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conference & expo

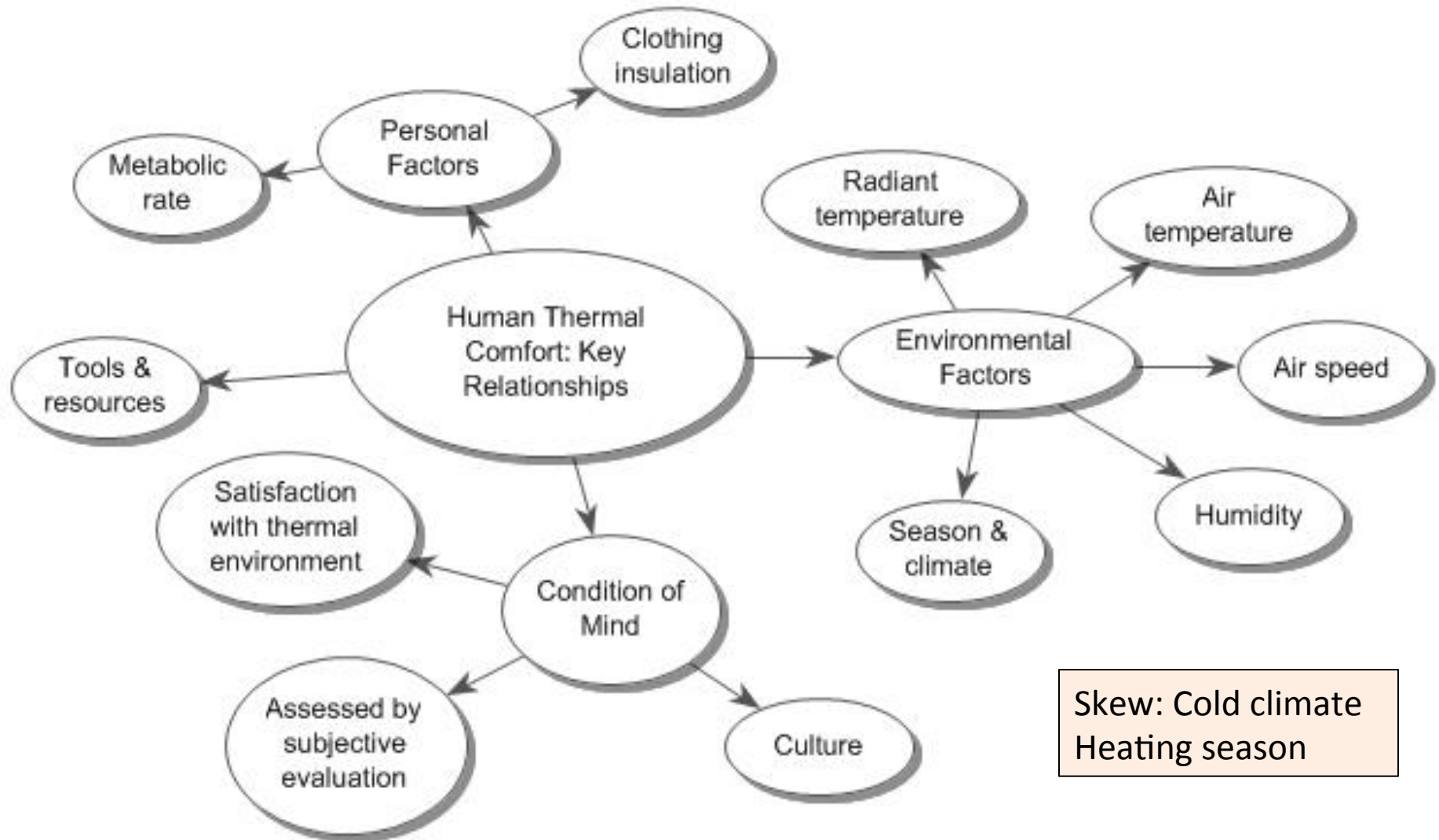
2016 Energy Design Conference & Expo  
February 22–24, 2016, Duluth, Minn.

# Human Thermal Comfort: Dialing it in with ASHRAE 55

**“In the long run, we only hit  
what we aim at.”**

Henry David Thoreau

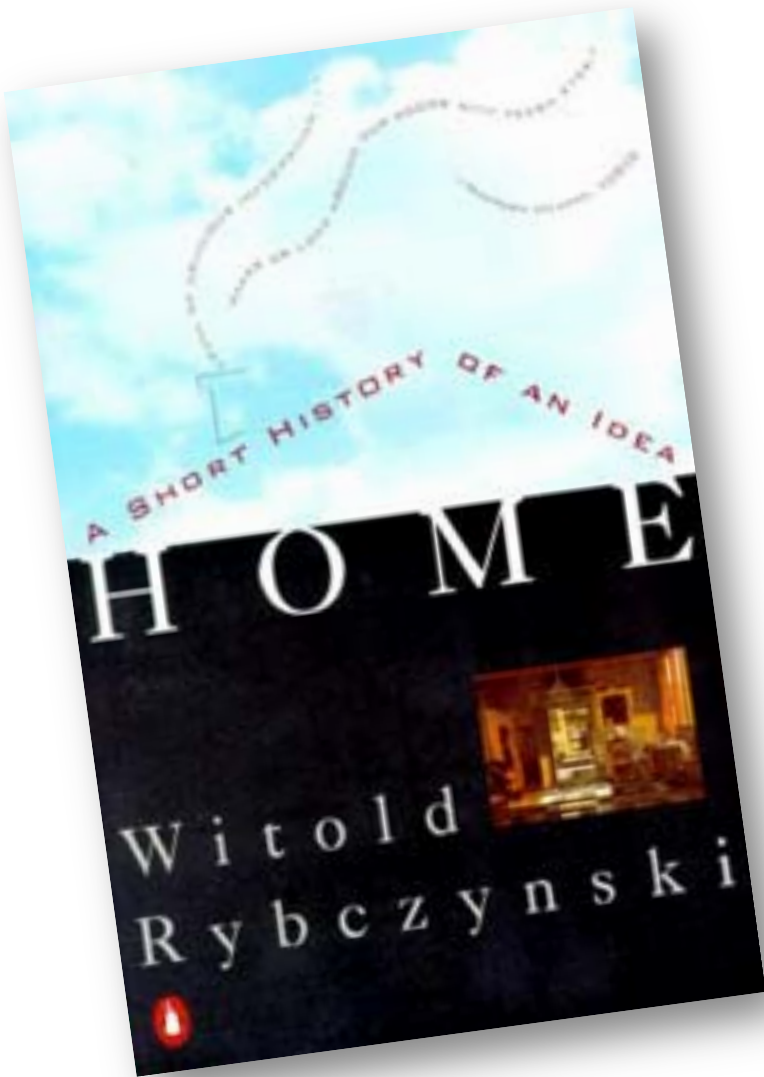
*Today's Aim* is to expand our understanding to better recognize opportunities, avoid problems & meet goals for personal comfort, indoor environmental quality, outdoor emissions reduction & home energy use.



In accordance with the Department of Labor and Industry's statute 326.0981, Subd. 11,

“This educational offering is recognized by the Minnesota Department of Labor and Industry as satisfying **1 hour** of credit toward **Building Officials and Residential Contractors** continuing education requirements.”

For additional continuing education approvals, please see your credit tracking card.



**“During the six years of my architectural education the subject of comfort was mentioned only once.** It was by a mechanical engineer whose job it was to initiate my classmates and me into the mysteries of air conditioning and heating. He described something called the **“comfort zone,”** which, as far as I can remember, was a kidney-shaped, crosshatched area on a graph that showed the relationship between temperature and humidity. **Comfort was inside the kidney, discomfort was everywhere else.** This, apparently, was all that we needed to know about the subject. It was a curious omission from an otherwise rigorous curriculum; one would have thought that comfort was a crucial issue in preparing for the architectural profession, like justice in law, or health in medicine.”

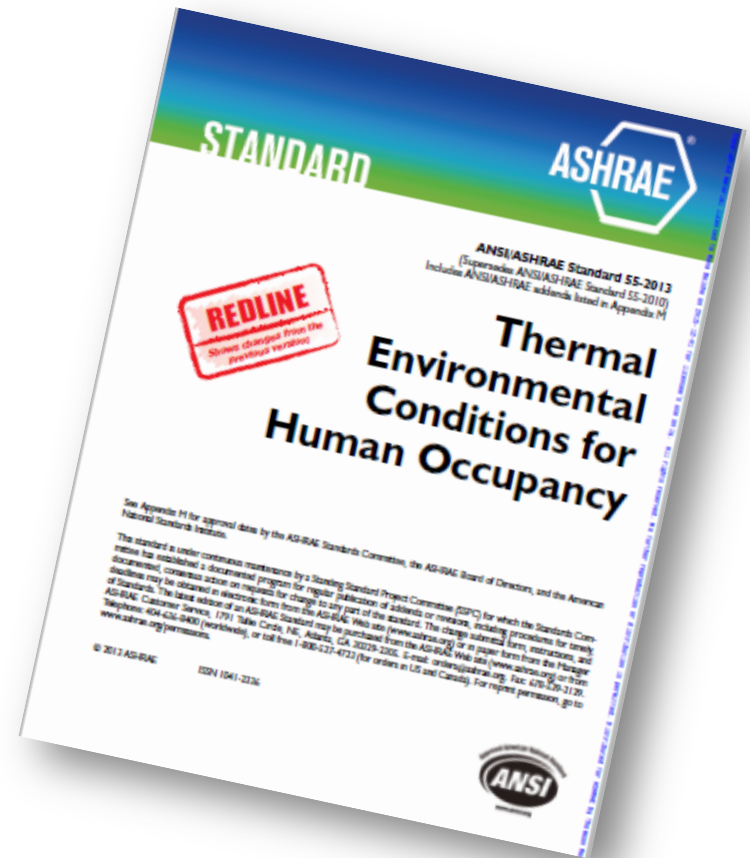
Witold Rybczynski, *Home—A Short History of an Idea*

# Human Thermal Comfort In a Nutshell



# ANSI/ASHRAE Std 55-2013

**“The Purpose of this standard is to specify the combinations of indoor thermal environmental factors and personal factors that will produce thermal environmental conditions acceptable to a majority of the occupants within the space.”**



**ASHRAE Standard 55-2013**

*Thermal Environmental Conditions for Human Occupancy*

<http://www.techstreet.com/products/1868610;>

# The Father of Thermal Comfort

P. Ole Fanger  
1934-2006

Wikipedia



**Human thermal comfort**  
is defined by ASHRAE as “*the state of mind that expresses satisfaction ...*”

“...with the surrounding environment.” Std. 55-2010

“...with the thermal environment and is assessed by subjective evaluation.”

ASHRAE Std. 55-2013

Thermal Comfort: Analysis and Applications  
in Environmental Engineering

# Thermal Comfort Guru

"Comfort is in your head, and in your client's head & will always be subjective!"

Robert Bean



***Top notch resource***  
[www.healthyheating.com](http://www.healthyheating.com)



# “Subjective Evaluation”



# Getting to Predicted Mean Vote (PMV)

## Subjective Evaluation -- Adjustment & Control Survey

How satisfied are you with the temperature in your space?

If dissatisfied, how would you best describe the source of this discomfort?

**Comfort  
Communications**

Humidity too high (damp)	Drafts from vents
Humidity too low (dry)	My area hotter/colder than others
Air movement too high	Thermostat is inaccessible
Air movement too low	Thermostat adjusted by other people
Incoming sun	Clothing policy is not flexible
Heat from office equipment	Heating/cooling system slow to respond
Drafts from windows Deficient windows (not operable)	Hot/cold surrounding surfaces (floor, ceiling, walls or windows)

# Evaluating Comfort in Existing Spaces

## Subjective Evaluation -- Adjustment & Control Survey

Which of the following do you personally adjust or control in your space?

Window blinds or shades	Ceiling fan
Room air-conditioning unit	Adjustable floor air vent (diffuser)
Portable heater	Portable fan
Permanent heater	Thermostat
Door to interior space	Operable window
Door to exterior space	None of these
Adjustable air vent in wall or ceiling	Other

# Human Thermal Comfort is Complex & Interactive

“It is intended that  
all of the criteria in this standard be applied together  
since comfort in the indoor environment is complex  
and responds to the interaction  
of all of the factors that are addressed.”

# Ten Factors Affecting Thermal Comfort

<b>General Environmental Factors</b>	<b>Localized Environmental Factors</b>
<b>Dry Bulb (Air) Temperature</b>	Vertical Air Temperature Differences *
<b>Mean Radiant Temperature *</b>	Radiant Temperature Asymmetry *
<b>Humidity</b>	Floor Temperature *
<b>Air Speed</b>	Drafts *
<b>Occupant Characteristics</b>	
<b>Metabolic Rate</b>	<b>Clothing</b>

(\* strictly influenced by enclosure performance; dry bulb & rh is co-influenced by enclosures exclusively conditioned with air-based HVAC systems.)

# Factors the Standard Doesn't Address

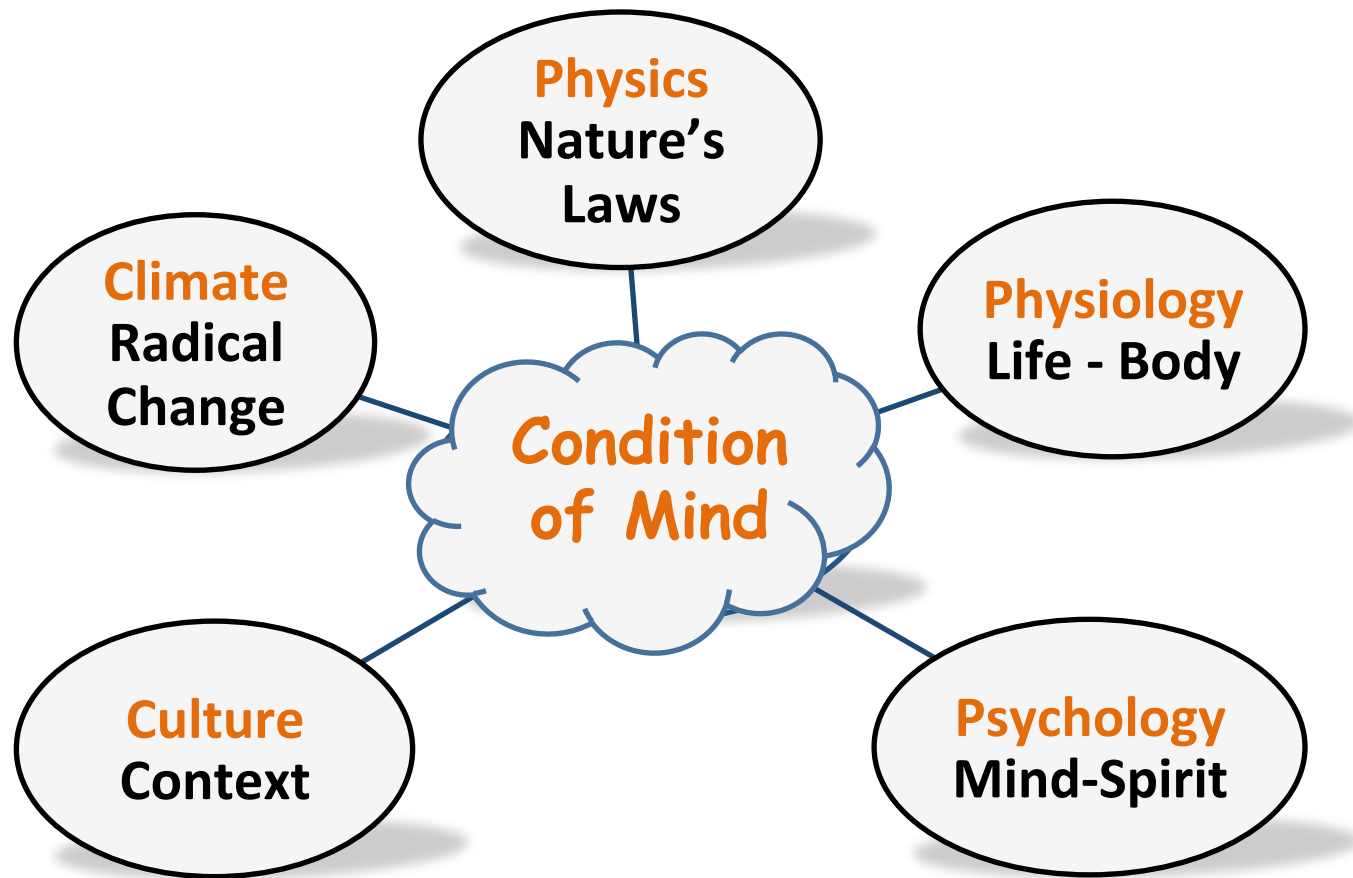
## Specifically

- Non-thermal environmental factors
- Air quality
- Acoustics
- Illumination
- Contaminants--physical, chemical or biological
- ASHRAE 62.2--ventilation

## General

- Non-steady state conditions
- Odor
- Vibration
- Age, gender, health, etc.

# Beyond Building Science to the Comfort Crossroads



# Psychological Factors

- Perception of control
- Sense of purpose
- Peer pressure
- Sense of well-being
- Consistency with value system



## **sī-'kā-lə-jē**

1: the science or study of the mind and behavior

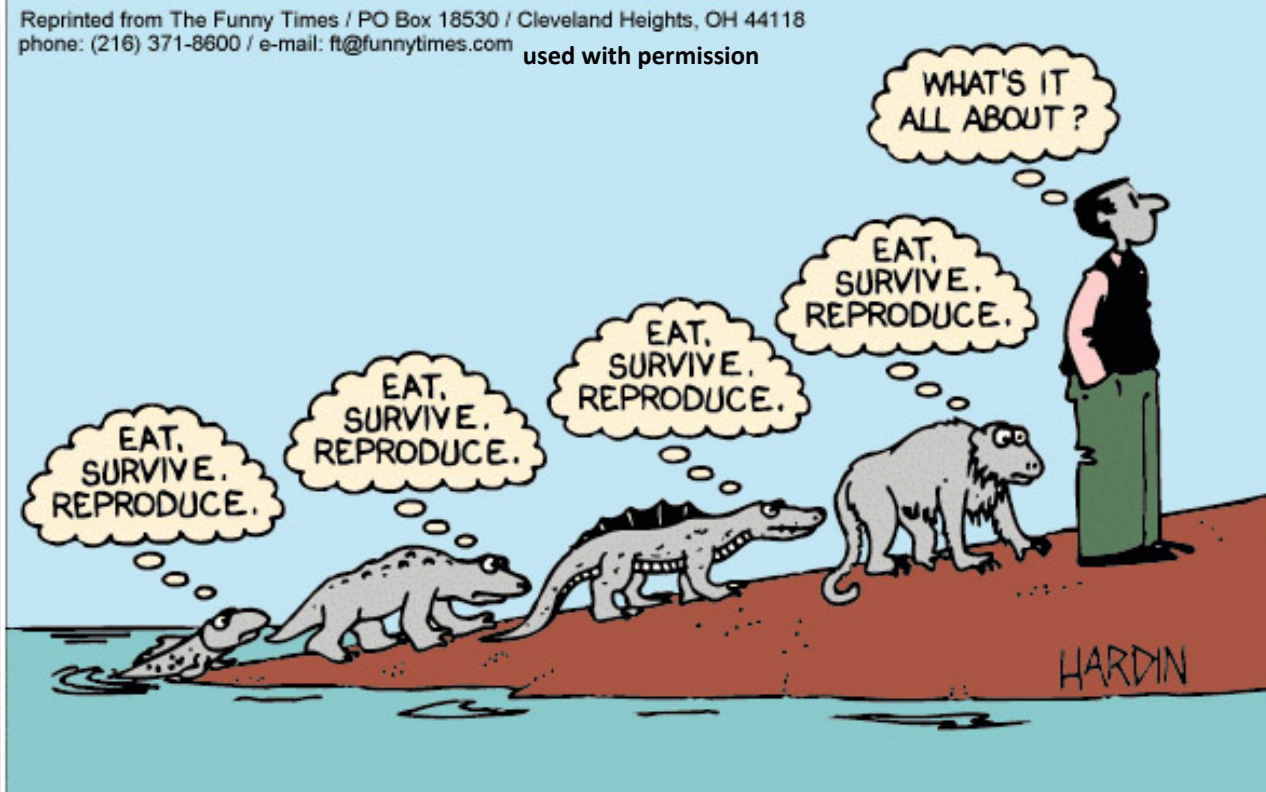
2: the way a person or group thinks

First known use: 1653 Mirriam Webster On-line Dictionary

Thanks to Linda Wigington & Associates for initial work on this list



# Physiology – More than Meets the Eye



## fi-zē-'ä-lə-jē

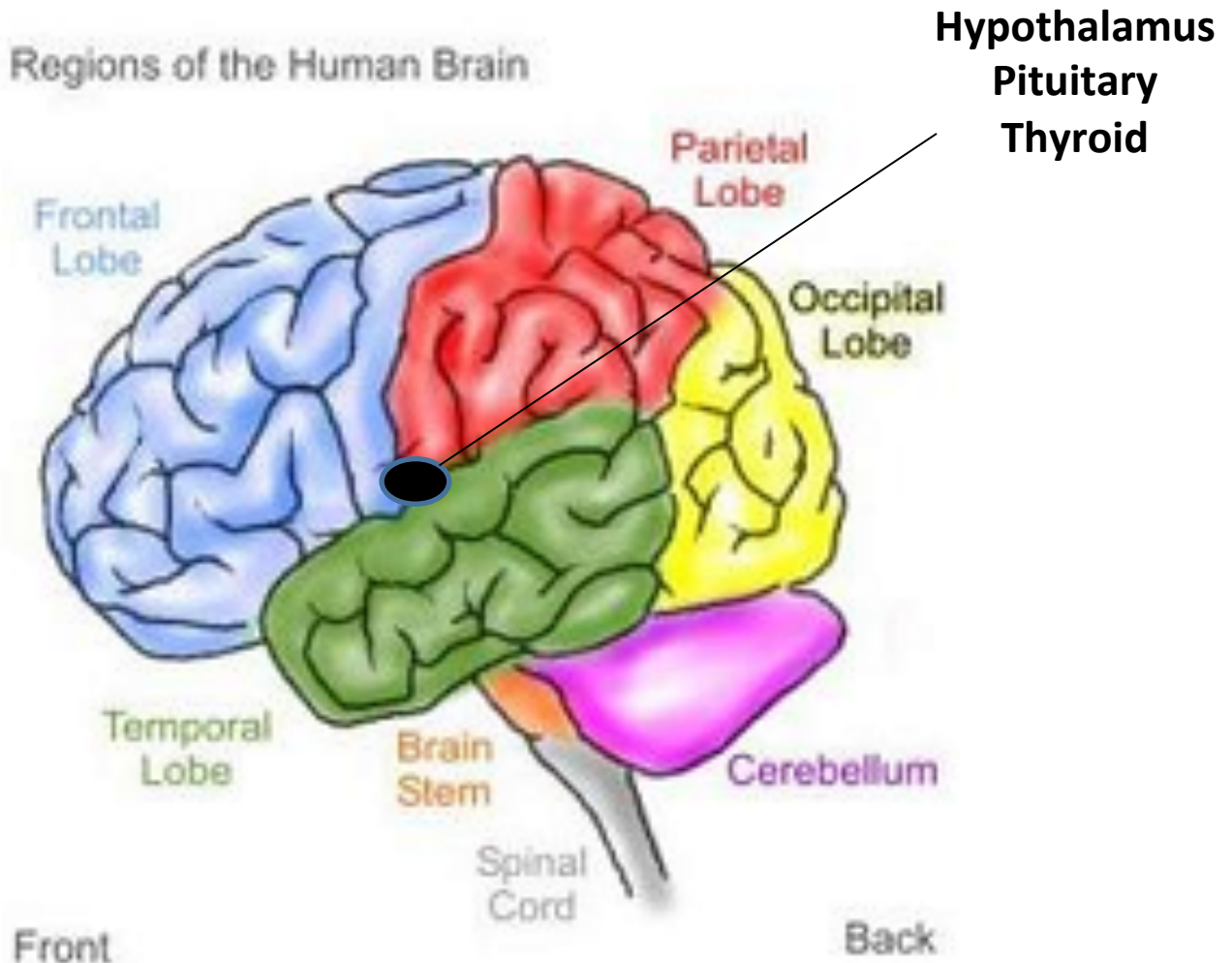
1: a branch of biology that deals with the processes and activities that keep living things alive

First Use: 1615 Mirriam Webster On-Line Dictionary

# Physiology -- State of Brain & Mind

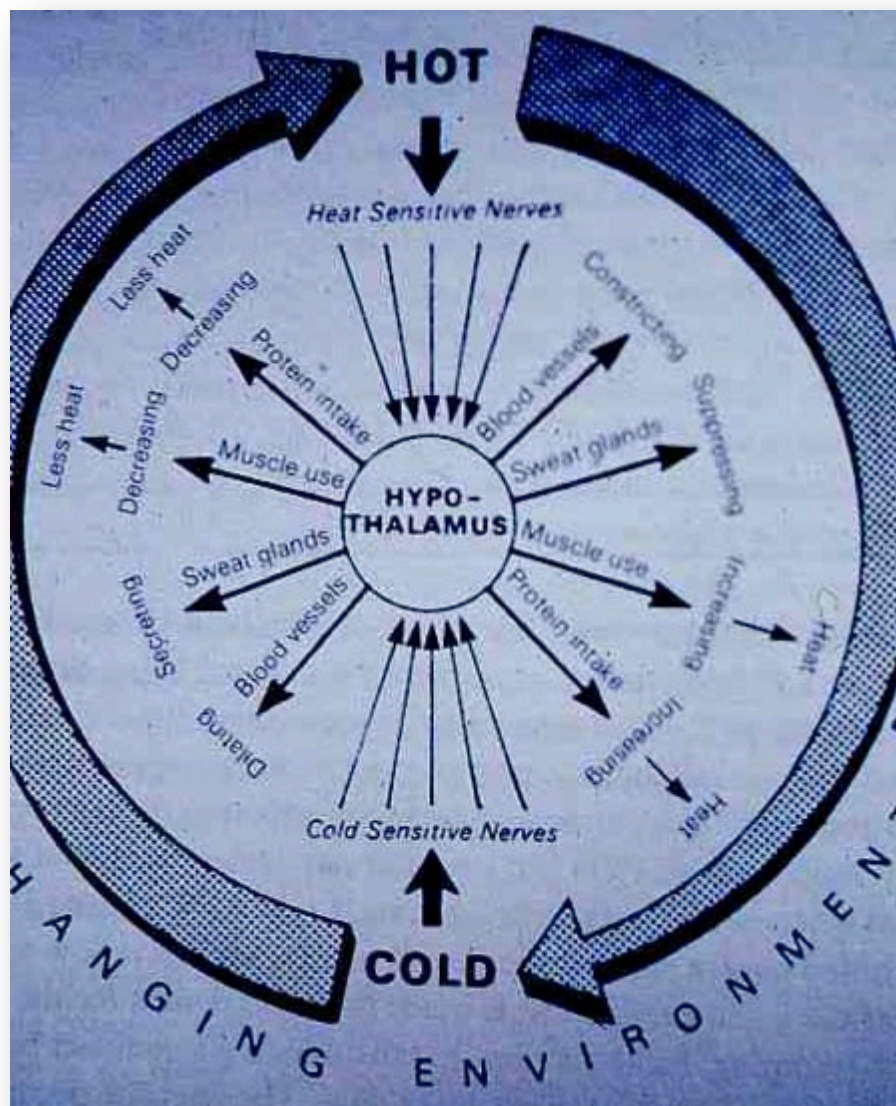
HPT =  
Comfort Control  
Central

Regions of the Human Brain



**QUICK CHECK:**  
What is your current  
thermal comfort level?

# Unconscious Bodily Responses



Source: Heat Homeostasis in the Body, RECCG 2007

"Just like blinking or developing rashes, you simply have little to no control over how the body automatically responds to negative thermal stimuli."

Robert Bean

## Cellular Processes

- Blood Flow
- Digestive processes
- Respiratory rate
- Muscular activity

## Result in

### Shedding Heat

- Vasodilation
- Pore expansion
- Sweating
- Evaporation of sweat cools

### Retaining Heat

- Goose bumps
- Pilo erection (hair)
- Shivering
- Huddling

# The Skinny on Skin

- The human body's largest organ is the skin. Skin helps regulate body temperature by making the pores larger or smaller & increasing or decreasing blood flow.
- The nerves in skin receive the stimuli that are then interpreted by the brain as touch, heat, cold, and pain.
- Skin is the principal organ for dissipating heat. We have roughly 166,000 thermal receptors in our skin with most of them sensitive to heat loss. (Zhang, 2003)
- These nerve endings are not evenly distributed. Higher concentrations are located in the typically exposed body areas: feet, ankles, calves, hands, wrists, neck, face, & head.
- Skin's emissivity makes it almost a perfect radiator & absorber—greater than almost any other known substance. (Dr. A. Marsh)

# Humans . . . Sensing Sacs of Seawater

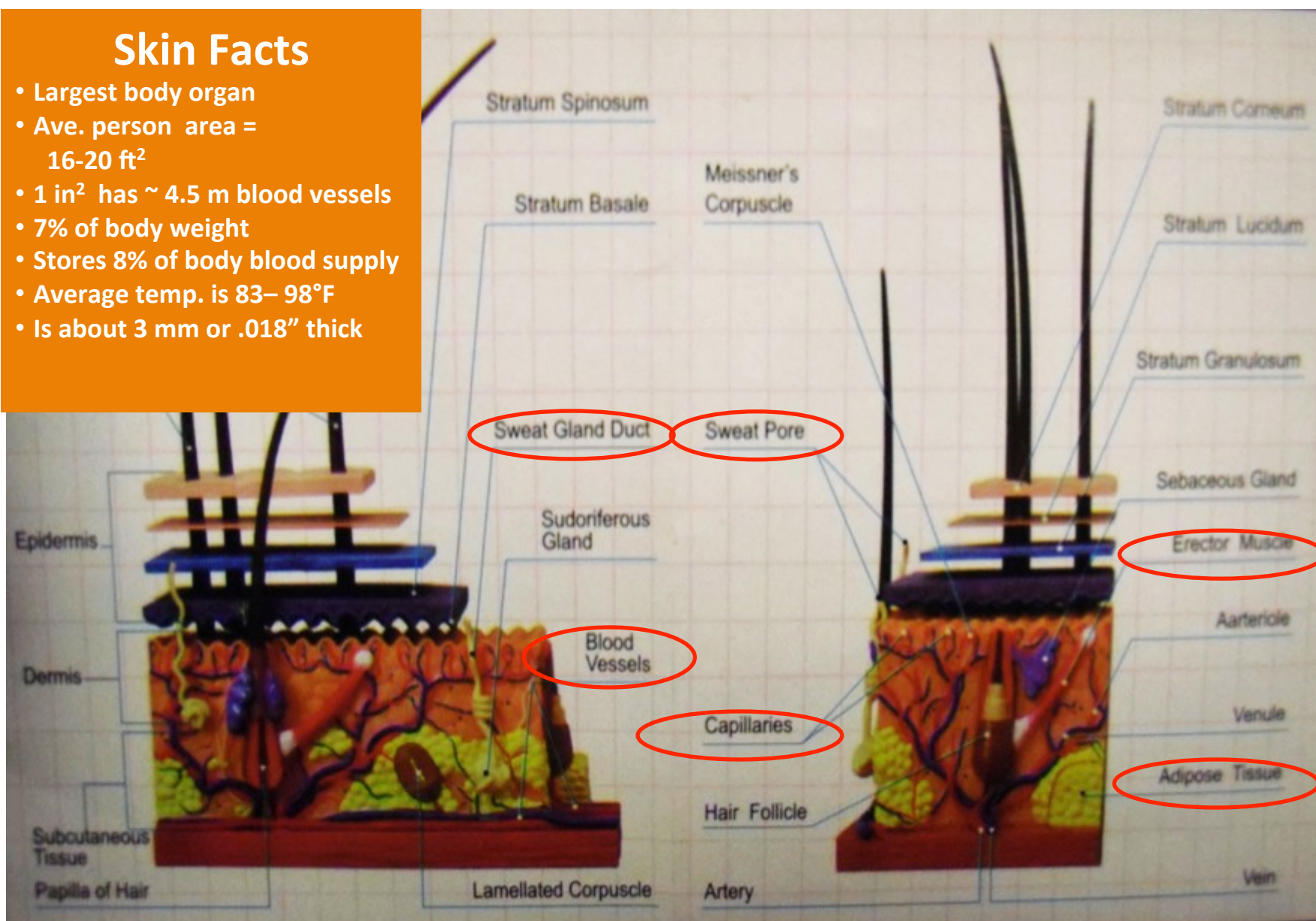


Umlaut Sculpture Garden,

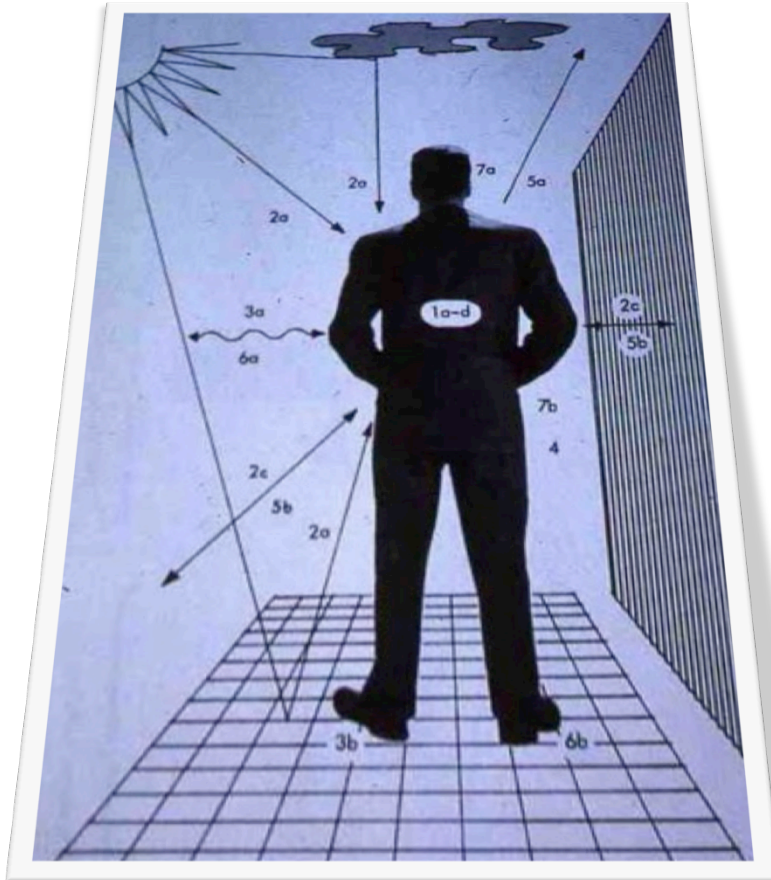
Photo: Rana Belshe

## Skin Facts

- Largest body organ
- Ave. person area = 16-20 ft<sup>2</sup>
- 1 in<sup>2</sup> has ~ 4.5 m blood vessels
- 7% of body weight
- Stores 8% of body blood supply
- Average temp. is 83– 98°F
- Is about 3 mm or .018" thick



# That Comfort Feeling



- Actual core & skin temperature are in state that provides sensation of thermal neutrality
- Thermal comfort is maintained when the human metabolism achieves thermal equilibrium with the surroundings
- Any heat gain or loss beyond this generates a sensation of discomfort

# Personal Factors Affecting Thermal Comfort

- Metabolic Rate (met)
- Insulation due to Clothing (clo)



# We're All "Hotties"—in Btus/Hr

Metabolic factor can be broken into fundamental of heat energy expended over time.



**Sleeping - 220**



**Slow Walking - 722**



**Hand Sawing - 1,588**



**Reading - 325**



**Sex 1,111**



**Jogging - 2,262**



**Sweeping - 550**



**Fast Walking - 1,372**



**Rowing 3,286**