILITY
MANAGEMENT

PUBLIC HEALTH
PHYSICIANS

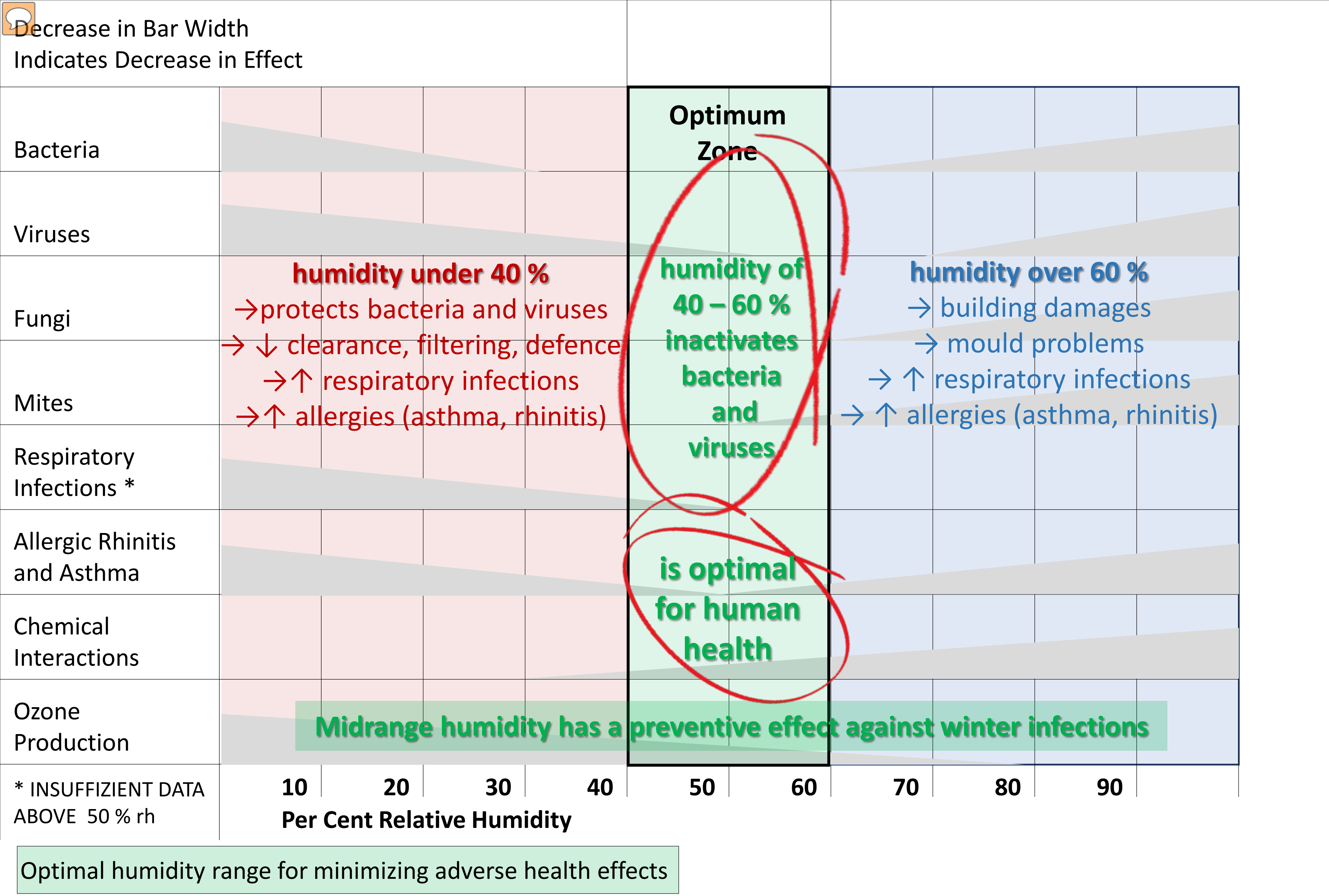
REGULATORY AUTHORITY'S
BUILDING CODES

DOC's VIEW

Public Health and physicians are not sufficiently involved and don't take their share of the responsibility … they should take the lead !



Arundel AV, Sterling EM et al, Indirect Health Effects of Relative Humidity in Indoor Environment, Environmental Health Perspectives Vol. 65, 351-61, **1986**



Arundel AV, Sterling EM et al, Indirect Health Effects of Relative Humidity in Indoor Environment, Environmental Health Perspectives Vol. 65, 351-61, **1986**

Nine studies on the preventive effect of humidification in winter, comparing two collectives:

1. **Sale Ch**, Humidification to Reduce Respiratory Illnesses in Nursery School Children, Southern Medical Journal, July 1972, Vol. 65, No 7
2. **Green G**, The Effect of Indoor Relative Humidity on Absenteeism and Colds in Schools, ASRAE JOURNAL, January 1975
3. **Green G**, Winter Humidities and Related Absenteeism in Canadian Hospitals. Digest of the 3rd CMBES Clinical Engineering Conference, 1981
4. **Green G**, The Effect of Indoor Relative Humidity on Absenteeism and Colds in Schools, ASHRAE Trans. 1975, Vol. 80,Part. II.
5. **Green G**, Indoor Relative Humidities in Winter and Related Absenteeism, ASHRAE Trans. 1985, Vol.91, Part I
6. **Ritzel G**, Sozialmedizinische Erhebung zur Pathogenese und Prophylaxe von Erkältungskrankheiten, Zeitschrift für Präventivmedizin 1966, 11. 9-16
7. **Serati A**, **Wüthrich M,** Luftfeuchtigkeit und Saisonkrankheiten, Schweizerische Medizinische Wochenschrift, 99, 48-50, 1969
8. **Gubéran E**, **Dang VB.**, **Sweetnam PM,** L'humidification de l'air des locaux préventielle les maladies respiratoires pendant l'hiver? Schweizerische Medizinische Wochenschrift, 108, Nr. 22, 1978
9. **Gelperin A**, Humidification and Upper Respiratory Infection Incidence. Heating, Piping and Air Conditioning, 45:3, 1973

Summary of conclusions

preventive humidification reduced the number of respiratory infections in collectives of

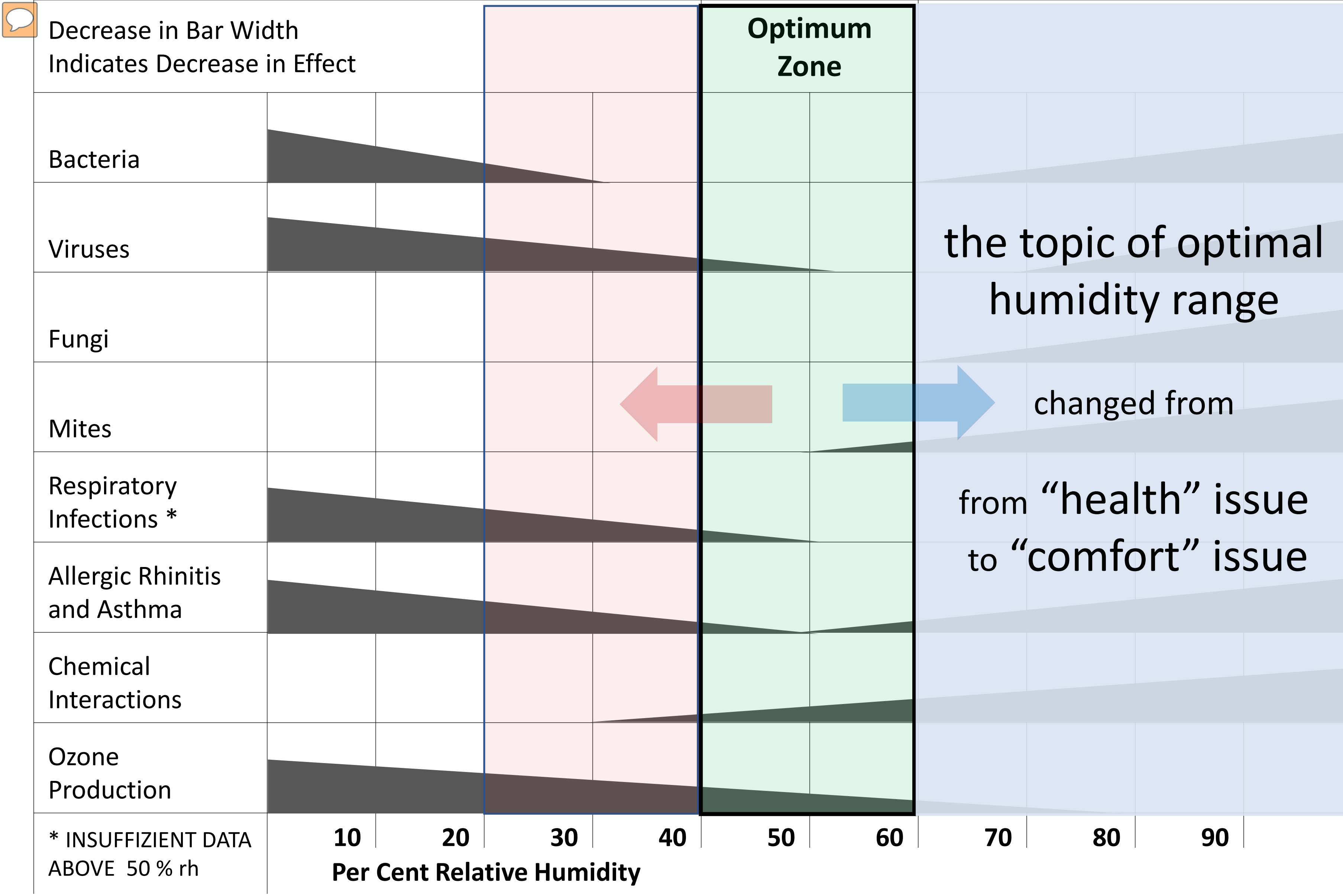
- **Adults by 25 percent**
- **Children by 50 percent**

Absolute reduction of sick days in winter

- **20 percent**

Loss of productivity (sick days, reduced performance by workforce) corresponds to around **0.9 percent of the annual payroll**

(extrapolations by the speaker, based on historic data projected for current swiss economy)

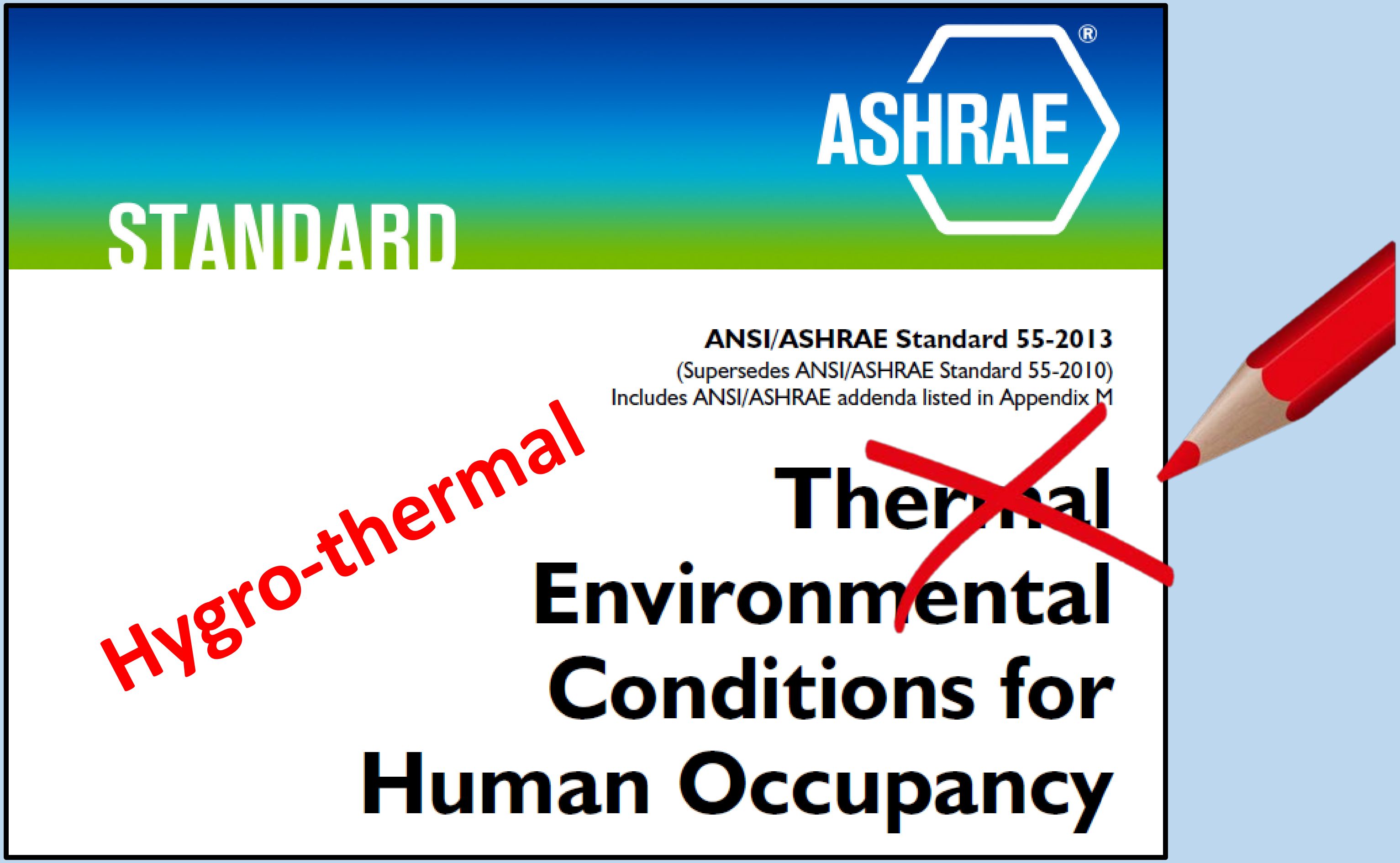


Optimal humidity range for minimizing adverse health effects

Arundel AV, Sterling EM et al, Indirect Health Effects of Relative Humidity in Indoor Environment, Environmental Health Perspectives Vol. 65, 351-61, **1986**

Does a thermal comfort zone exist ?

No - it's always a hygro–thermal comfort zone !



From a physician's point of view, focused on health and physiology, the ANSI/ASHRAE Standard 55-2013 on "Thermal Environmental Conditions for Human Occupancy" is perfect for unoccupied spaces, but is inhuman for occupancy!

humidity and temperature of air are like twins or Yin & Yan - interdependent and linked by physical laws

It is impossible to change temperature or relative humidity in air **independently** as long as the vapor content remains constant - this explains the **interdependence** of temperature and humidity

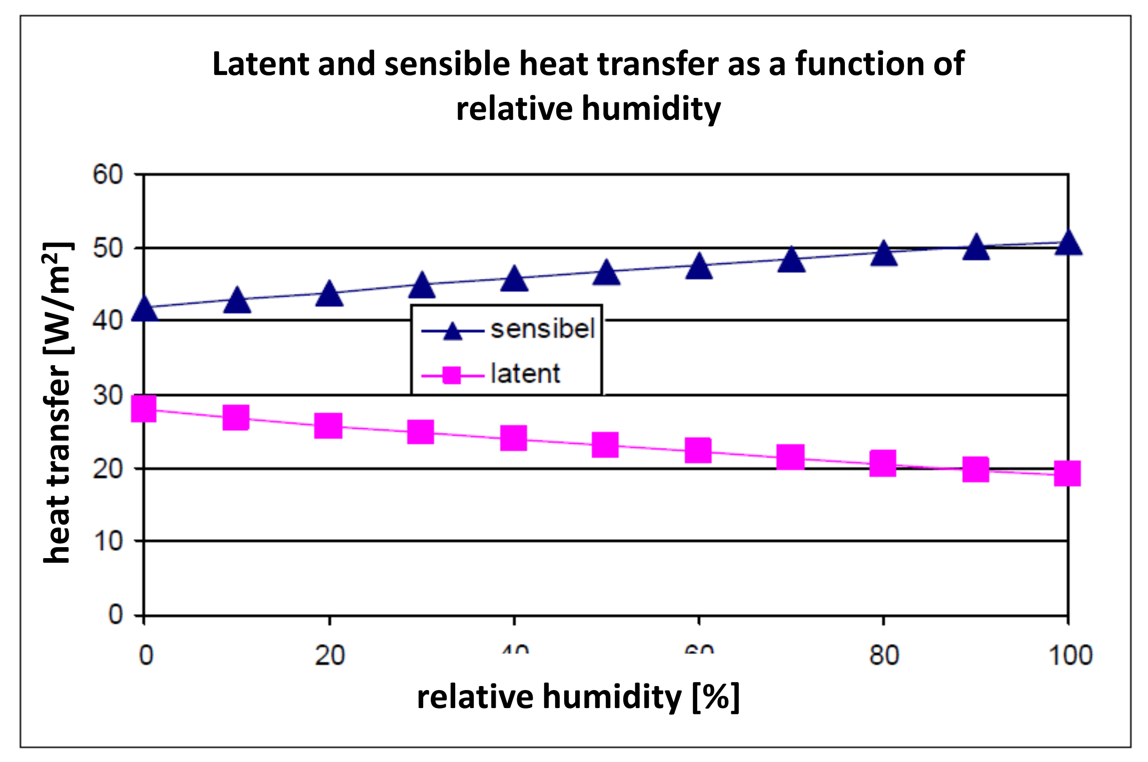
HEAT AND DISCOMFORT INDEX

HUMIDEX INDEX OF APPARENT TEMPERATURE (degree C)

	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	100%
42°	48	50	52	55	57	59	62	64	66	68	71	73	75	77	80	82
41°	46	48	51	53	55	57	59	61	64	66	68	70	72	74	76	79
40°	45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75
39°	43	45	47	49	51	53	55	57	59	61	63	65	66	68	70	72
38°	42	44	45	47	49	51	53	55	56	58	60	62	64	66	67	69
37°	40	42	44	45	47	49	51	52	54	56	58	59	61	63	65	66
36°	39	40	42	44	45	47	49	50	52	54	55	57	59	60	62	63
35°	37	39	40	42	44	45	47	48	50	51	53	54	56	58	59	61
34°	36	37	39	40	42	43	45	46	48	49	51	52	54	55	57	58
33°	34	36	37	39	40	41	43	44	46	47	48	50	51	53	54	55
32°	33	34	36	37	38	40	41	42	44	45	46	48	49	50	52	53
31°	32	33	34	35	37	38	39	40	42	43	44	45	47	48	49	50
30°	30	32	33	34	35	36	37	39	40	41	42	43	45	46	47	48
29°	29	30	31	32	33	35	36	37	38	39	40	41	42	43	45	46
28°	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
27°	27	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
26°	26	26	27	28	29	30	31	32	33	34	34	35	36	37	38	39
25°	25	25	26	27	27	28	29	30	31	32	33	34	34	35	36	37
24°	24	24	24	25	26	27	28	28	29	30	31	32	33	33	34	35
23°	23	23	23	24	25	25	26	27	28	28	29	30	31	32	32	33
22°	22	22	22	22	23	24	25	25	26	27	27	28	29	30	30	31

An increase of relative humidity from 30% to 50% corresponds to an increase in felt temperature of 2 to 3 °C → decreases therefore operative heating demand

Latent and sensible heat transfer of humans



Heat transfer of humans in Watt/m^2 body surface. In increasing humidity and consistent comfort feeling, the ratio between latent and sensible heat transfer shifts.
Assumptions: 1,2 met, 1,4 clo, V_{air} = 0,15 m/s, PMV = 0 (operative room temperature 18.3 to 21 °C)
PMV = Predicted Mean Vote

Increasing humidity results in a shift from **latent heat transfer** (evaporation) to **sensible heat transfer** (radiant heat).

Adapted to English: Energetische Bewertung von Wohnungslüftungsgeräten mi Feuchterückgewinnung, Forschungs-Projekt Passivhaus-Institut, 2008, page 31

Latent and sensible heat transfer of humans

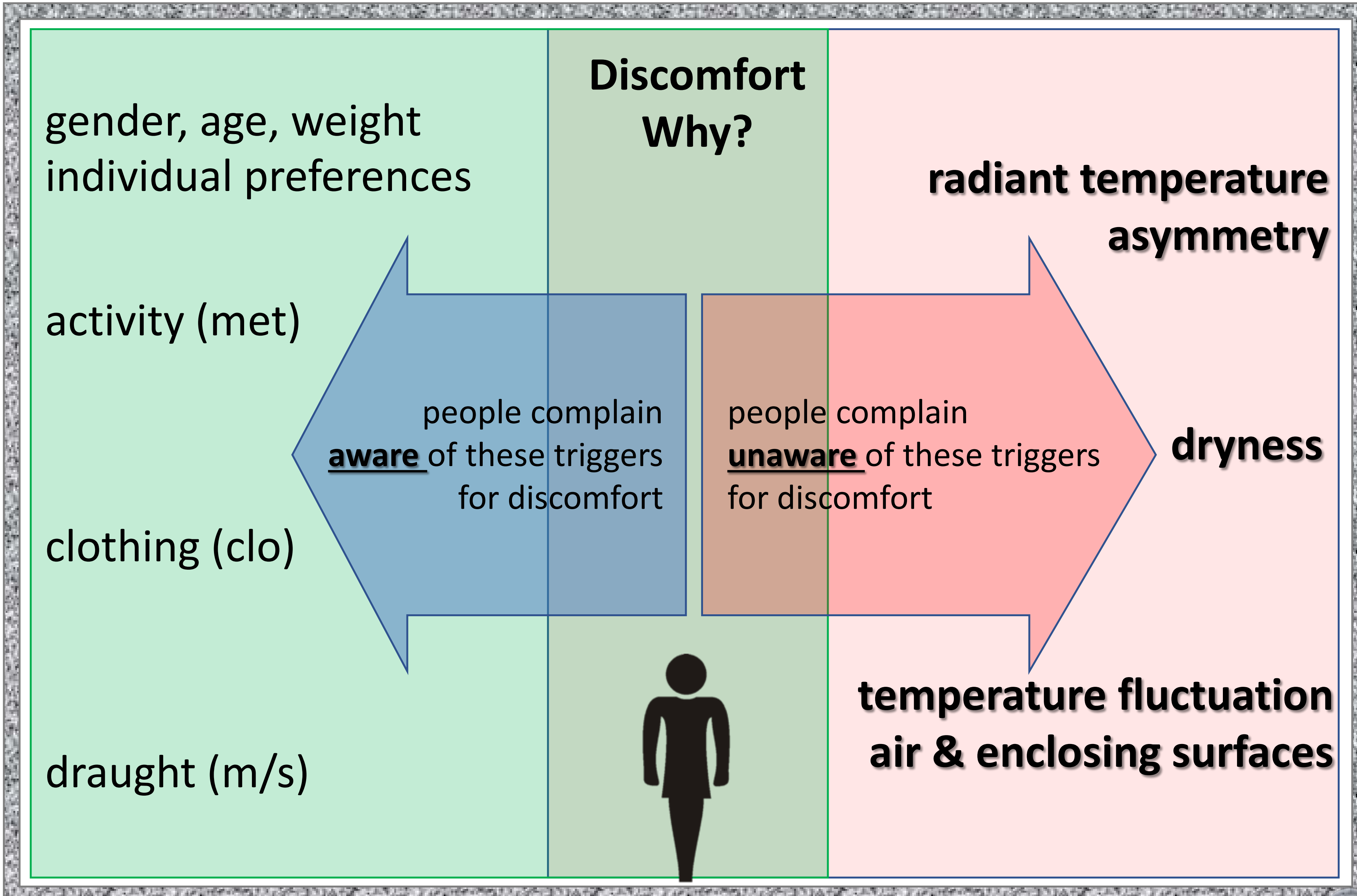
Activity	Air temperature	°C	18	20	22	23	24	25	26
No work load or easy work	$\dot{Q}_{tr}$ (dry)	W	100	95	90	85	75	75	70
	$\dot{Q}_{f}$ (humid)	W	25	25	30	35	40	40	40
	$\dot{Q}_{ges}$	W	125	120	120	120	115	115	115
	vapor production	g/h	35	35	40	50	60	60	65
Heavy work load	$\dot{Q}_{ges}$	W	270	270	270	270	270	270	270
	$\dot{Q}_{tr}$ (dry)	W	155	140	120	115	110	105	95

Human thermal regulation system reacts on decreasing or increasing air temperature with a parallel increase or decrease of skin evaporation, counteracting (partly compensating) the temperature shift by adaptive evaporative cooling effect on skin.

Increasing humidity in consistent air temperature therefore increases the felt temperature level

Adapted to English: FGK STATUS-REPORT 17, Bewertung des Innenraumklimas, Fachverband Gebäudeklima e.V., 2011

Hygro-thermal comfort zone



Hygro-thermal comfort zone

these parameters in building and climate standards have been **reduced** in the last 30 years ….

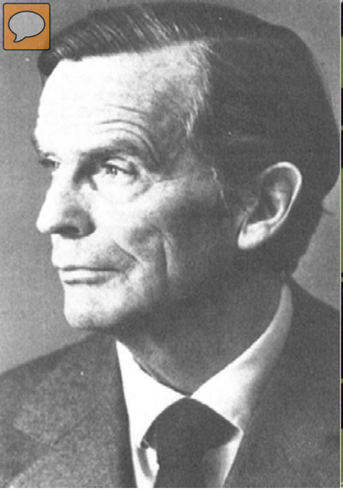
… allowing construction of light-weight, eye-catching architectural design …

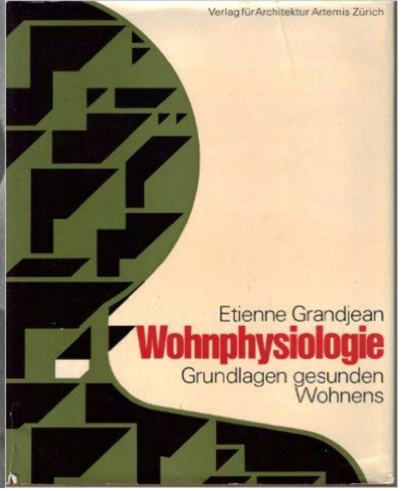
at the **expense of occupants health and comfort!**

radiant temperature asymmetry

dryness

temperature fluctuation air & enclosing surfaces





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Chair of the Institute for Hygiene and Occupational Physiology
Swiss Federal Inst. of Technology, Zurich
Physician and engineer 1950-1983

Book: **Physiology in Dwellings**, fundamentals of healthy living, pub. 1972

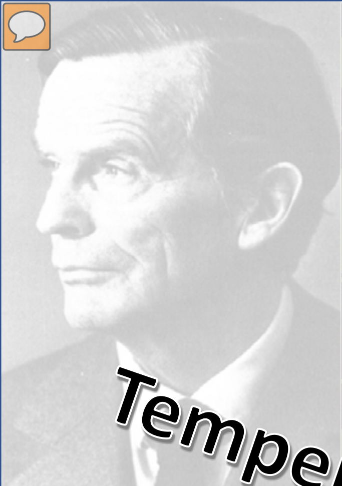
«Temperature differences air - enclosed surfaces should by no means exceed 2 to 3 degree centigrade»

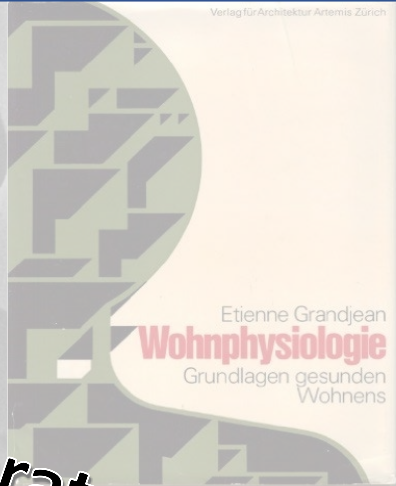
Standards of indoor climate from the standpoint of a physiologist

W. Diebschlag, Prof. Dr.-Ing.,Dr.med.

Chair of Institute for Ergonomics
Technical University Munich
Physician and engineer, 1938-2004

"Temperature differences room air - enclosing surfaces of more than 3°C create a "radiant deficit" … and therefore should be 3°C at maximum".





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Temperature asymmetries of more than 2 to 3 °C are felt by humans and result in a decreases comfort feeling … physiology tells us …

Standards of indoor climate from the standpoint of a physiologist

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“Temperature differences room air - enclosing surfaces of more than 3°C create a “radiant deficit” … and therefore should be 3°C at maximum”.

Europe: DIN EN ISO 7730, Permitted limits for radiant temperature asymmetries

Radiant temperature asymmetry

Category	Radiant temperature asymmetry °C			
	Warm ceiling	Cool wall	Cool ceiling	Warm wall
A	< 5	< 10	< 14	< 23
B	< 5	< 10	< 14	< 23
C	< 7	< 13	< 18	< 35

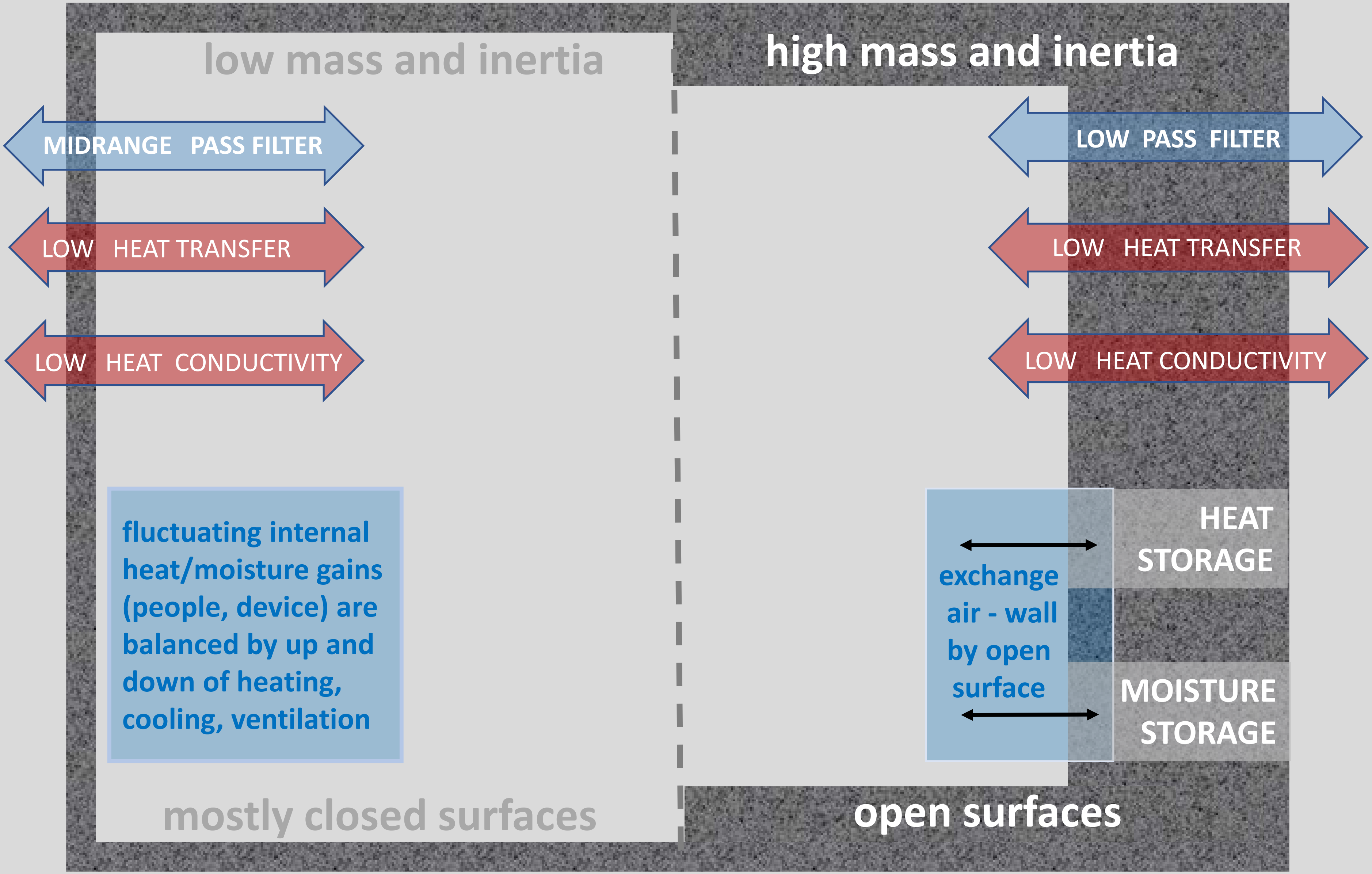
USA: ASHRAE 55-2013, Thermal Environmental Conditions for Human Occupancy

TABLE 5.3.4.2
Allowable Radiant Temperature Asymmetry

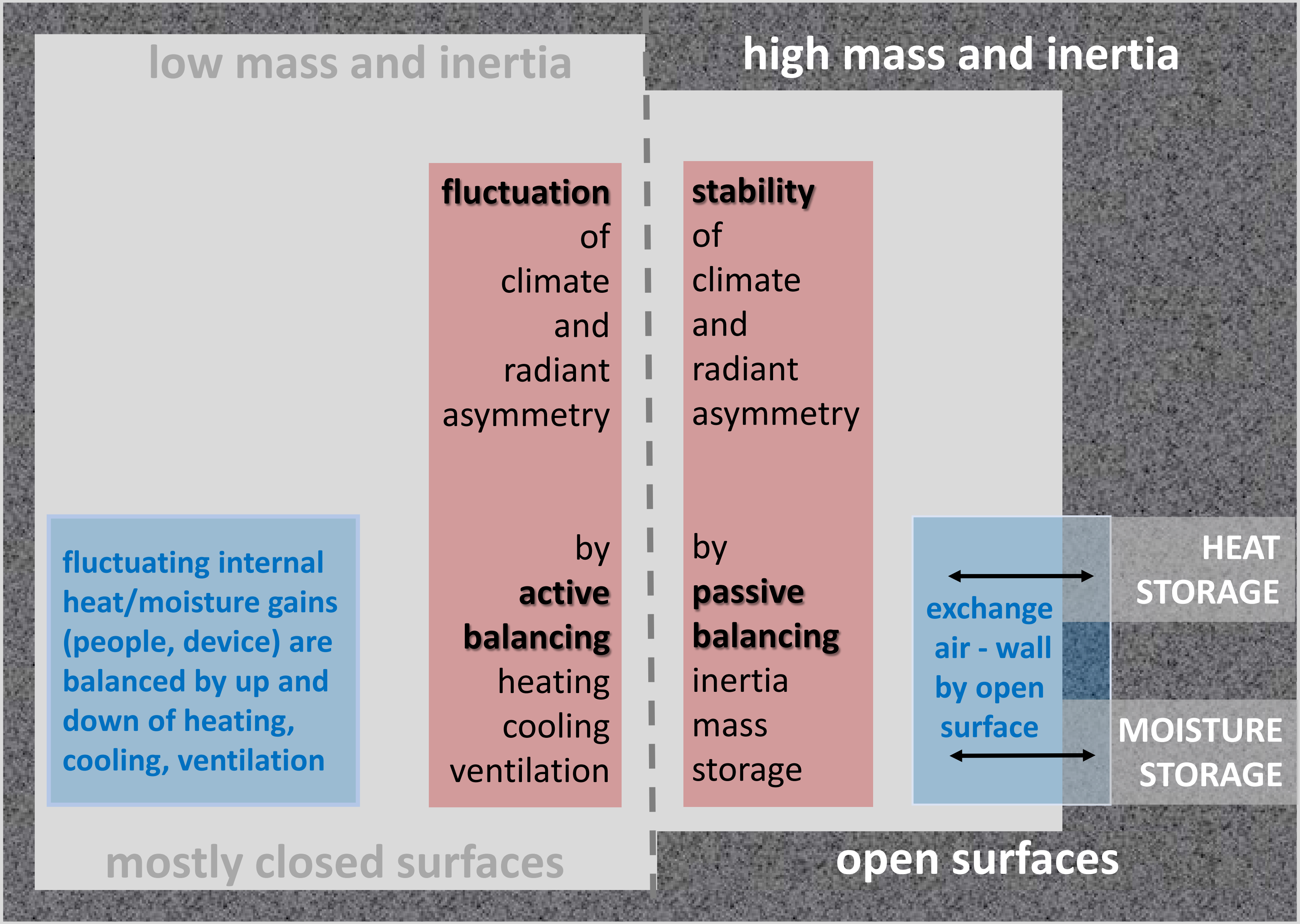
Radiant Temperature Asymmetry °C (°F)			
Ceiling Warmer than Floor	Ceiling Cooler than Floor	Wall Warmer than Air	Wall Cooler than Air
<5 (9.0)	<14 (25.2)	<23 (41.4)	<10 (18.0)

Current radiant temperature asymmetries in Europe and USA are far from what is optimal in regard of human physiology!

Two energy efficient building concepts
lightweight, high tech –low tech, mass/inertia



Two energy efficient building concepts
lightweight, high tech – low tech, mass/inertia



Air is always thirsty, striving for full water vapor saturation …

… at room temperature relative air humidity is the perfect measure for this competition …

… this creates an eternal competition for water between thirsty air on one hand …

and humans and hygroscopic materials on the other hand …

Building - protection

mould causes huge real estate value losses by destruction of building shells …

Health - protection

microbial growth on cold walls **causes health problems**

To prevent mould growth by low indoor humidity has been tried for decades – with modest success!

In the boom years after the 2nd world war building industry neglected insulation because energy was so cheap …

mould growth has to be prevented by optimal insulation !

Dampness (water in porous materials!) not moisture in the room air allows mould growth !

Buildings don't care about low humidity! **«the dryer - the better»**

Occupants' airways need humidity «minimal 40 % RH»

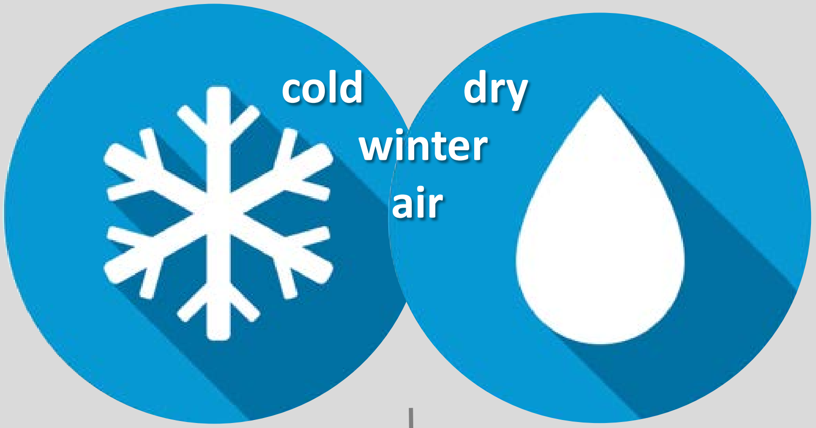
progressive side effects «to dry»

What is the optimum humidity ?

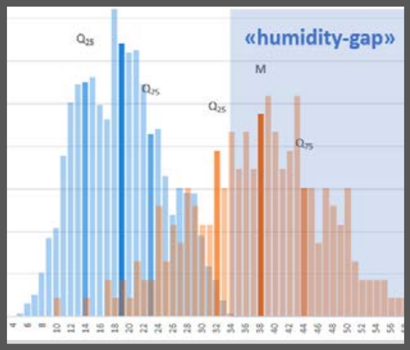
progressive side effects «to humid»

0	10	20%	30%	40%	50%	60%	70%	80

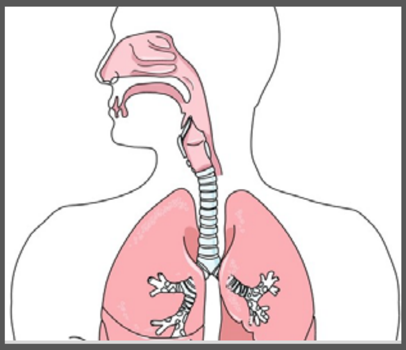
winter challenge



desert like indoor climate



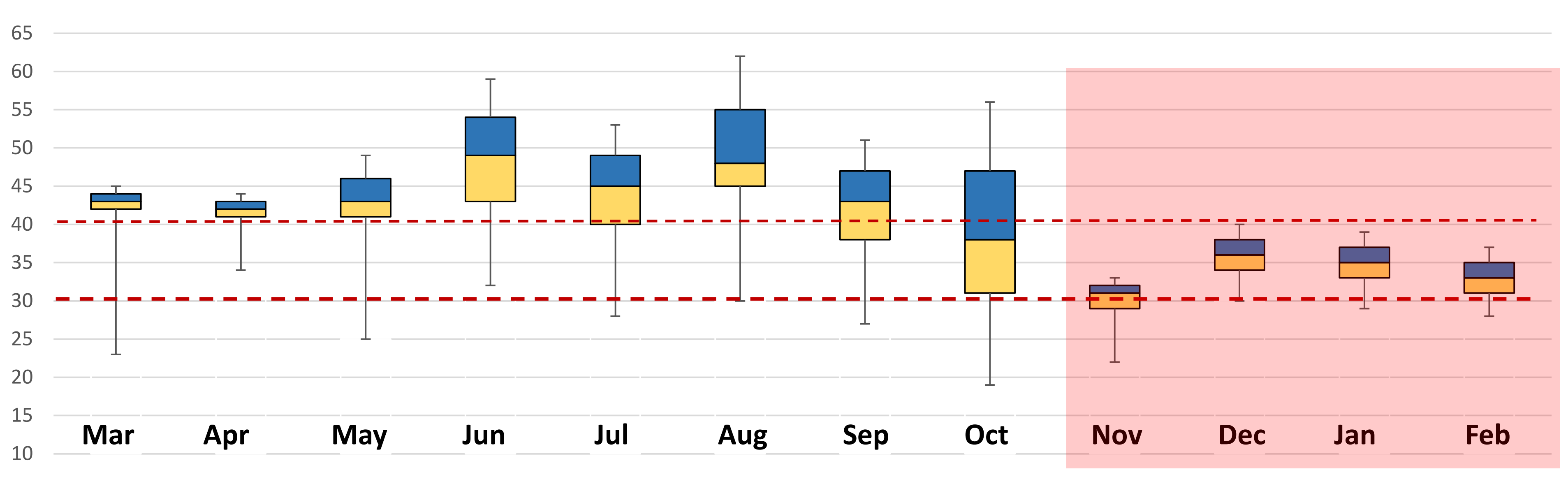
dangerous humidity – gap

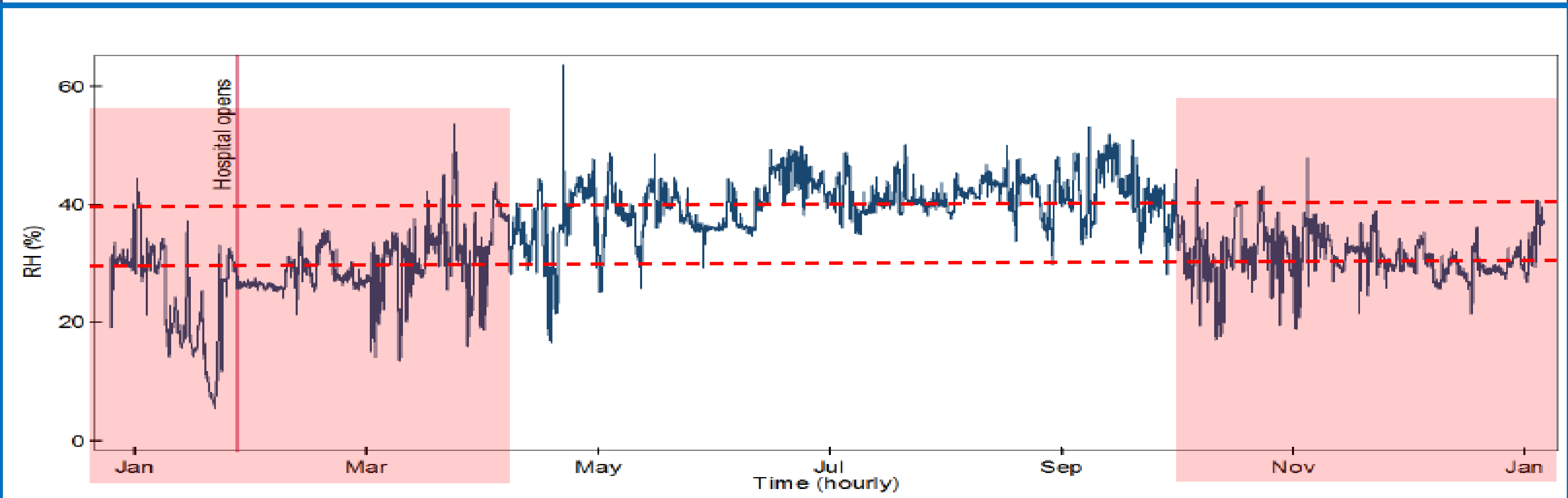


dehydration of mucous membranes

Open space office in Zurich, Switzerland, annual data set on relative humidity, 2009/2010

(box plot's with median values, 25/75% quartile, min and max values)

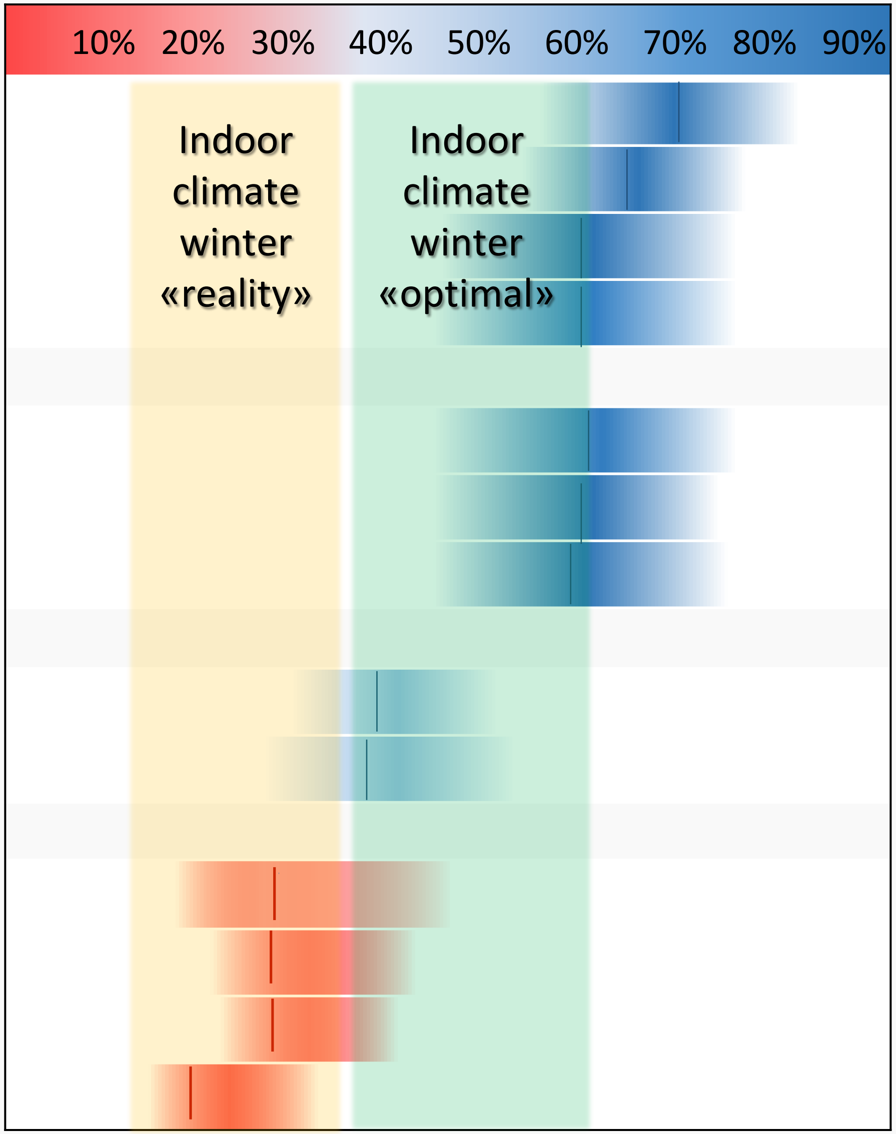




Hourly average RH (%) in one patient room over the duration of the measurement period (Jan 2013 to Jan 2014) Hospital Microbiome Project

How humid is ambient air at 20 to 24 °C (indoor comfort temperature)

CITY	TYPE	MW*
Palermo	costal cities	70.5
San Diego (USA)		66.7
Amsterdam		**62.0**
Hamburg		61.9
Eindhoven	inland cities	**60.1**
München		60.3
Berlin		58.8
St. Moritz (CH)	mountain cities	40.4
Denver (USA)		39.1
Tucson (USA)	desert cities	31.0
Riad (KSA)		30.6
Medina (KSA)		29.3
Tamanrasset (ALG)		22.1



MW* = median values RH (%) at 20-24 °C
Data based on hourly values for temperature and relative humidity (averaged over 10 years), at 20 to 24°C
Source: World Meteorological Data, www.wmo.int

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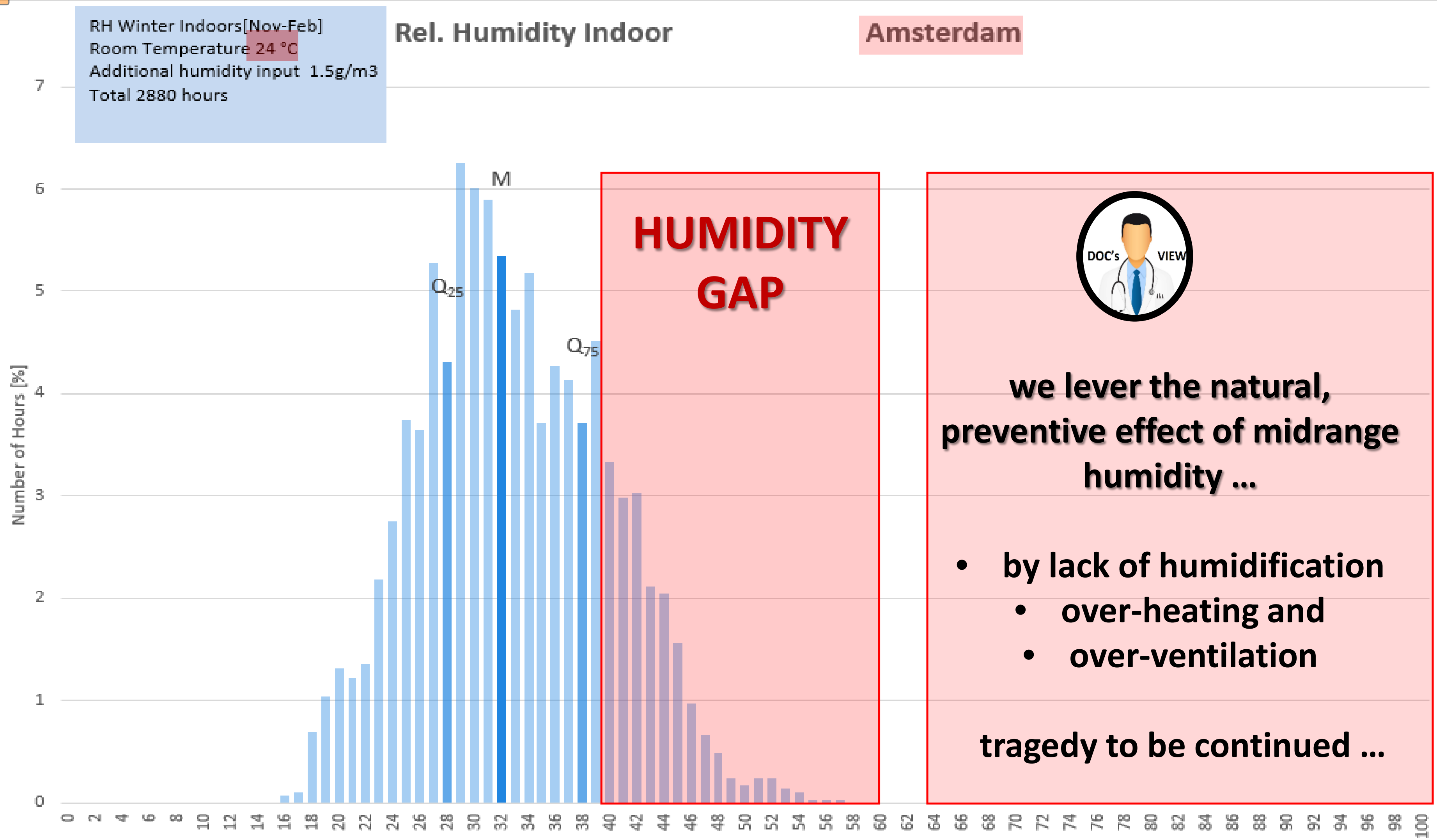


Histogram shows calculated frequency distribution of RH from Nov. to Feb. in Dutch buildings

Assumptions: temperature 24 °C, ventilation 29 m^3 ODA/person/hour → humidity input by occupants 1,5 g/m^3 ODA.

Meteorological data from www.meteonorm.com for Amsterdam, averaged data over 10 years.

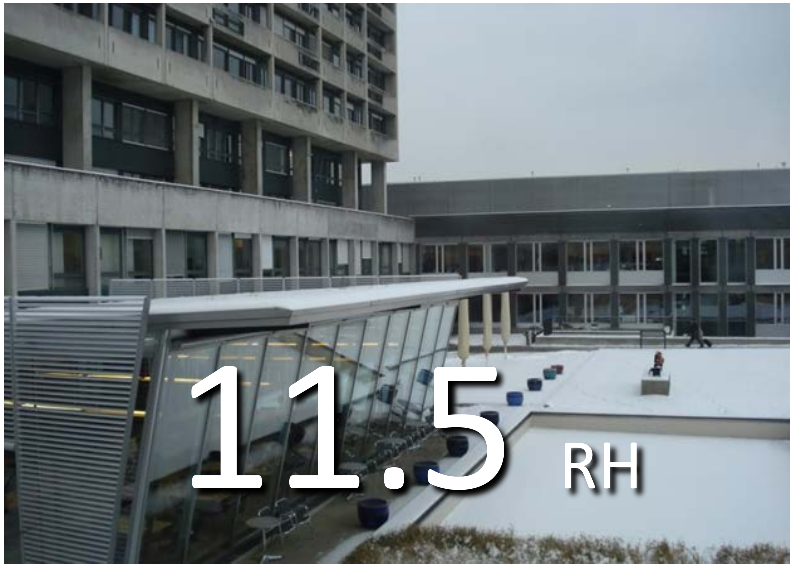

in traditional houses
with massif walls and
natural ventilation
air was dry in winter ...


in modern, energy-efficient,
airtight, mechanically ventilated
buildings of light-construction
indoor dryness has reached
dimensions never seen before !


… it is desert dry in
our office buildings
and dwellings …

Outdoor feb. 12th 2010

1°C 52% RH



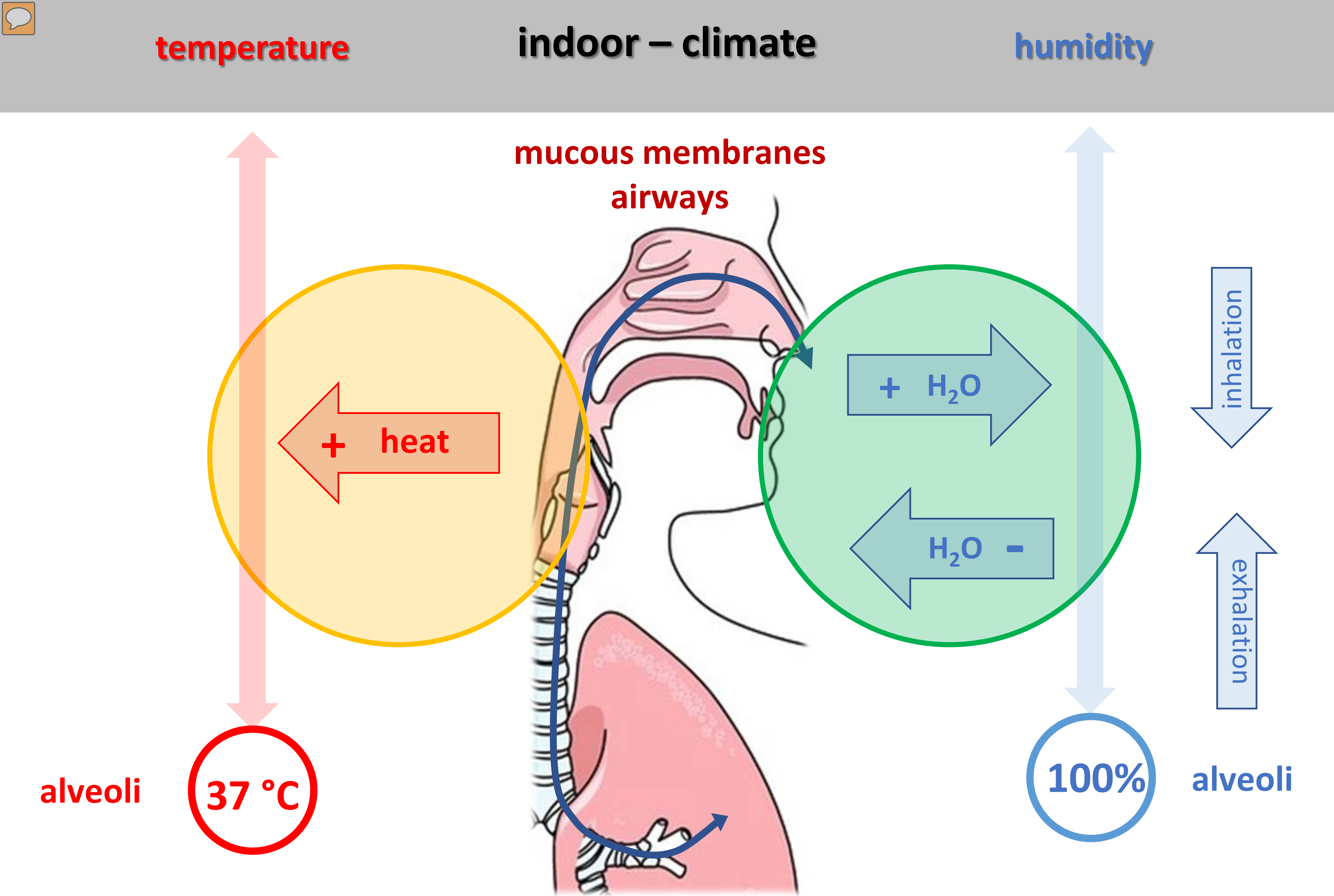
2.12th, 2010, 24.5 °C, waiting room, children dep. Triemlispital

2.12th, 2010, 17.30 Uhr, 21.9 ºC, Kunsthaus Zürich

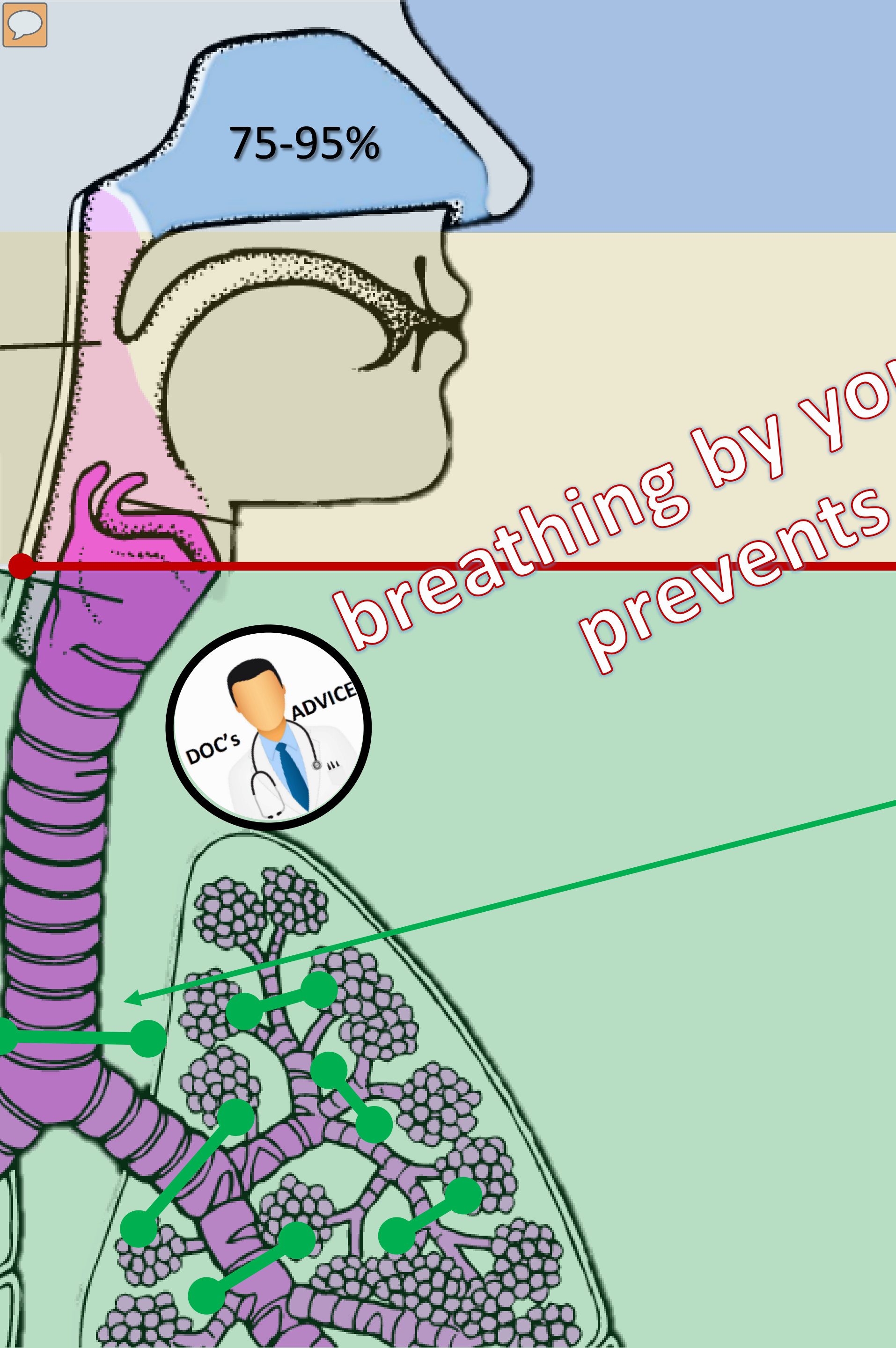
2.12th, 2010, 18.30 Uhr, T. 22.3 ºC, reading hall ETH

2.12th, 2010, 18.00 Uhr, T 19.9 ºC, salesroom for pianos

indoor – climate



Inhaled air must reach 37°C temperature and 100% humidity – this is physiologically required and essential for gas exchange



75-95 % of air conditioning
> 50 % of filtration 1-100 µm

Consequences overburdened dried out noses ?

breathing by your nose prevents disease !

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**

ES ENGINEERED SYSTEMS

January 2010, BY STEVEN WELTY, LEED AP, CIE, CAFS

“Engineers play a key role in reducing disease transmission that occurs in buildings”

Quote: ASHRAE Position Document on Airborne Infectious Diseases, January 2014

Disease transmission in building depends on the following topics:

- **air climate** (humidity/temperature and convection)
- **surface temperatures**
- **material choice**
- **and water treatment**

Building technology and construction determine ALL these conditions!

Two persons in the room have a respiratory infection

What can engineering do in order to prevent the spread of viruses?

It's all up to Your engineering decisions …

Yes, You <u>can</u> prevent infections …
and be a lifesaver

DOC's VIEW

People with infectious diseases spread microbes by breathing, talking, coughing, vomiting and diarrhea …..

The number of dispersed microbes (viruses, bacteria) into room air and on surfaces is

- **several to hundreds per minute**
- **hundreds of thousands per day**

… a few inhaled viruses or bacteria may cause a new infection in a second person …

What factors are decisive for the risk of secondary infection?

- Number of infected people and infection control behavior: "cough etiquette", hand washing, surface cleaning
- Vulnerability of the secondary hosts
- Exposure time to floating, viable microbes
  - Survival time in air
  - Settling speed of aerosols
  - Resuspension rate
  - Air change rate (ACR, Exfiltration rate)

All these factors are depending on engineering decisions and humidity

Building engineering can **promote**

- **occupants' health and comfort**

Building engineering can **prevent**

- **chronic disease of airways**
- **airborne transmission of disease**
- **airborne allergic reactions**

Building engineering can **prevent**

- **mould/bacterial growth on surfaces**

Building engineering can **inactivate**

- **airborne and settled microbes**

Building engineering can **reduce**

- **re-suspension of settled pathogens**

Building engineering can **reduce**

- **exposure to particulate matter**

How ?

Building engineering can **promote**

- occupants' health and comfort

Building engineering can **prevent**

- chronic disease of airways
- airborne transmission of disease
- airborne allergic reactions

Building engineering can **prevent**

- mould/bacterial growth on surfaces

Building engineering can **inactivate**

- airborne and settled microbes

Building engineering can **reduce**

- re-suspension of settled pathogens

Building engineering can **reduce**

- exposure to particulate matter

by

- **maintaining humidity range between 40 and 60 % RH (ideal 45 to 55 %)**
- **preventing cold surfaces by good insulation standards**
- **deciding for optimal ventilation concepts**
- **regulating ventilation «on demand»**
- **refraining from re-circulating air**
- **use of air filters in special situations**
- **keeping an eye on air pressure differences and thermal convection**

Viruses and bacteria that can trigger winter epidemics, have some remarkable similarities:

- Influenza-Virus
- RS-Virus
- Corona-Virus (incl. SARS)

Flue cold viruses

- Noro-Virus
- Rota-Virus

winter vomiting
winter diarrhoea

- Measles-Virus
- Chickenpox-Virus
- Rubella-Virus

Childhood diseases

- Streptococci
- Pneumococci
- Meningococci
- (Staphylococci)

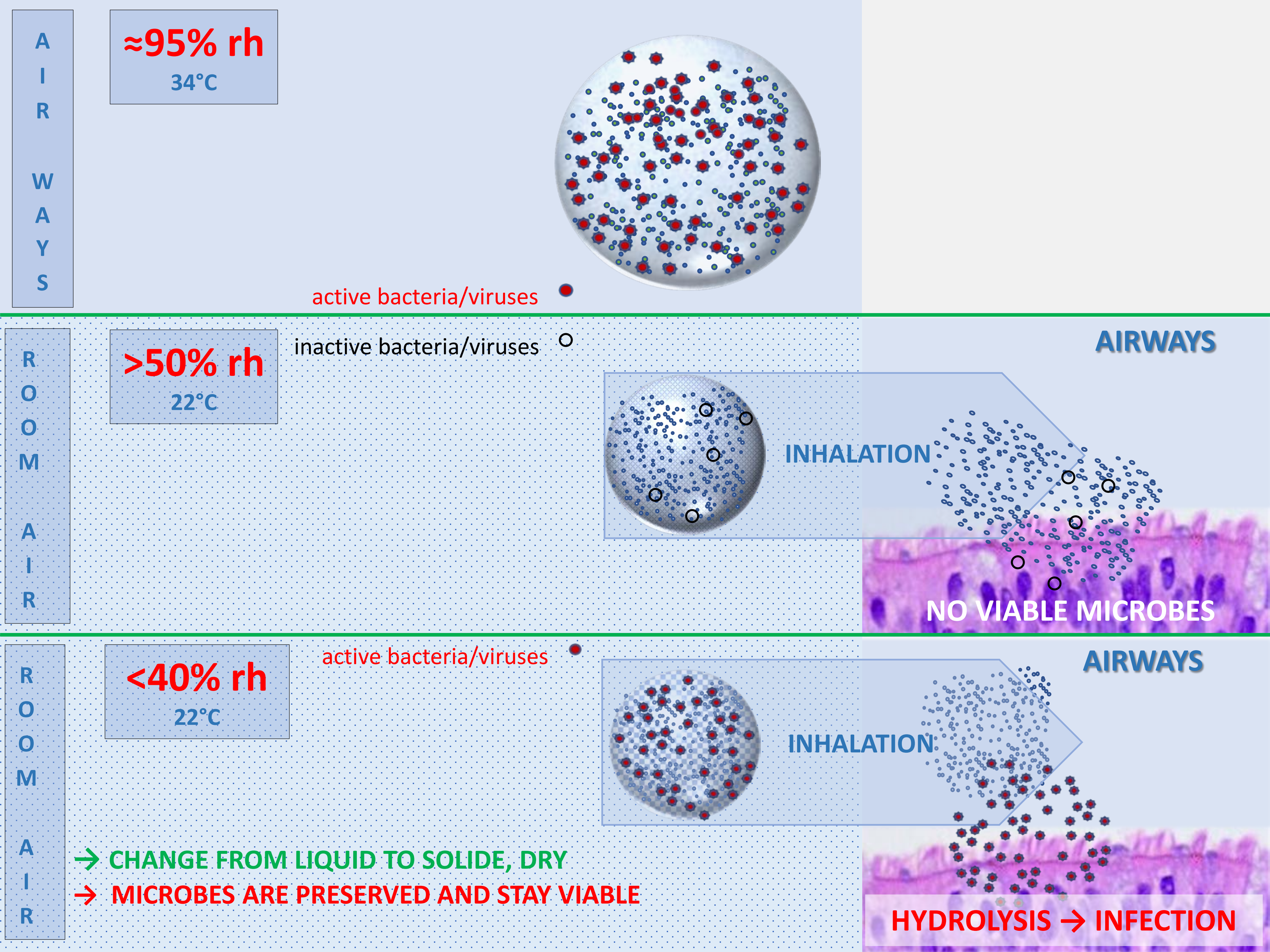
bacterial diseases
angina, pneumonia

All these viruses and bacteria:

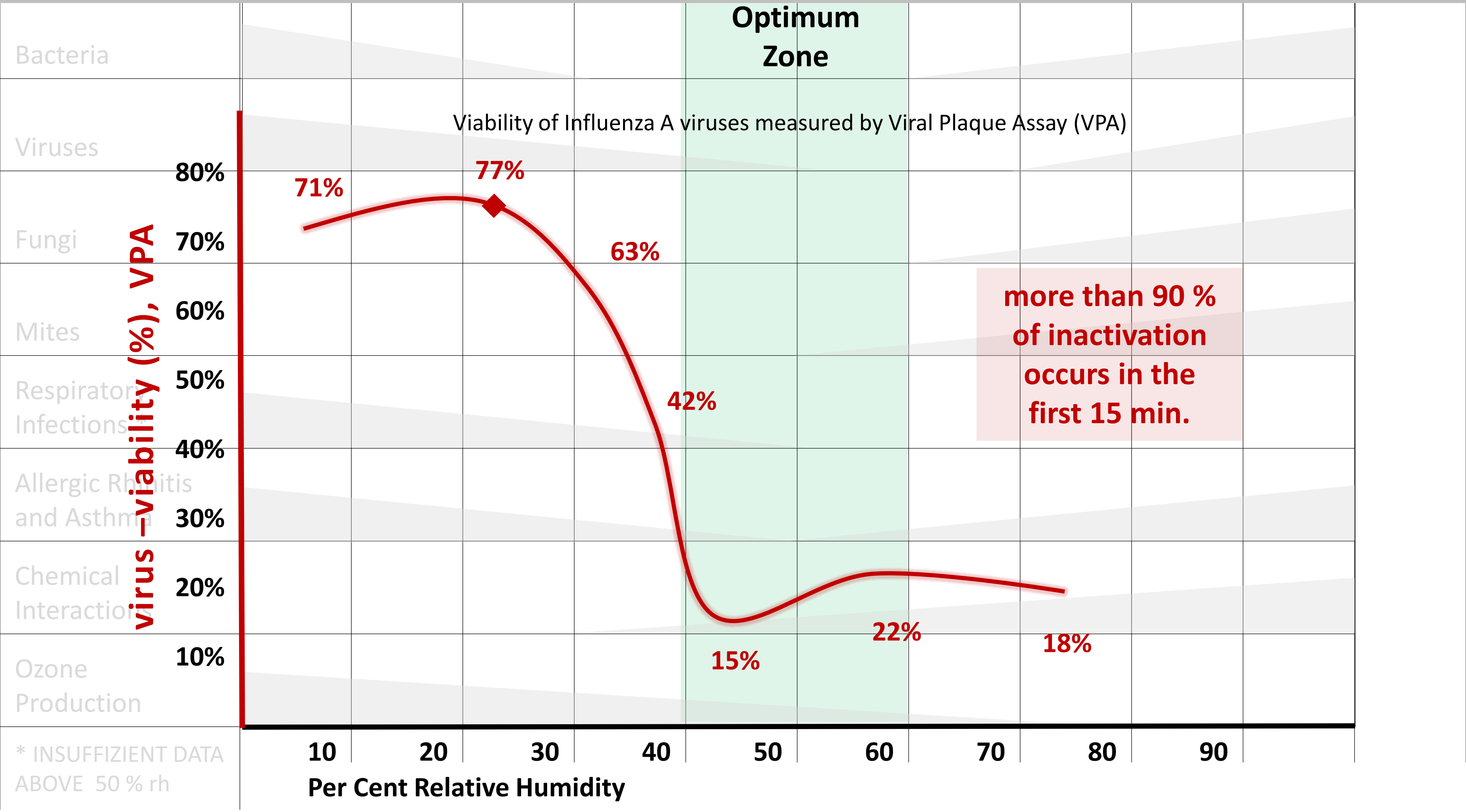
- Are easily transmittable by air (**airborne infections**)
- In mid-range humidity they become quickly **inactivated in the air and on surfaces.**
- are **«dryness-resistant»,** i.e. in dry environments they survive longer on surfaces and in the air.

When heating season starts , these germs take there chance for airborne transmission and quick spreading in our buildings ...

...most winter epidemics are "manmade" and "homemade"

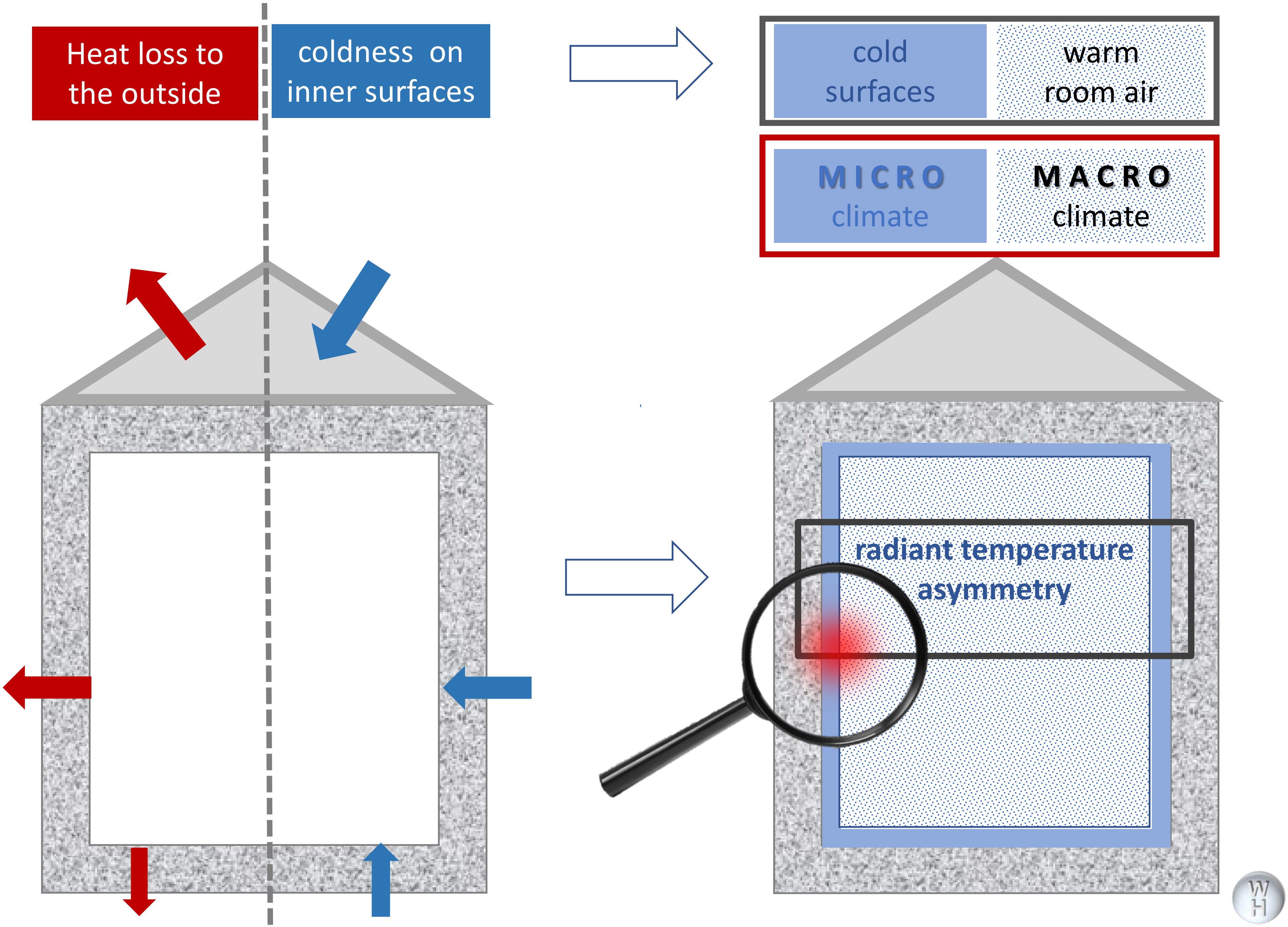

A I R W A Y S
≈95% rh
34°C
active bacteria/viruses
R O O M A I R
>50% rh
22°C
inactive bacteria/viruses
AIRWAYS
INHALATION
NO VIABLE MICROBES
R O O M A I R
<40% rh
22°C
active bacteria/viruses
AIRWAYS
INHALATION
→ CHANGE FROM LIQUID TO SOLIDE, DRY
→ MICROBES ARE PRESERVED AND STAY VIABLE
HYDROLYSIS → INFECTION

Percentage of viable flu viruses coughed up into a climate chamber after 1 hour RH from 7% to 73%

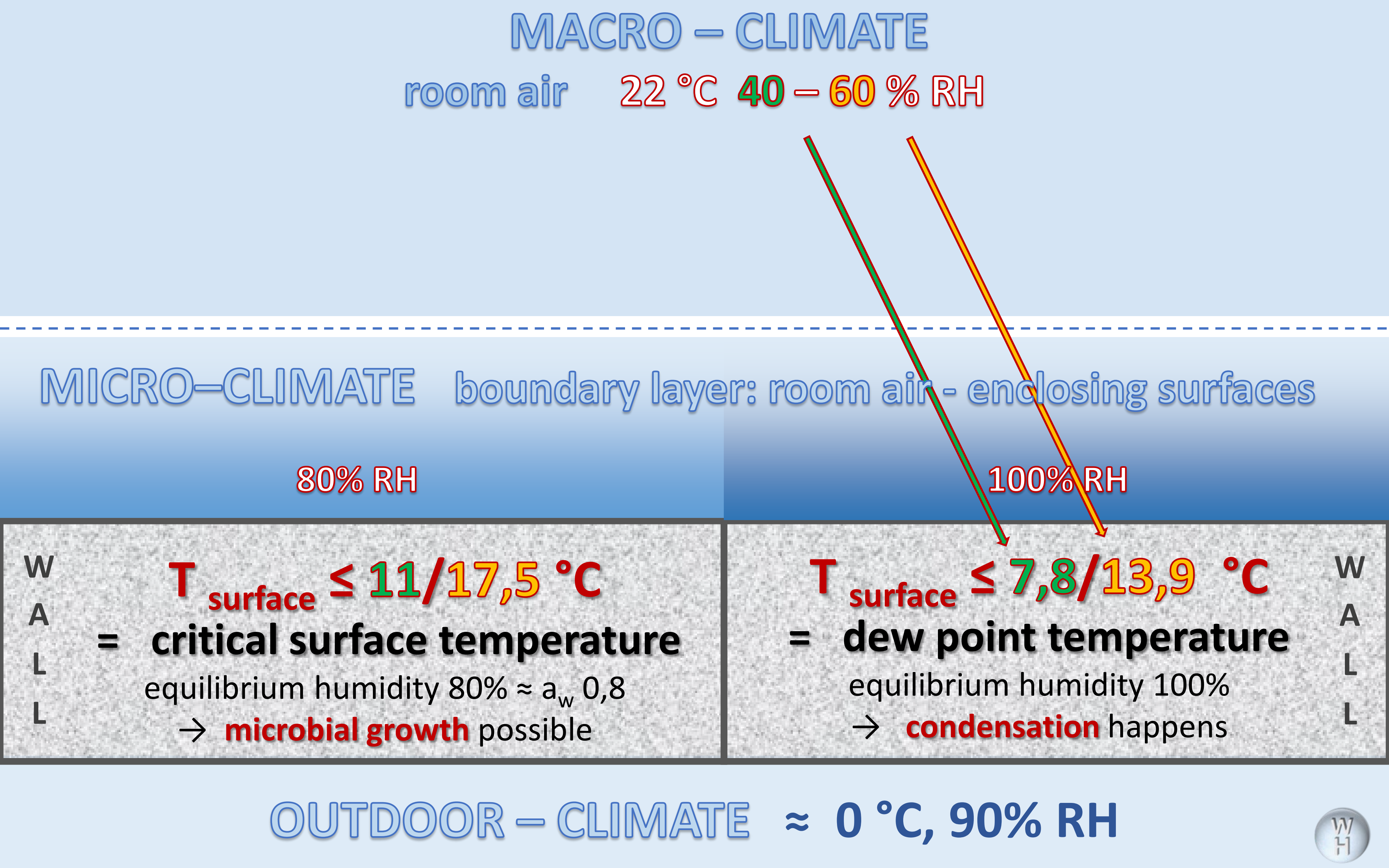


John D. Noti et al, High Humidity Leads to Loss of Infectious Influenza Virus from Simulated Coughs, PLOS ONE, **Feb. 2013**,Vol. 8, Issue 2 (study CDC, Morgantown)

Radiant temperature asymmetry causes a split climate …



Macro- und Micro- Climate in buildings
(winter situation in temperate climate)



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

W A L L

$T_{surface}$ ≤ 11/17,5 °C

= critical surface temperature

equilibrium humidity 80% ≈ a_w 0,8

→ **microbial growth** possible

$T_{surface}$ ≤ 7,8/13,9 °C

= dew point temperature

equilibrium humidity 100%

→ **condensation** happens

W A L L

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

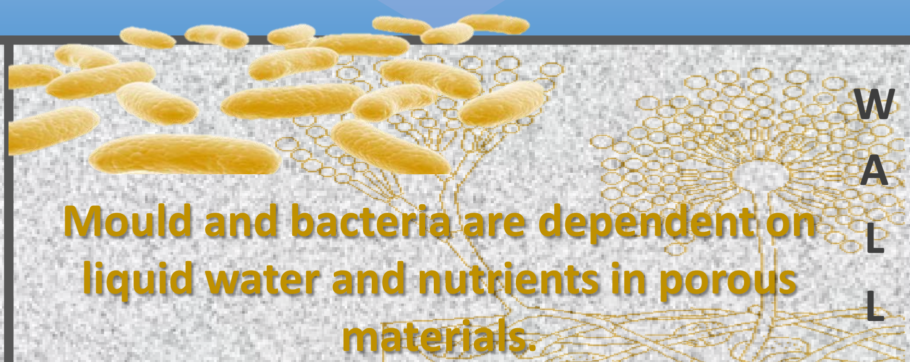
W A L L

$T_{surface} \leq 3$ °C

= **critical surface temperature**

equilibrium humidity 80% ≈ a_w 0,8

→ **microbial growth** possible

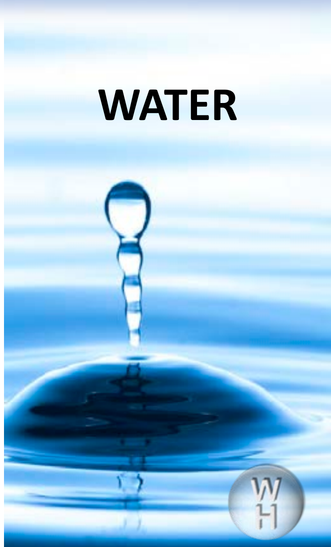


Mould and bacteria are dependent on liquid water and nutrients in porous materials.

W A L L

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

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



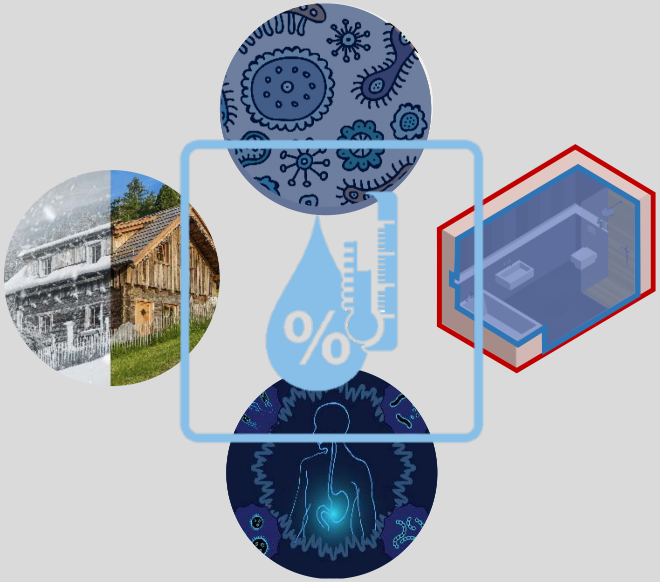
VISIBLE AND HIDDEN EFFECTS of WATER/DAMPNESS – NOT OF HUMIDITY !

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

BUILDING CLIMATE AND HEALTH

CRUCIAL ROLE OF AIR HUMIDITY

Dear audience
Take on the challenges!



Because our health is worth it!

Thank You for Your attention

CONDAIR MEETING AMSTERDAM Feb. 14th, 2017