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What Should Drive The Sustainability Bus IEQ Or Energy?

robert bean

principal, indoor climate consultants inc.

director www.healthyheating.com

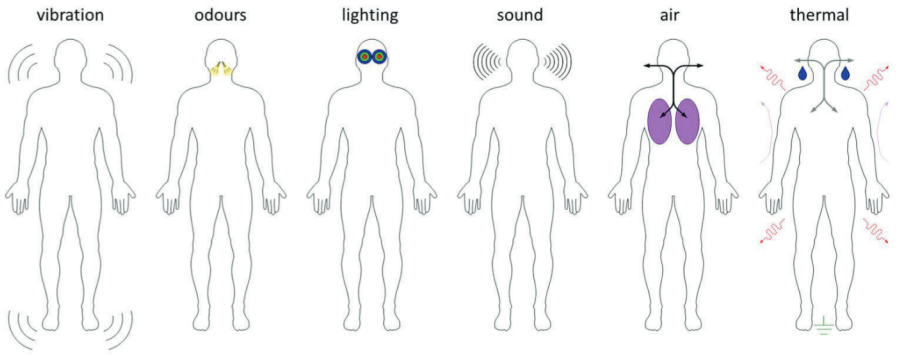
ashrae tc 2.1, 6.1, 6.5, 7.4, rbc, sspc 55, & liaison to sspc 62.2 & sspc 90.2

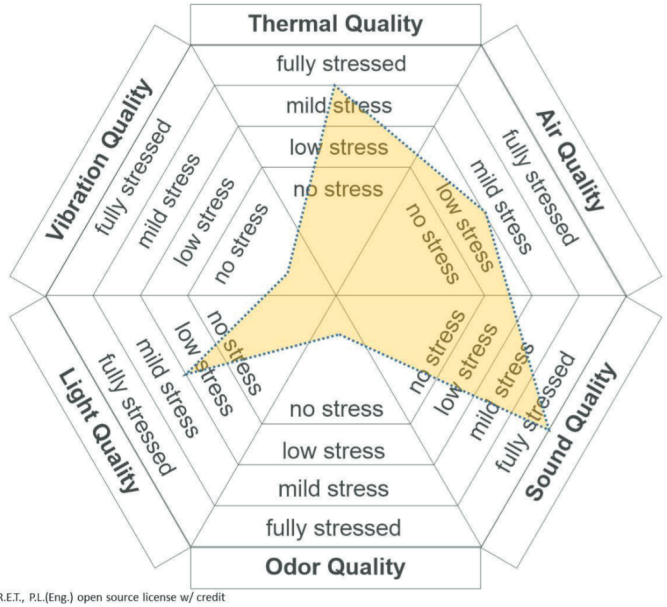
design for people - good buildings follow

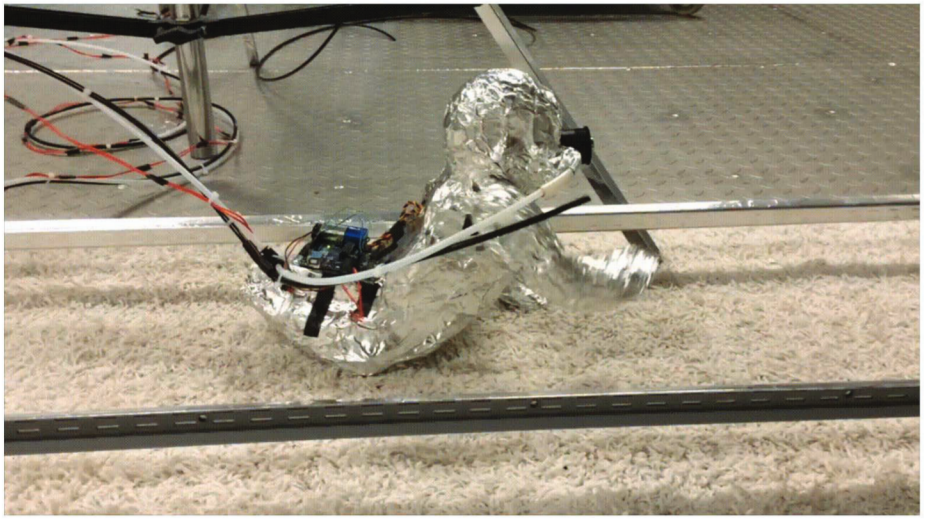
behind every Btu, kW, or m^3 of carbon oxides associated with architecture, are occupants avoiding stress due to discomfort

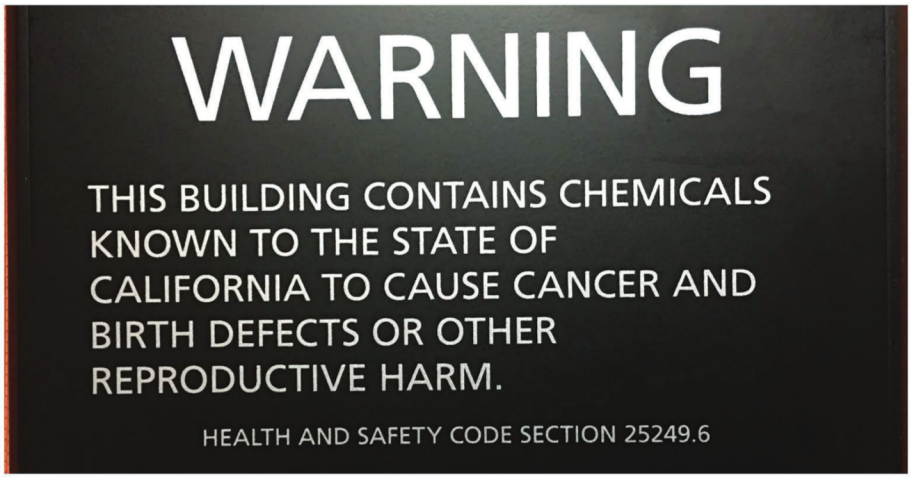
$$ieq = ivq + ioq + ilq + isq + iaq + itq$$

IAQ is not a proxy for IEQ, nor does IEQ exclusively represent IAQ…IEQ is the sum of the body's sensory systems – ALL OF THEM!

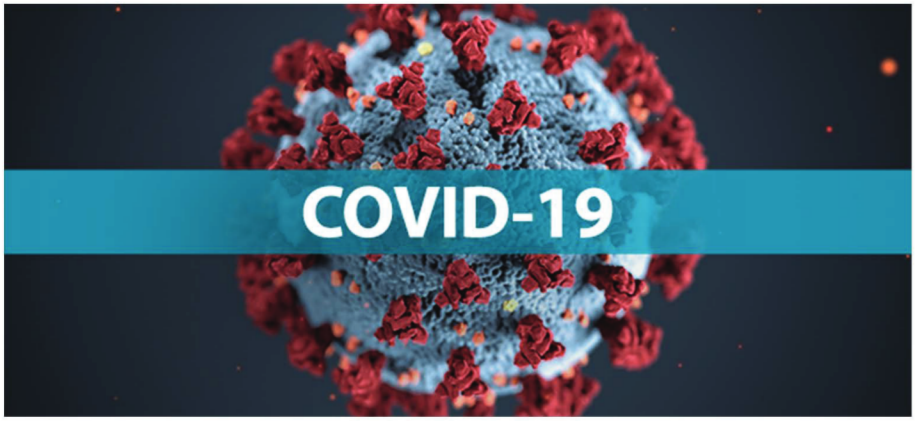




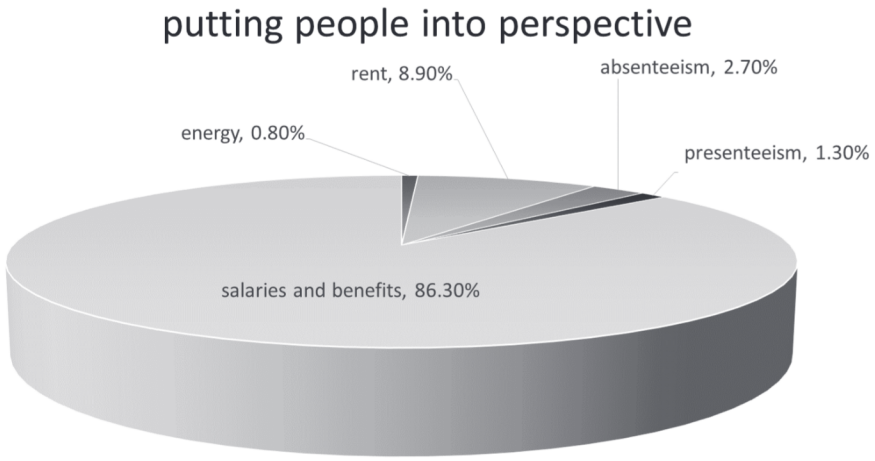




credit: Wu, Boor et al, Purdue University



google search “thermostat wars” video



≈ $3/sf/yr for utilities
≈ $30/sf/yr for rent
≈ $300/sf/yr for salaries

sources: us dept. of labor 2010, boma 2010, bls 2011

just how big a challenge is indoor environmental quality (ieq) in buildings?

first understand ieq = sound + thermal + air + light + odours + vibration

second understand *minimums in code have become maximum in practice*

estimated 85% of buildings in North America under 25,000 sf (ala Sir Mathis)

as an example: HVAC designed by non-professionals with zero ieq training

≈ 500 designs/whlsr/yr x ≈ 5 whlsrs/city x ≈ 150 cities ≈ 375,000 designs/yr

as an example: HVAC designed by professionals with limited ieq training

≈ 20 designs/firm/yr x ≈ 10 firms/city x ≈ 150 cities ≈ 30,000 designs/yr

≈ 405,000$^{+/-}$ designs per year without a focus on the occupants

≈ 4,000,000$^{+/-}$ over 10 yrs focusing on code compliance, energy conservation and efficiency of the building systems while ignoring the people in the buildings

occupants have never had

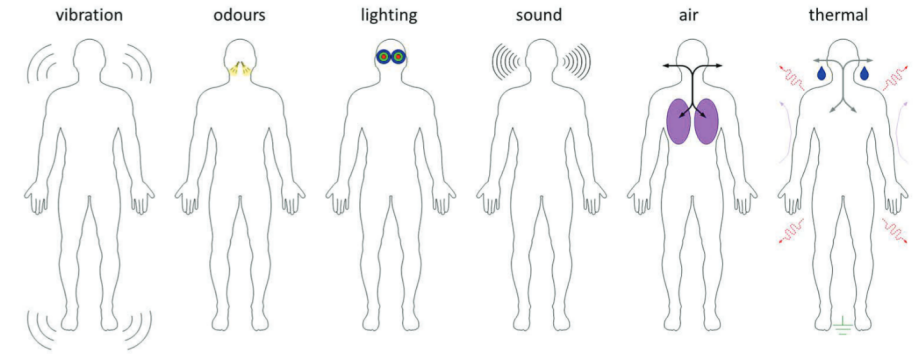
energy problems

they have always had

discomfort problems

energy use is the consequence

$$ieq = ivq + ioq + ilq + isq + iaq + itq$$



why we need to understand the air based sciences

air flow is

transportation for

contaminants, pollutants, toxicants

resource: hodgson, e., a textbook of modern toxicology, third edition, 2004

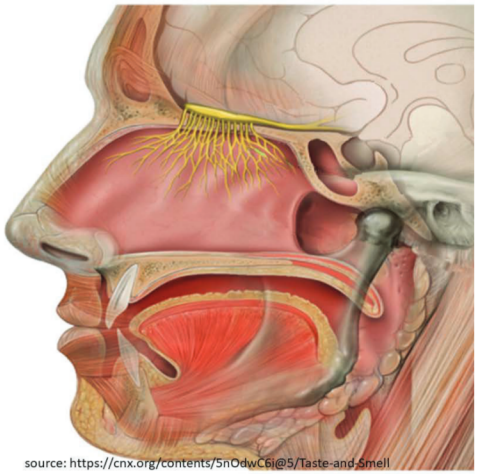
inhalation: early warning system

smells

heats

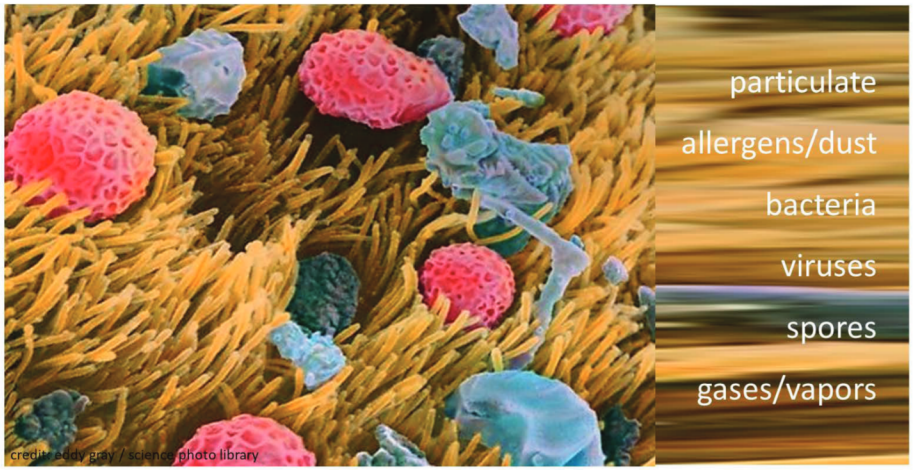
filters

expels



source: https://cnx.org/contents/5nOdwC6i@5/Taste-and-Smell

cilia and mucous - self defense



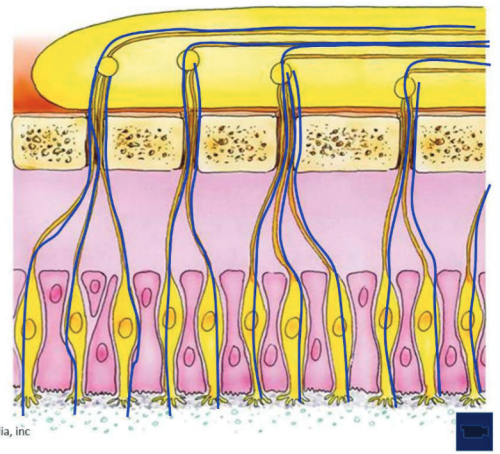
the human factor: respiratory organs

olfactory nerve

smell receptors

cilia, mucosa

sneezing



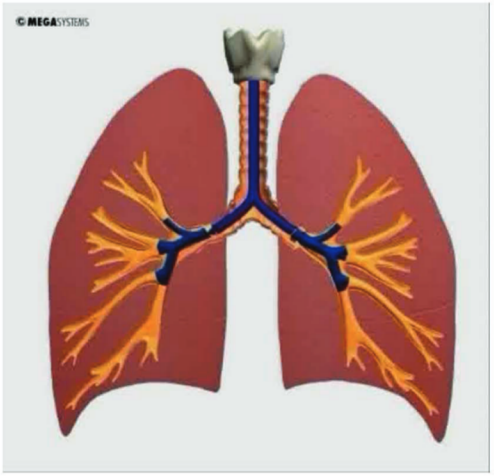
human duct work

heats & filters

clears/expels

diverts

distributes



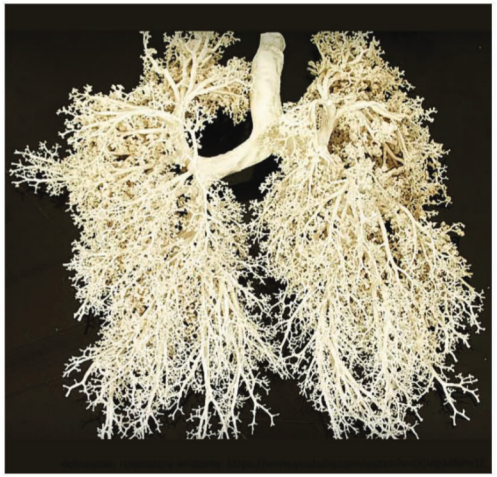
breathing is not an option

the lungs

outside goes in

inside comes out

Δp = 1 mmhg



permeable gas exchanger

alveoli

the $O_2 \leftrightarrow CO_2$

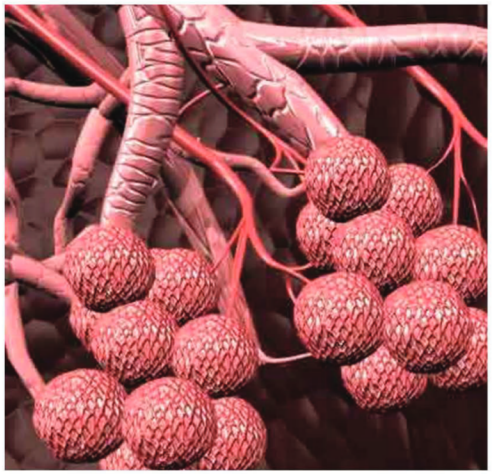
avg 300 to 500 million $^{+/-}$

≈ 0.05mm to 0.2mm dia

≈ 50μm to 200μm

≈ 1 mm^3 = 170 alveoli

biomedical multimedia unit, faculty of medicine, dentistry and health sciences, the university of melbourne



permeable gas exchanger

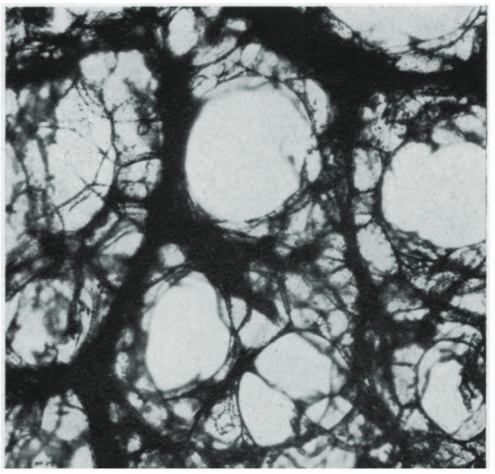
alveoli

the $O_2 \leftrightarrow CO_2$

x52 scale

showing vessels between alveoli

the-microanatomy of the alveolar duct system, w. f. whimster', thorax (1970), 25, 141.



gas exchanger & host to macrophages

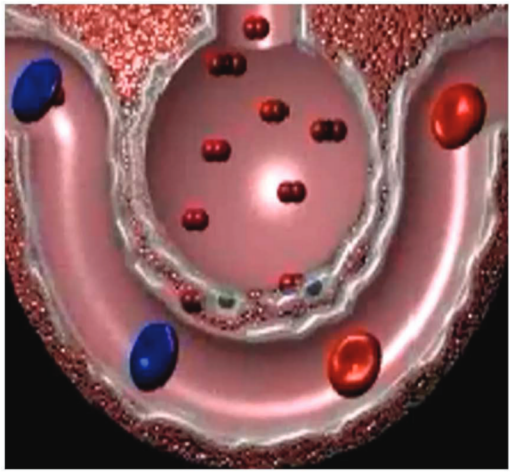
alveoli

single cell thick

last "external"

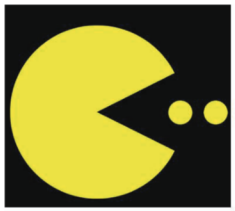
defense barrier

biomedical multimedia unit, faculty of medicine, dentistry and health sciences, the university of melbourne



defense mechanisms in the alveoli

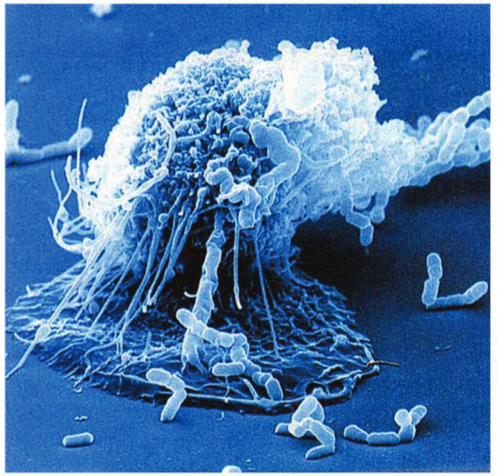
macrophages



eating the bad outside stuff

Ø ≈21 μm

source: https://srxawordonhealth.com/tag/macrophages/

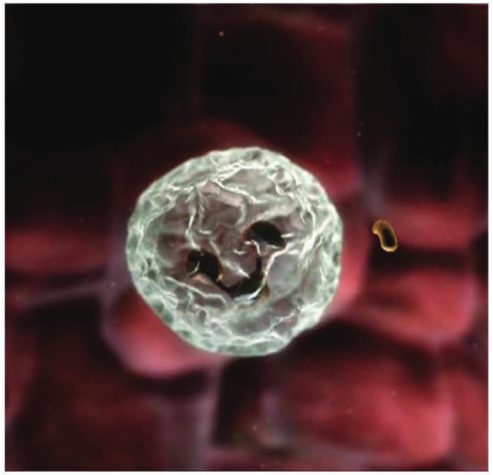


internal defense mechanisms

white blood cells

"eating" the bad stuff inside

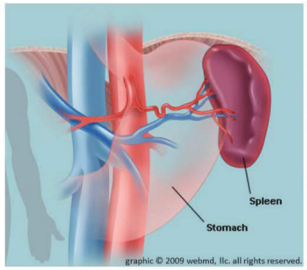
Ø ≈15 μm

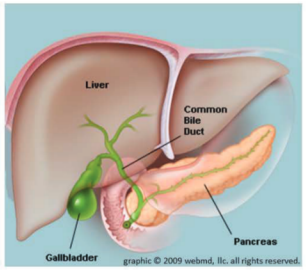


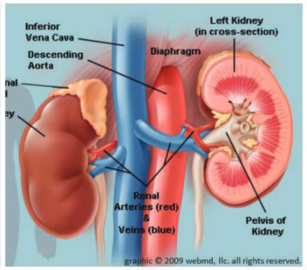
animation from "the human body book" copyright© 2007 dorling kindersley limited all rights reserved

dealing with some of the outside that gets inside

filtration, repair, recycle and removal







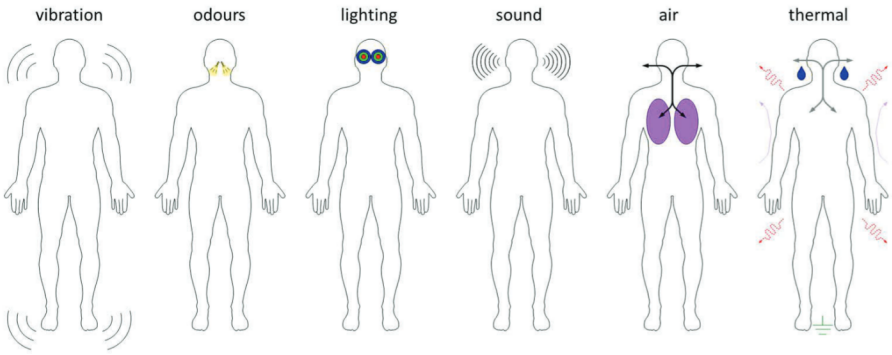
spleen
immune system, blood filter, red cell recycler, stores white cells, fights bacteria

liver
digestive blood filter, detoxifies chemicals and metabolizes drugs, bile secretion

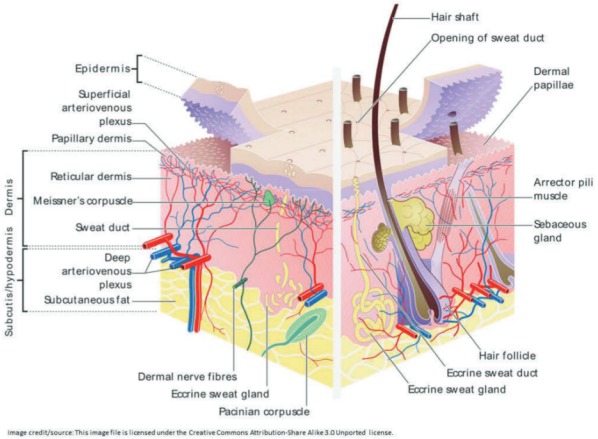
kidneys
blood filter, maintains fluid and electrolyte balance, waste removal

environmental stressors: a personal story

$$ieq = ivq + ioq + ilq + isq + iaq + itq$$



thermoreceptors: temperature change



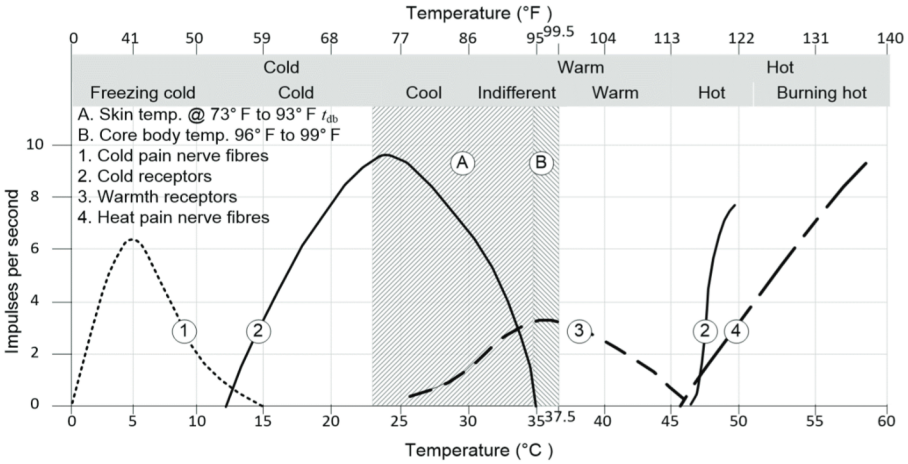
free nerve endings - thermoreceptors

≈150,000 sensitive to heat loss.

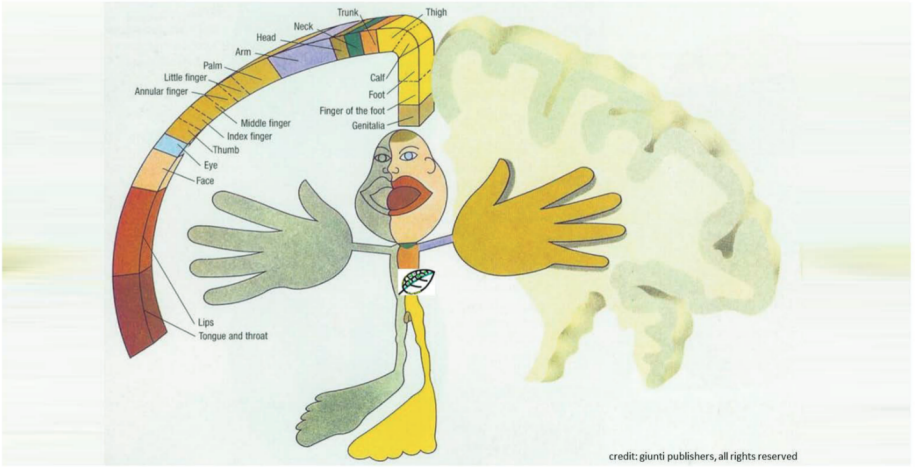
≈16,000 sensitive to heat gain

A. Marsh, Ph.D.

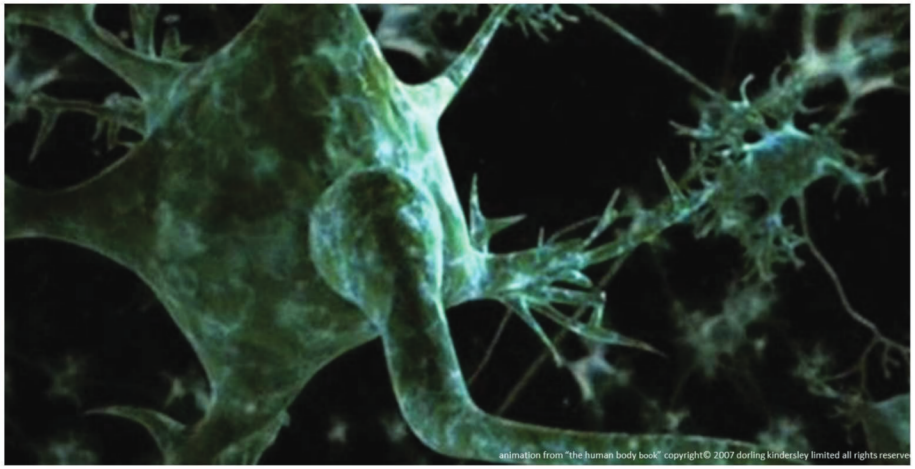
thermoreceptors: temperature change



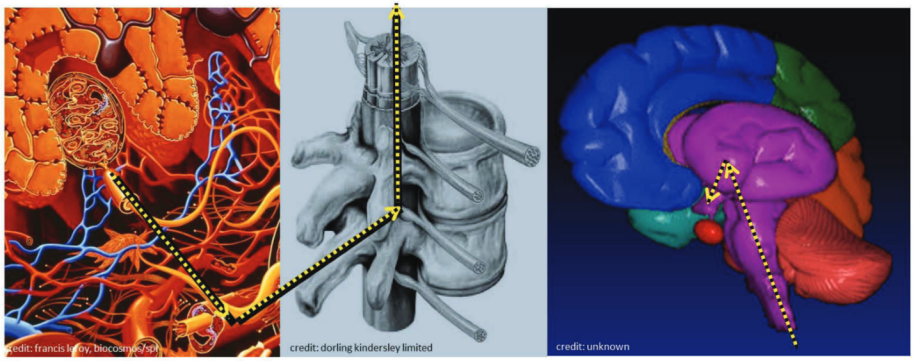
sensory receptors: general distribution



central nervous system



central nervous system



sensors nerves thalamus and hypothalamus

central nervous system

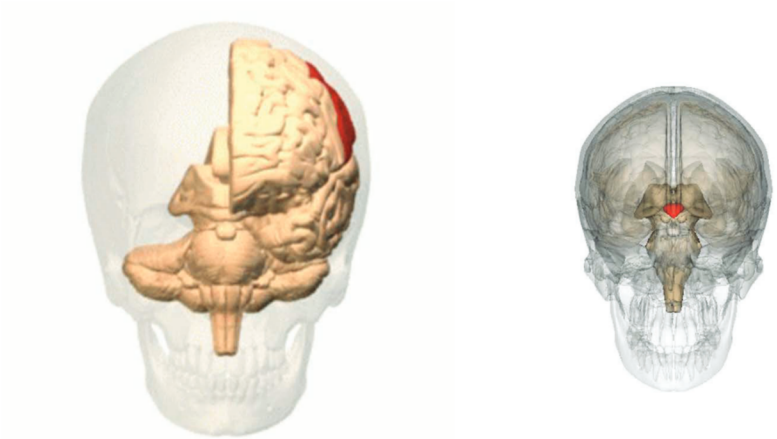


Image credit: BodyParts3D, © The Database Center for Life Science licensed under CC Attribution-Share Alike 2.1 Japan

cns, ans, cardiovascular & endocrine system

comfort:

state of mind

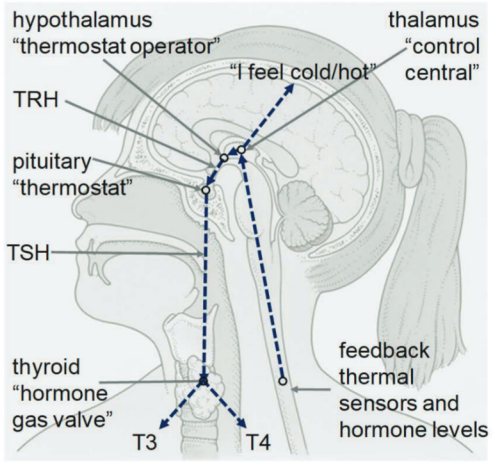
endocrine/

autonomic

nervous

systems

(ans)



thermal and stress response

neurotransmitters/ hormones

T3, T4

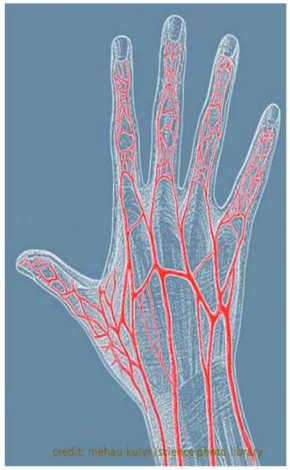
epinephrine, norepinephrine

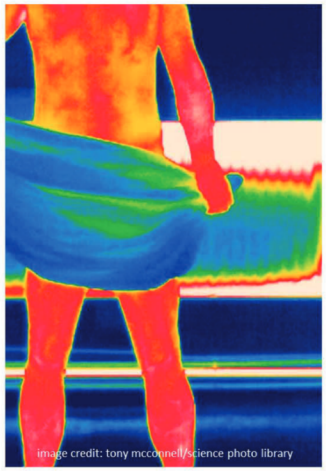
cortisol

vis a vis

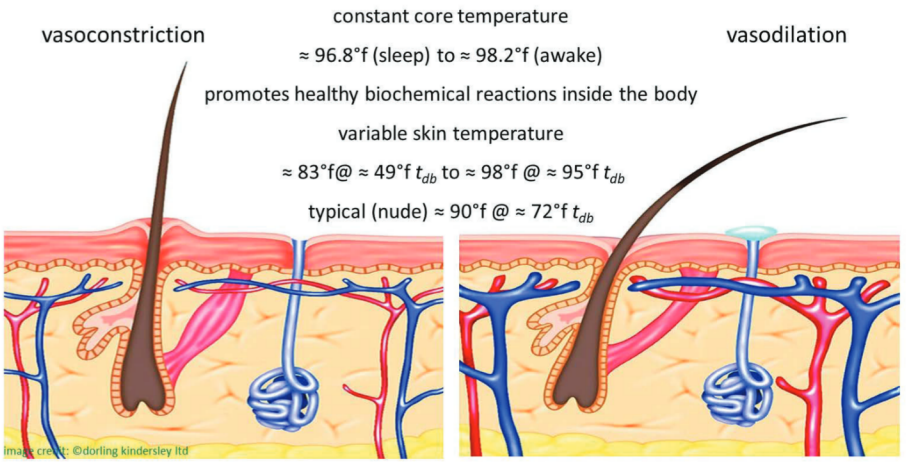
hypothalamus TRH/CRH & pituitary TSH/ACTH thyroid/adrenal gland

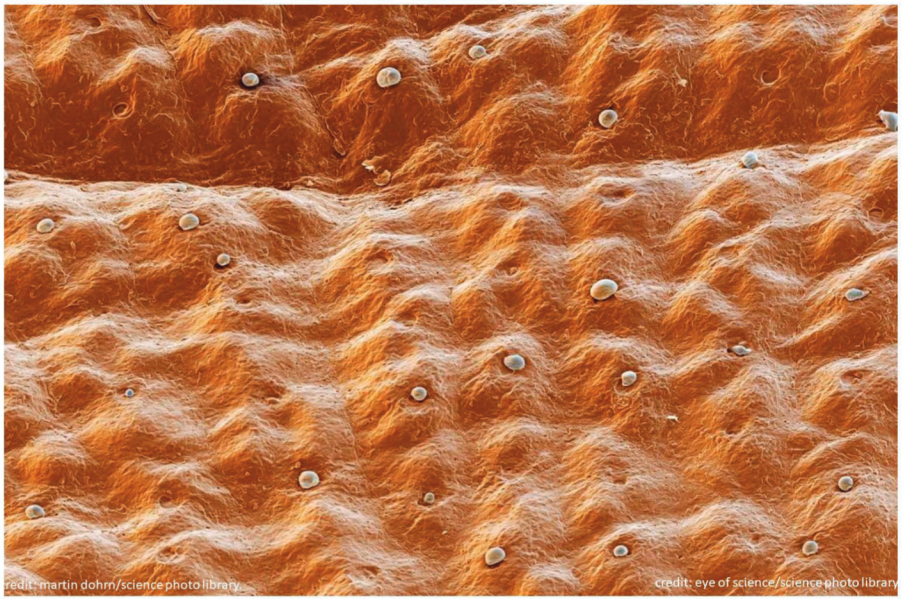
cns, ans, cardiovascular & endocrine system



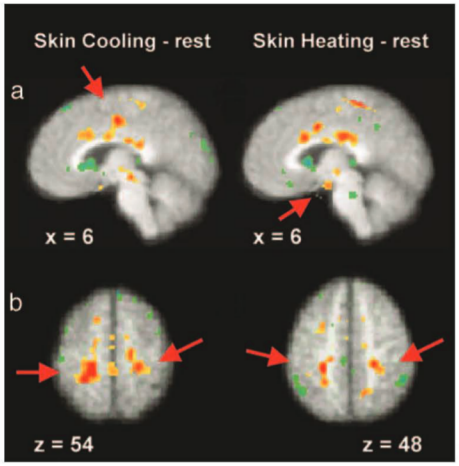


cns, ans, cardiovascular & endocrine system





the autonomic and endocrine system at work



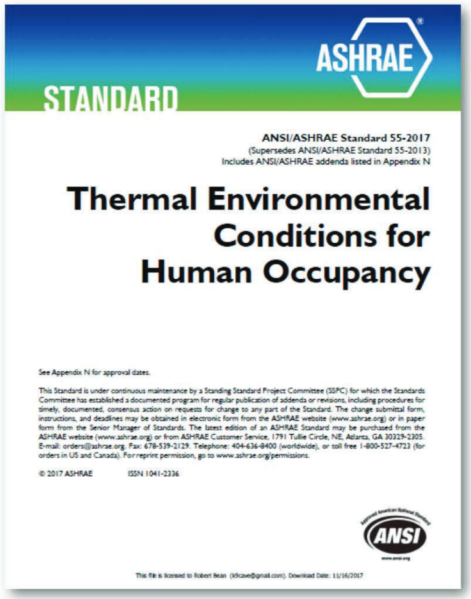
cortical, thalamic, and hypothalamic responses to cooling and warming the skin in awake humans: a positron-emission tomography study copyright 2004, national academy of sciences, u.s.a.,

in heating

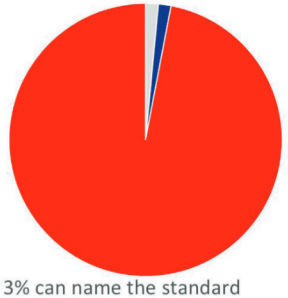
warm surfaces suppress the loss of body heat

in cooling

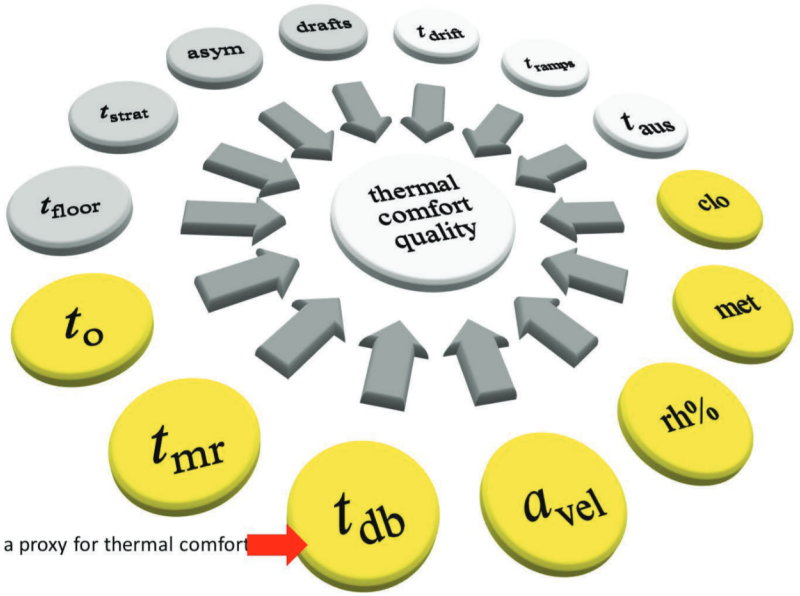
cool surfaces enable the loss of body heat



bean surveys industry audiences from 2002-2019, 100% were somehow tied to the "thermal comfort business"

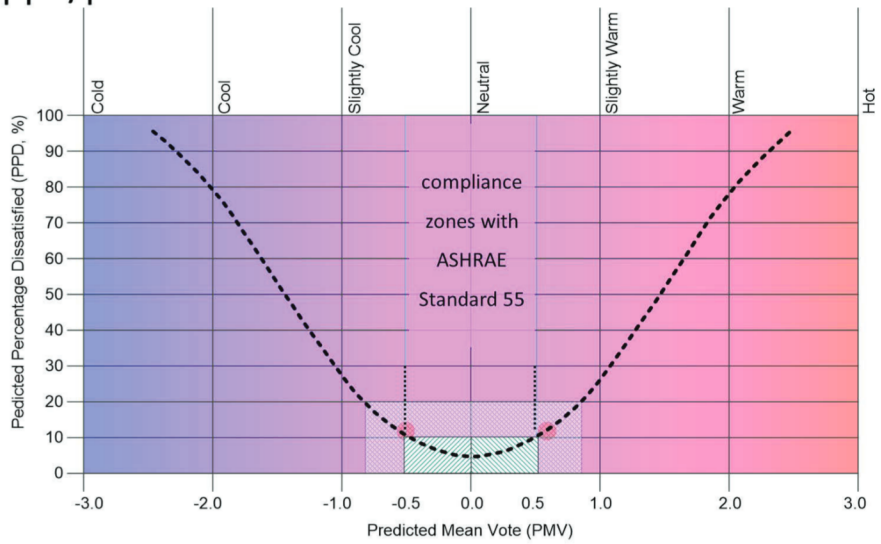


- only 3% can name the standard
- only 1/2 of the 3% are fluent in the standard
- 97% not familiar with the standard!



NOT a proxy for thermal comfort

ppd/pmv



how do codes address comfort?

national building code of canada says…

an **objective** of this Code is to **limit the probability** that, as a result of the design or construction of the building or facility,

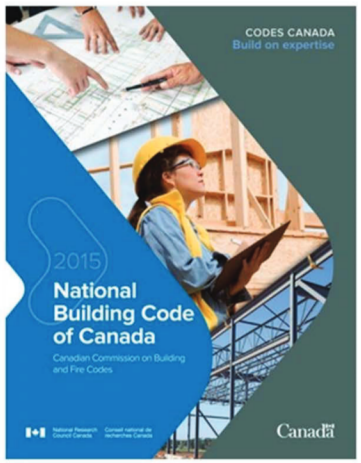
a person in the building or facility

will be exposed to an unacceptable

RISK OF ILLNESS due to inadequate…

air quality, thermal comfort, contact with moisture.

nbc of canada



"at the outside winter design temperature, required heating facilities shall be capable of maintaining an indoor **AIR** temperature of not less than 22°C (72°F) in all living spaces…"

this is what 72°F$^{+/-}$ (22°C$^{+/-}$) air temperature looks like

risk of illness ≠ risk of discomfort

codes ≠ comfort

heat loss & heat gain calculations

ARE NOT

thermal comfort calculations

hvac design by itself

IS NOT

thermal comfort design

making sense of the sensible

or what exactly <u>should</u> we be controlling?

via ashrae handbooks

Table 1 Representative Rates at Which Heat and Moisture Are Given Off by Human Beings in Different States of Activity

Degree of Activity	Location	Total Heat, Btu/h: Adult Male	Total Heat, Btu/h: Adjusted, M/F[a]	Sensible Heat, Btu/h	Latent Heat, Btu/h	% Sensible Heat that is Radiant[b]: Low V	% Sensible Heat that is Radiant[b]: High V
Seated at theater	Theater	390	350	245	105	60	27
Seated, very light work	Offices, hotels, apartments	450	400	245	155		
Moderately active office work	Offices, hotels, apartments	475	450	250	200		
Standing, light work; walking	Department store; retail store	550	450	250	200	58	38
Walking, standing	Drug store, bank	550	500	250	250		
Sedentary work	Restaurant[c]	490	550	275	275		
Light bench work	Factory	800	750	275	475		
Moderate dancing	Dance hall	900	850	305	545	49	35
Walking 3 mph; light machine work	Factory	1000	1000	375	625		
Bowling[d]	Bowling alley	1500	1450	580	870		
Heavy work	Factory	1500	1450	580	870	54	19
Heavy machine work; lifting	Factory	1600	1600	635	965		
Athletics	Gymnasium	2000	1800	710	1090		

Notes:
1. Tabulated values are based on 75°F room dry-bulb temperature. For 80°F room dry bulb, total heat remains the same, but sensible heat values should be decreased by approximately 20%, and latent heat values increased accordingly.
2. Also see Table 4, Chapter 9, for additional rates of metabolic heat generation.
3. All values are rounded to nearest 5 Btu/h.

[a]Adjusted heat gain is based on normal percentage of men, women, and children for the application listed, and assumes that gain from an adult female is 85% of that for an adult male, and gain from a child is 75% of that for an adult male.
[b]Values approximated from data in Table 6, Chapter 9, where V is air velocity with limits shown in that table.
[c]Adjusted heat gain includes 60 Btu/h for food per individual (30 Btu/h sensible and 30 Btu/h latent).
[d]Figure one person per alley actually bowling, and all others as sitting (400 Btu/h) or standing or walking slowly (550 Btu/h).

c/o anatomy & physiology, rice university, texas

Conduction is the transfer of heat by two objects that are in direct contact with one another. It occurs when the skin comes in contact with a cold or warm object. For example, when holding a glass of ice water, the heat from your skin will warm the glass and in turn melt the ice. Alternatively, on a cold day, you might warm up by wrapping your cold hands around a hot mug of coffee. Only about 3 percent of the body's heat is lost through conduction.

Convection is the transfer of heat to the air surrounding the skin. The warmed air rises away from the body and is replaced by cooler air that is subsequently heated. Convection can also occur in water. When the water temperature is lower than the body's temperature, the body loses heat by warming the water closest to the skin, which moves away to be replaced by cooler water. The convection currents created by the temperature changes continue to draw heat away from the body more quickly than the body can replace it, resulting in hyperthermia. About 15 percent of the body's heat is lost through convection.

Radiation is the transfer of heat via infrared waves. This occurs between any two objects when their temperatures differ. A radiator can warm a room via radiant heat. On a sunny day, the radiation from the sun warms the skin. The same principle works from the body to the environment. About 60 percent of the heat lost by the body is lost through radiation.

Evaporation is the transfer of heat by the evaporation of water. Because it takes a great deal of energy for a water molecule to change from a liquid to a gas, evaporating water (in the form of sweat) takes with it a great deal of energy from the skin. However, the rate at which evaporation occurs depends on relative humidity—more sweat evaporates in lower humidity environments. Sweating is the primary means of cooling the body during exercise, whereas at rest, about 20 percent of the heat lost by the body occurs through evaporation.

via uk's government health and safety executive

air temperature alone

is neither a valid

nor an accurate indicator of

thermal comfort or thermal stress

<http://www.hse.gov.uk/temperature/thermal/factors.htm> accessed oct 2017

via the rocky mountain institute

comfort is incredibly important to building occupant

but the traditional

air temperature-centric design approach

used in buildings for decades

is ineffective, inefficient, and expensive.

rocky mountain institute, re-defining and delivering

thermal comfort in buildings, 2016

via rod nav, ph.d. author of hyperphysics

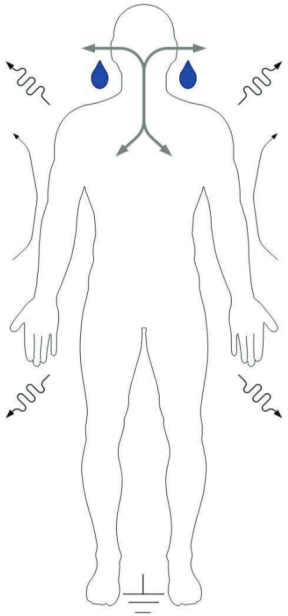
at ordinary room temperatures

radiation (from the body)

is the most important heat transfer mechanism

cooling of the human body @hyperphysics

credit: http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html



ASHRAE handbooks

medical text books

indoor environmental

ergonomic guidebooks

are in agreement...

radiant is the dominant mechanism

via major drafting and design software company

mean radiant temperature

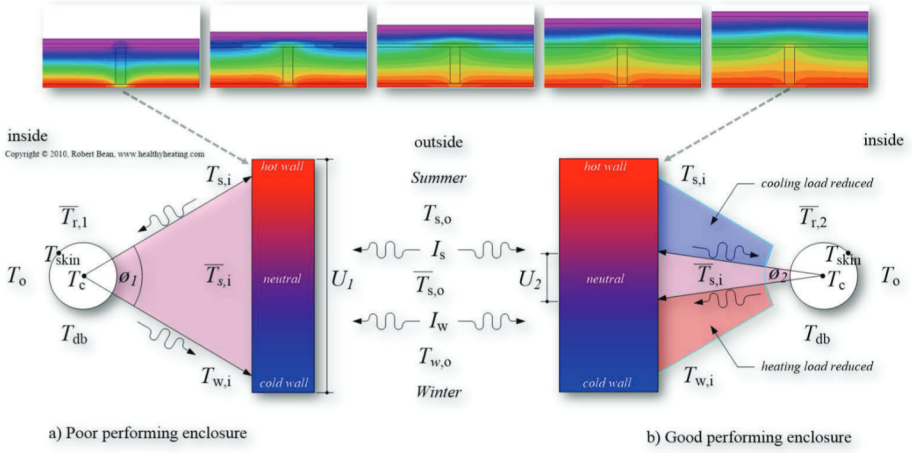
is the single most important parameter

in human thermal comfort...

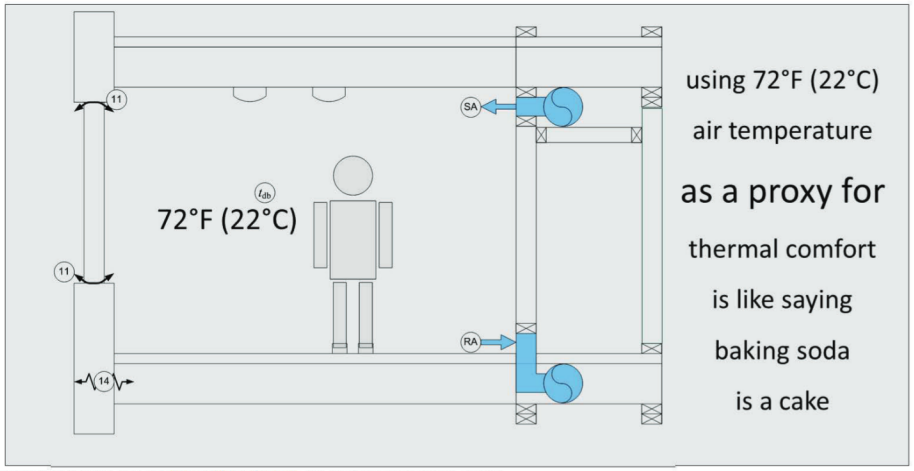
air temperatures matter less.

https://sustainabilityworkshop.????????.com/buildings/radiant-heating-and-cooling

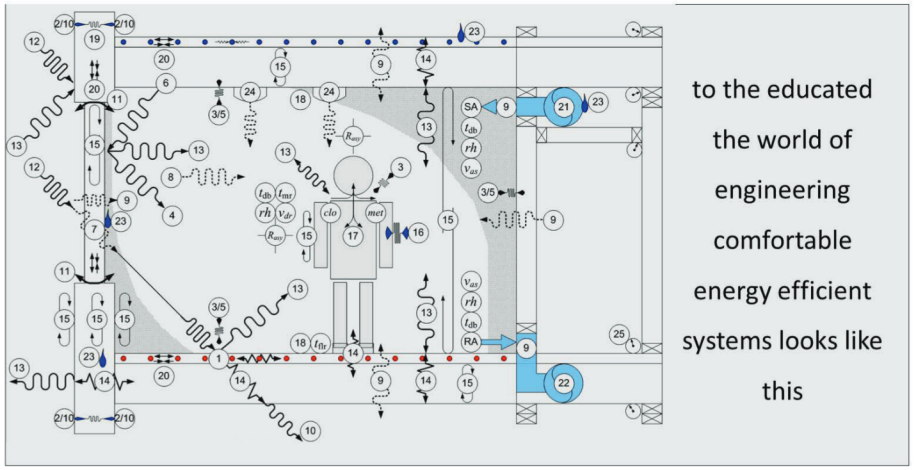
radiant is why enclosure U values are so important

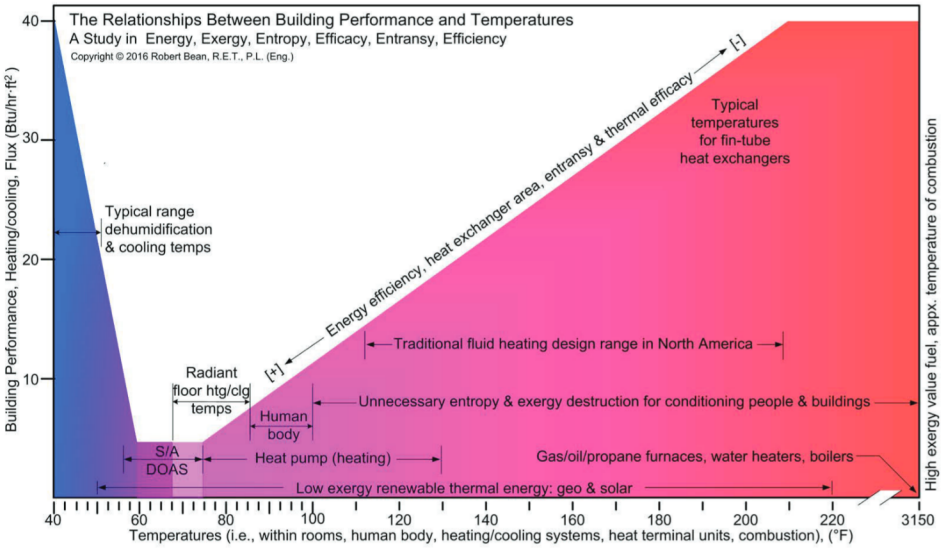


cognitive dissonance and illiteracy starts here



cognitive consonance and literacy starts here





all system temperatures

(from energy conversions to distribution)

related directly to thermal comfort

do not need to exceed

77.5°F +/- 22.5°F (25°C +/- 12.5°C)

perfectly matched to sustainable low eXergy systems

the message that matters

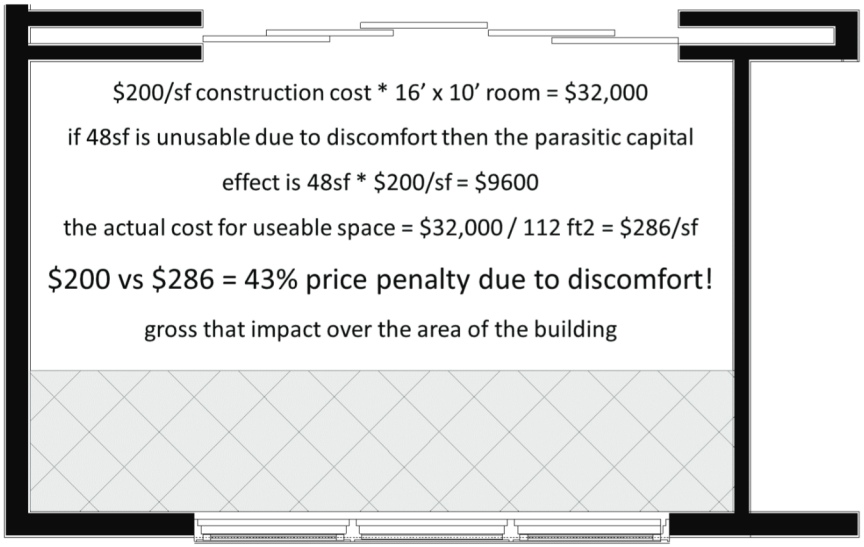
the vocabulary of ieq

is far more accessible to society than

the vocabulary of energy

science vs society

energy language	comfort language
needs education	needs no education
U-values / R-values	cold / cool / warm / hot
fenestration	dry / muggy / humid
solar heat gain coefficients	drafty / breezy / still
visible light transmittance	bright / dim / dark
conduction, convection, radiation	loud / quiet
air changes, ACH50	stinky / fresh
kilowatts, therms	comfortable / uncomfortable
thermal bridging	
sound transmission	



final thought #3

we cannot forget

energy efficiency in buildings

is for the benefit of

conditioning the occupants.

dr. b.w. olesen, ashrae president, 2018

final thought #2

energy efficiency should not be the exclusive goal

but rather the outcome

from successfully achieving

the desired indoor climate

nate adams & tedd kidd

final thought #1

people operate spaces

based on how they feel

not on energy models

design for people

good buildings follow™

questions?

What Should Drive The Sustainability Bus IEQ Or Energy?

robert bean

principal, indoor climate consultants inc.

director www.healthyheating.com

ashrae tc 2.1, 6.1, 6.5, 7.4, rbc, sspc 55, & liaison to sspc 62.2 & sspc 90.2

design for people - good buildings follow

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