Diyala University
Architecture Department
Architect and Environment
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4th stage
2nd lecture.

Thermal Comfort

Thermal Control

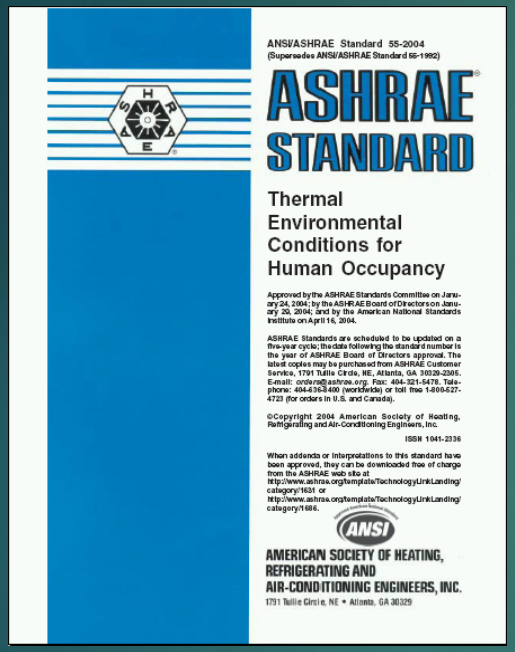
What is Thermal Comfort?

Man has always orient to create a thermally comfortable environment. This is reflected in building traditions around the world - from ancient history to present day.

Today, creating a thermally comfortable environment is still one of the most important parameters to be considered when designing buildings.

The indoor environment should be designed and controlled so that occupants' comfort and health are assured.

What is Thermal Comfort ?



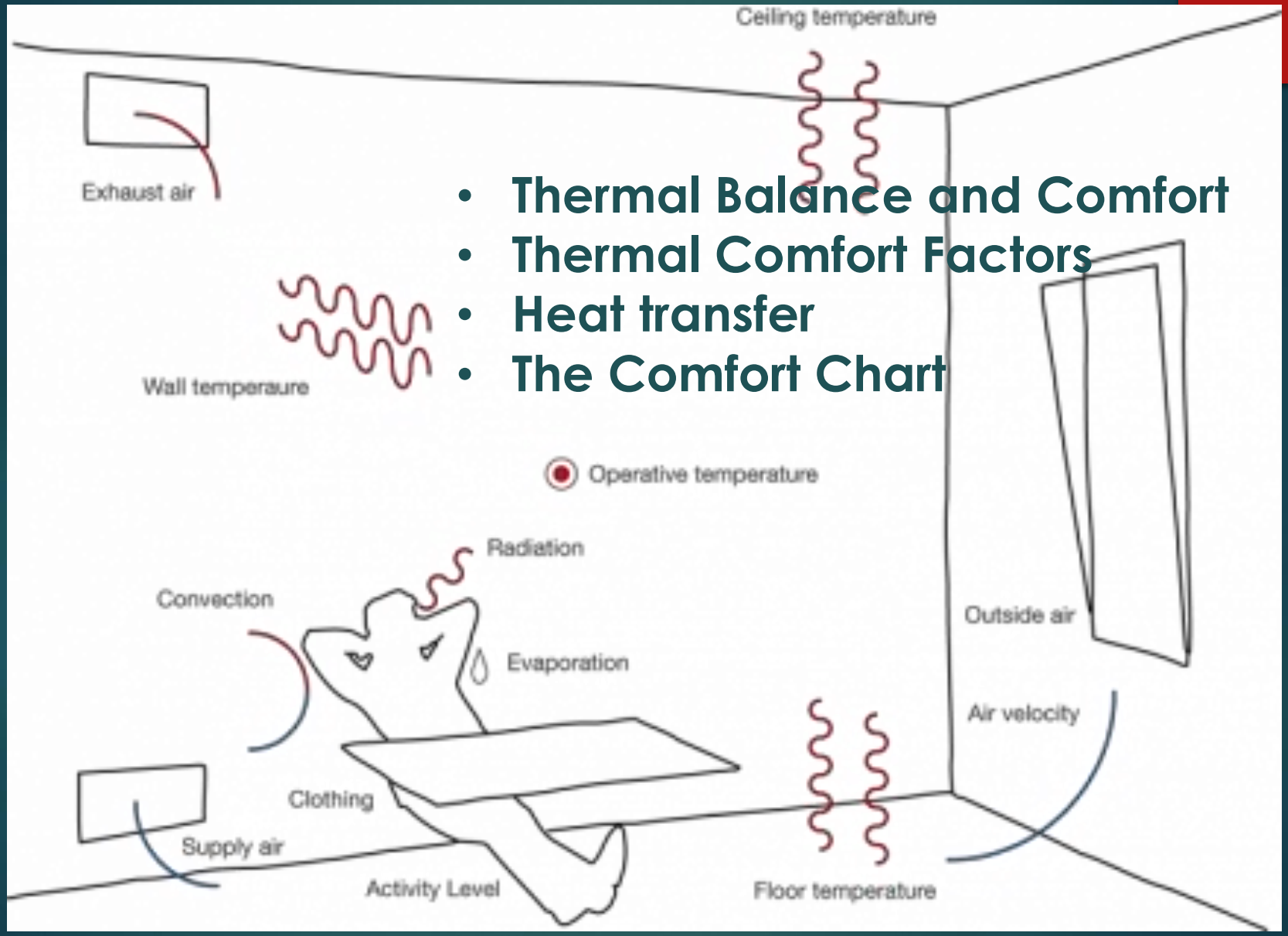
That condition of mind in which satisfaction is expressed with the thermal environment."

ANSI/ASHRAE Standard 55-2004:
Thermal Environmental Conditions for Human Occupancy

Comfort is a subjective issue and can vary widely from person to person

However, there are no conditions that will provide comfort for all people.

Thermal Comfort



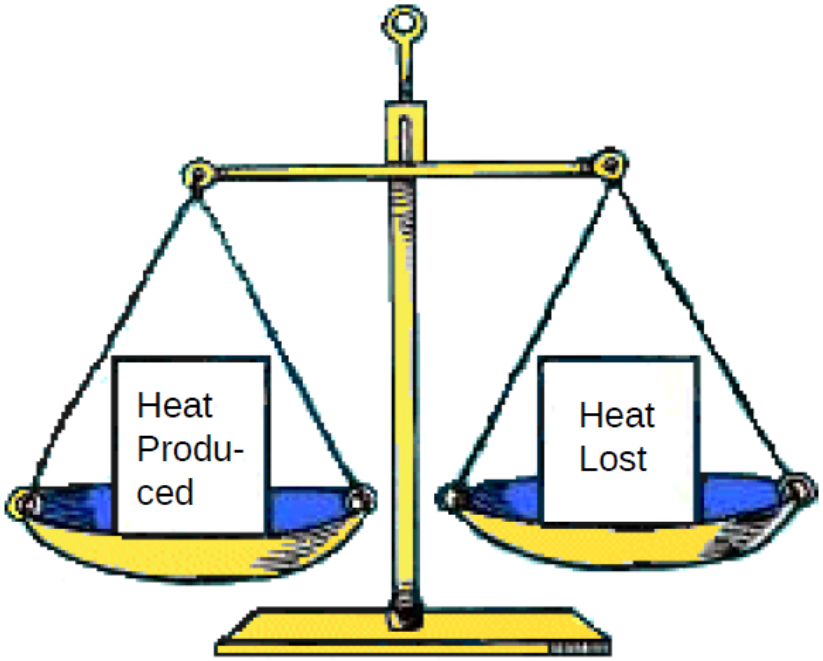
- Thermal Balance and Comfort
- Thermal Comfort Factors
- Heat transfer
- The Comfort Chart

Thermal Balance and Comfort

- very narrow range of body temperature must be maintained for a person to remain healthy and comfort

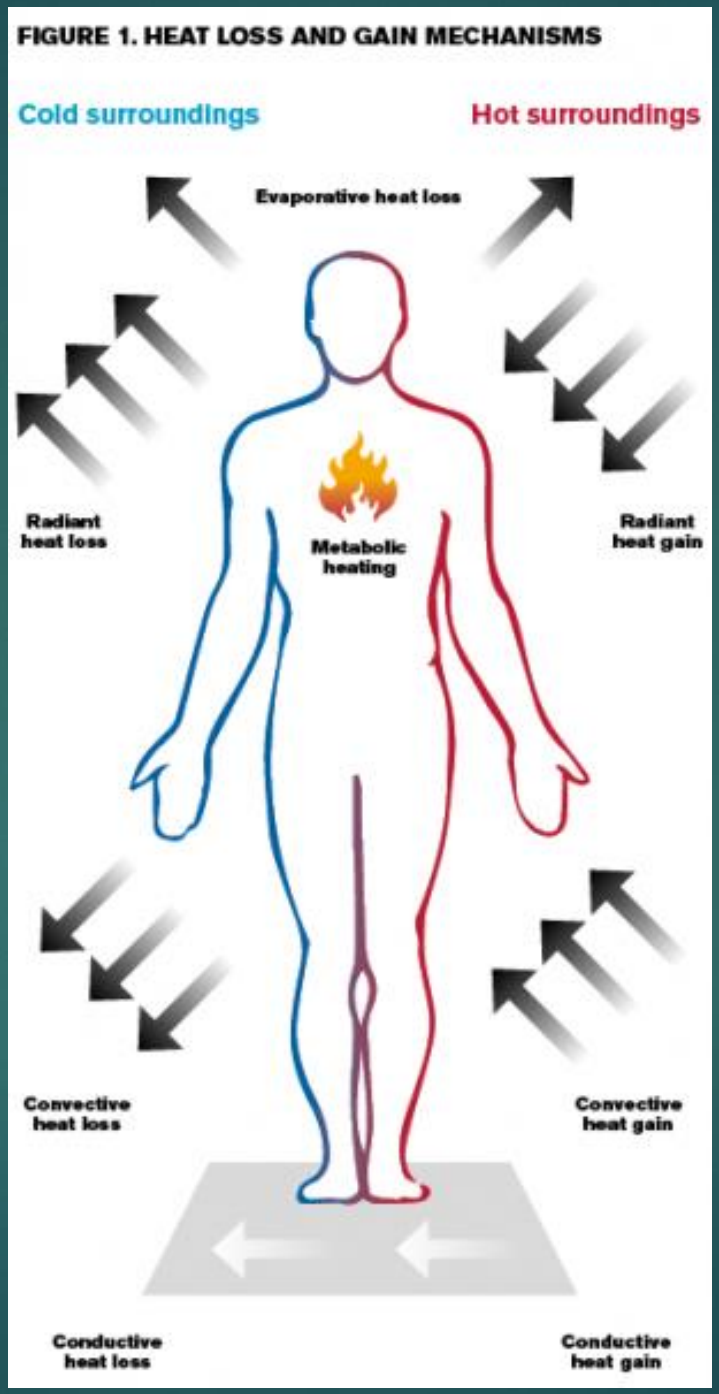
Thermal Balance and Comfort

The energy balance

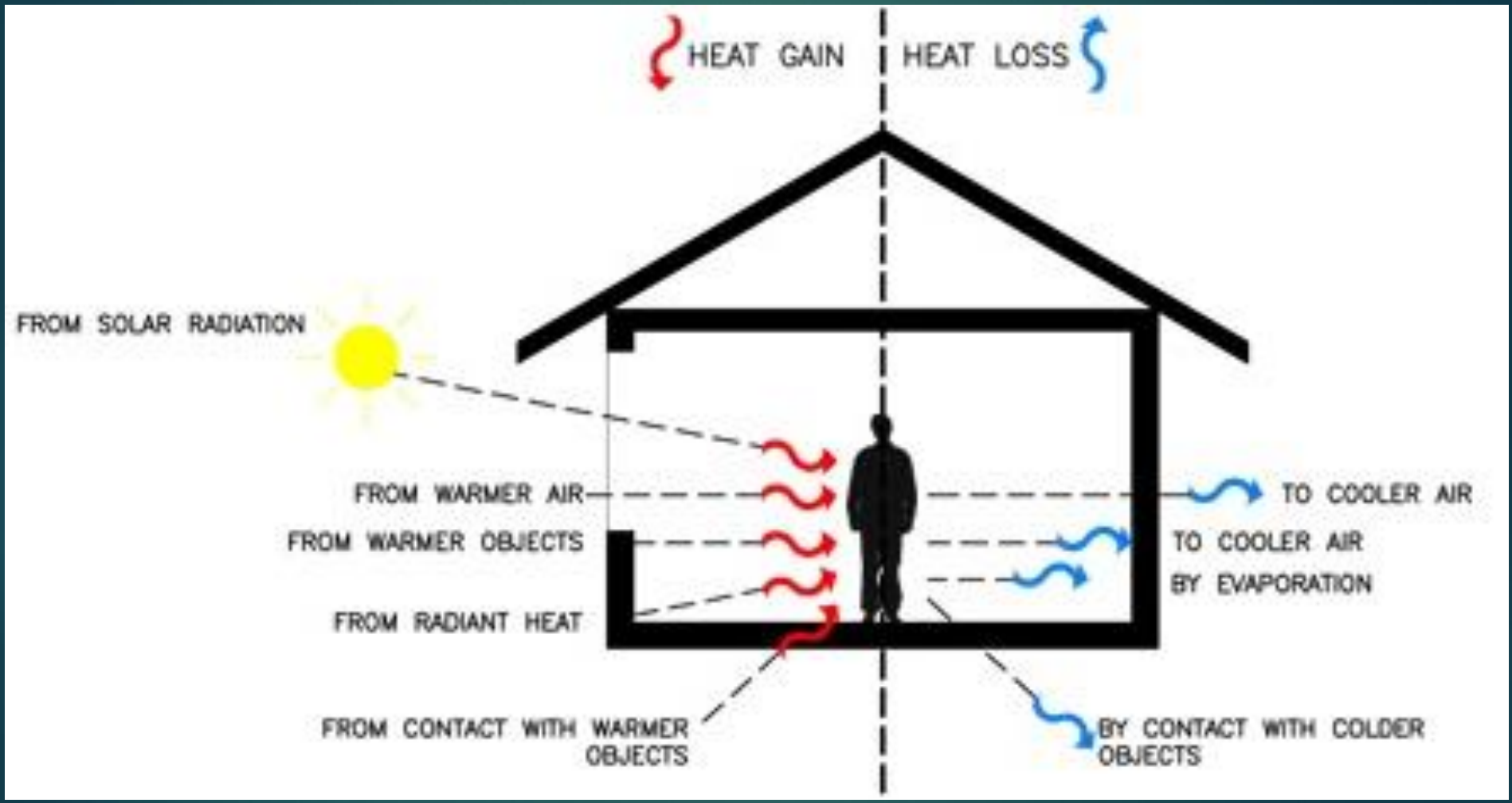


Thermal Comfort can only be maintained when heat produced by metabolism equals the heat lost from body

FIGURE 1. HEAT LOSS AND GAIN MECHANISMS



Thermal Balance of Buildings

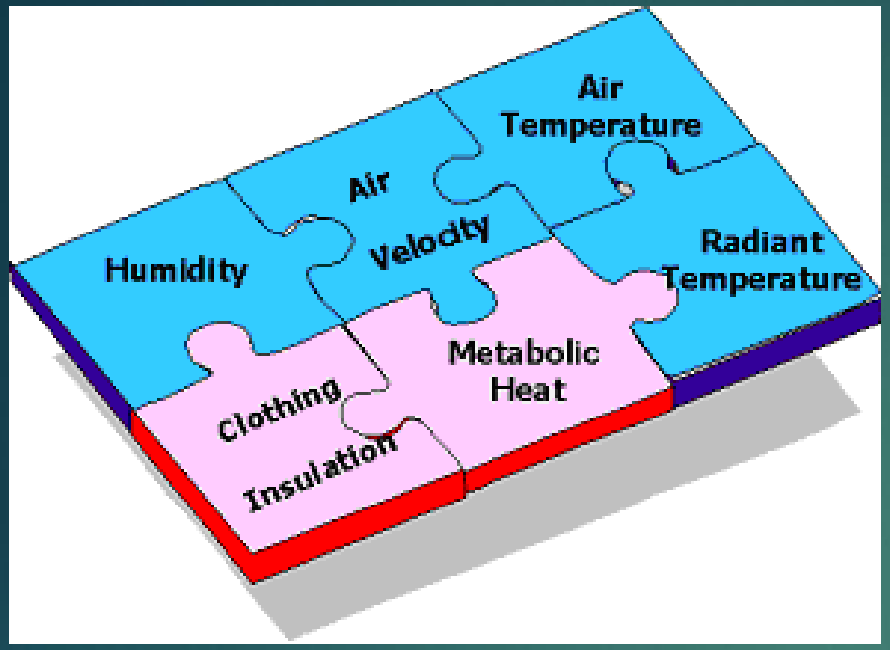


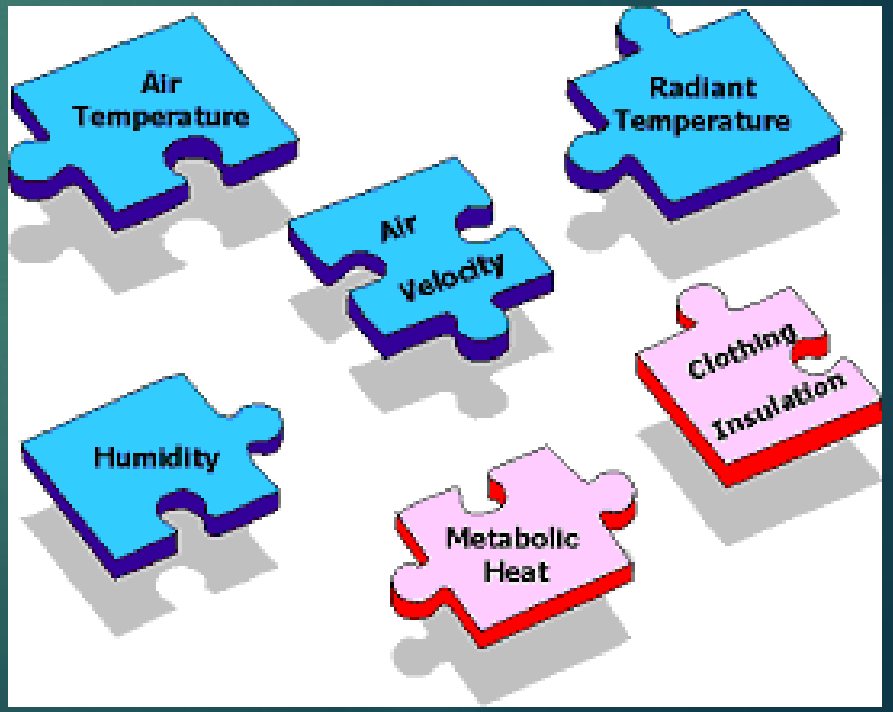
Thermal Comfort Factors

Thermal equilibrium which resulting thermal comfort are achieved by heat gained or lost to the environment.

Number of climatic and personal factors important to achieving this equilibrium:

Climatic Factors	Personal Factors
Air temperature	Level of physical activity
Humidity	Type of clothing worn
Air movement	Level of Adaptation
Radiant heat	Degree of fitness & health


Air
Temperature
Air
Velocity
Humidity
Radiant
Temperature
Metabolic
Heat
Clothing
Insulation

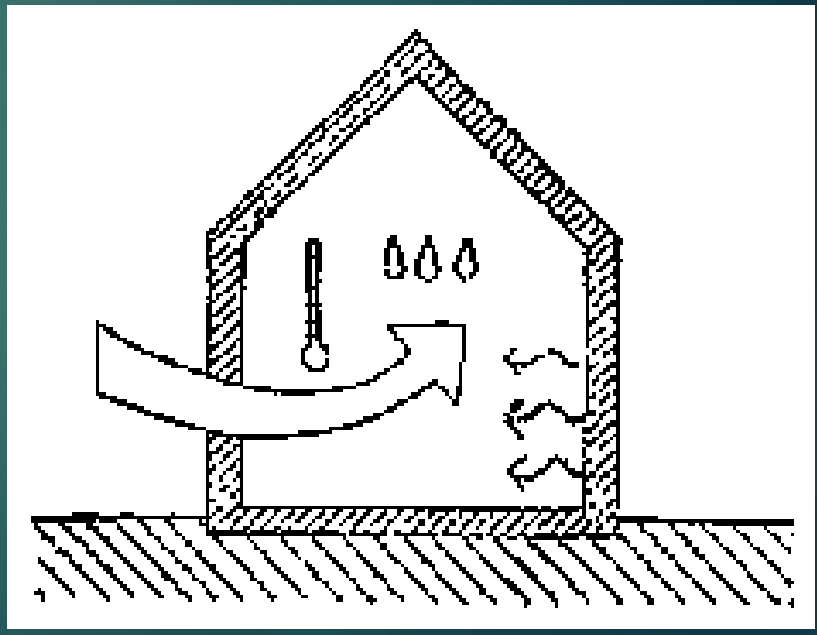

Air
Temperature
Radiant
Temperature
Air
Velocity
Clothing
Insulation
Humidity
Metabolic
Heat

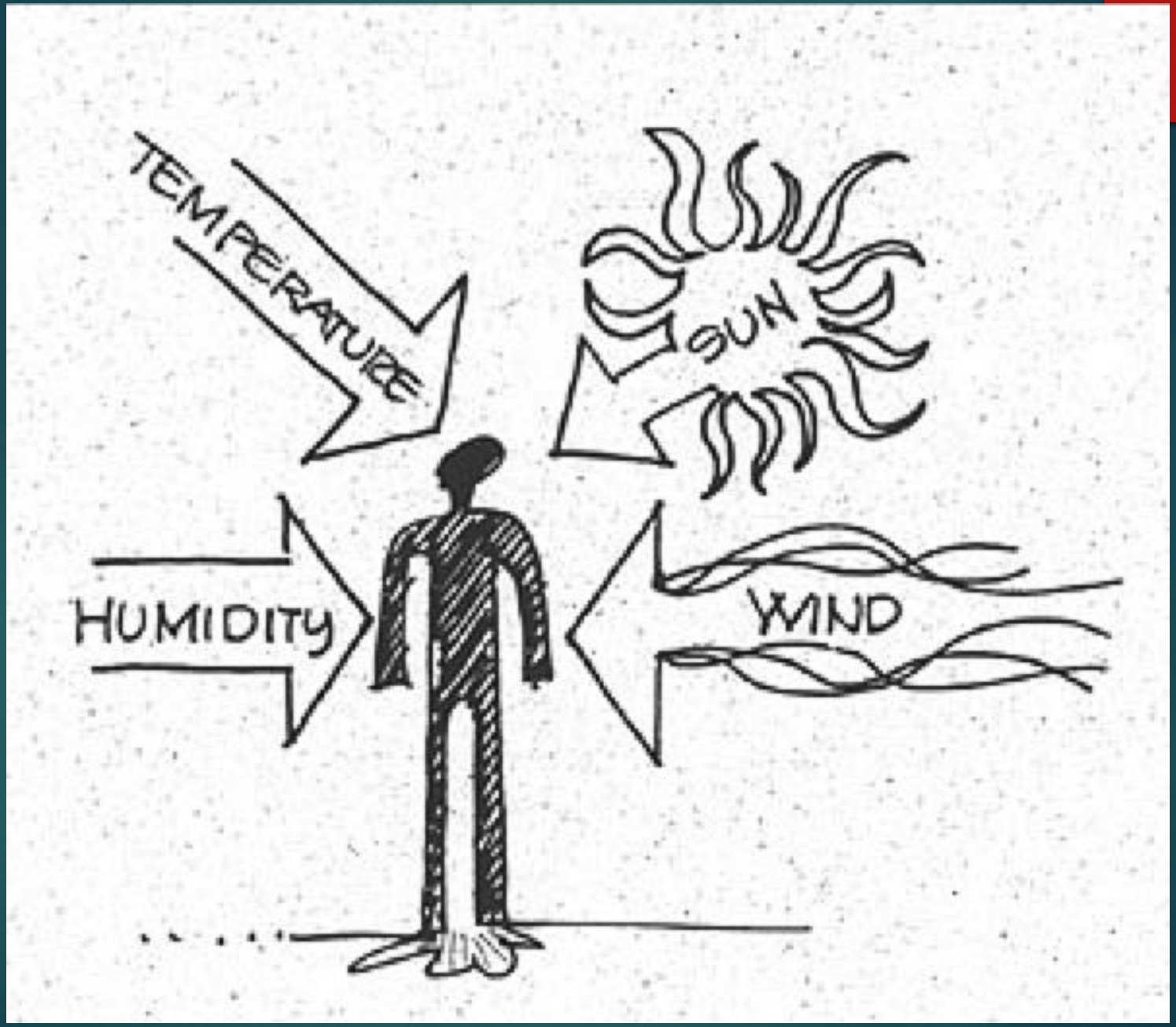
As any one of these variables changes, the others need to be adjusted to maintain the thermal equilibrium between heat gain and heat loss in order for a person to continue to feel comfortable.

Climatic Factors

Four factors can be used to describe the indoor environment relative to thermal comfort:

- **Air temperature,**
- **Mean radiant temperature**
- **Air movement**
- **Relative humidity.**

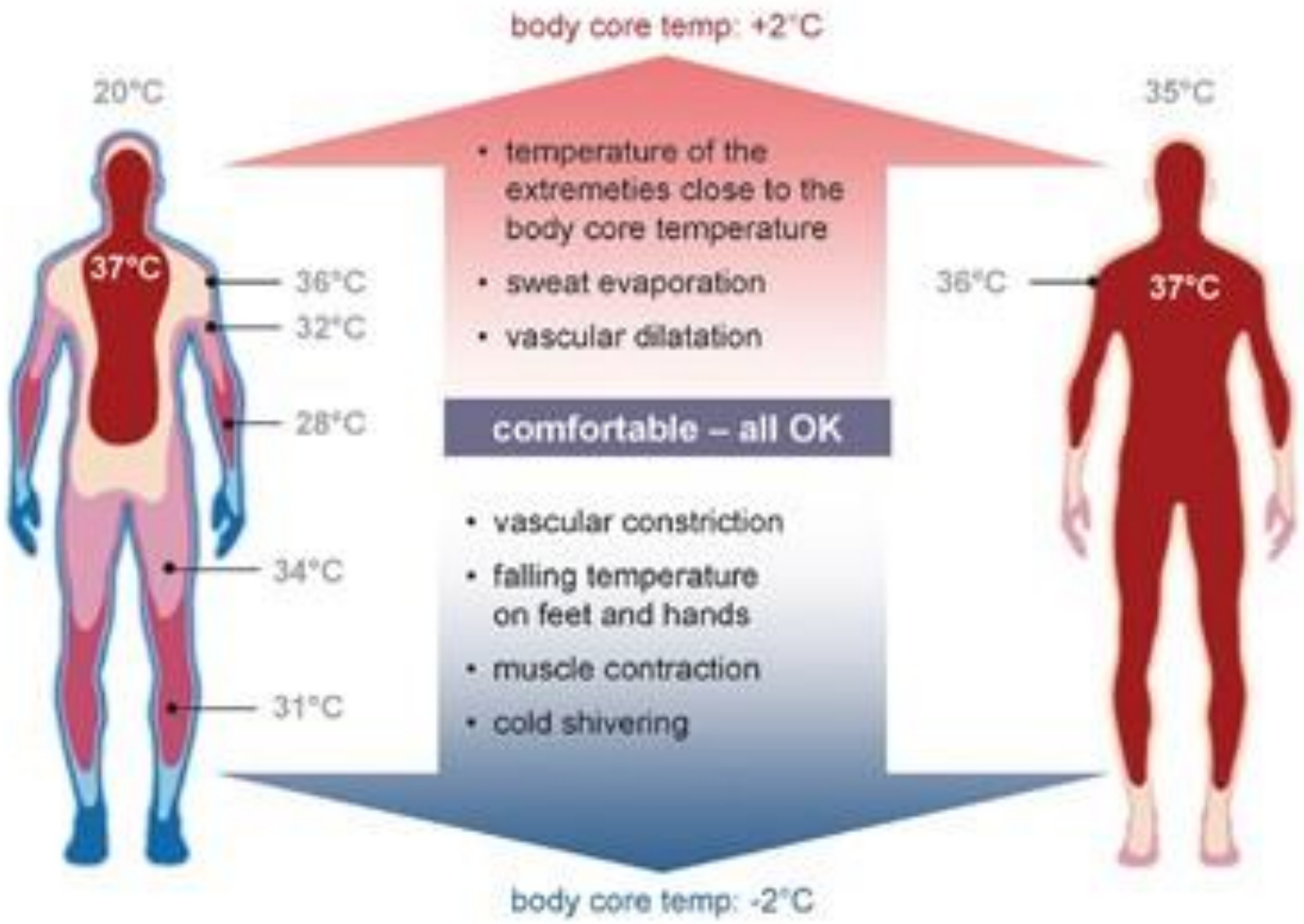



TEMPERATURE
SUN
HUMIDITY
WIND

Air temperature

Its influence on the surface temperature of objects in a room.

Air temperature is the most important environmental factor.


body core temp: +2°C
20°C
35°C
• temperature of the extremeties close to the body core temperature
• sweat evaporation
• vascular dilatation
37°C
36°C
32°C
28°C
34°C
31°C
36°C
37°C
comfortable – all OK
• vascular constriction
• falling temperature on feet and hands
• muscle contraction
• cold shivering
body core temp: -2°C

Mean Radiant Temperature :

all objects emit radiant energy at a level proportional to their temperature

We may feel comfortable with a very low air temperature if the radiation temperature is high; for example, a moderately cold winter day, may be nice at noon if we are receiving the sun radiation

Relative Humidity

high humidity reduces the rate of evaporative cooling from the skin and lungs.

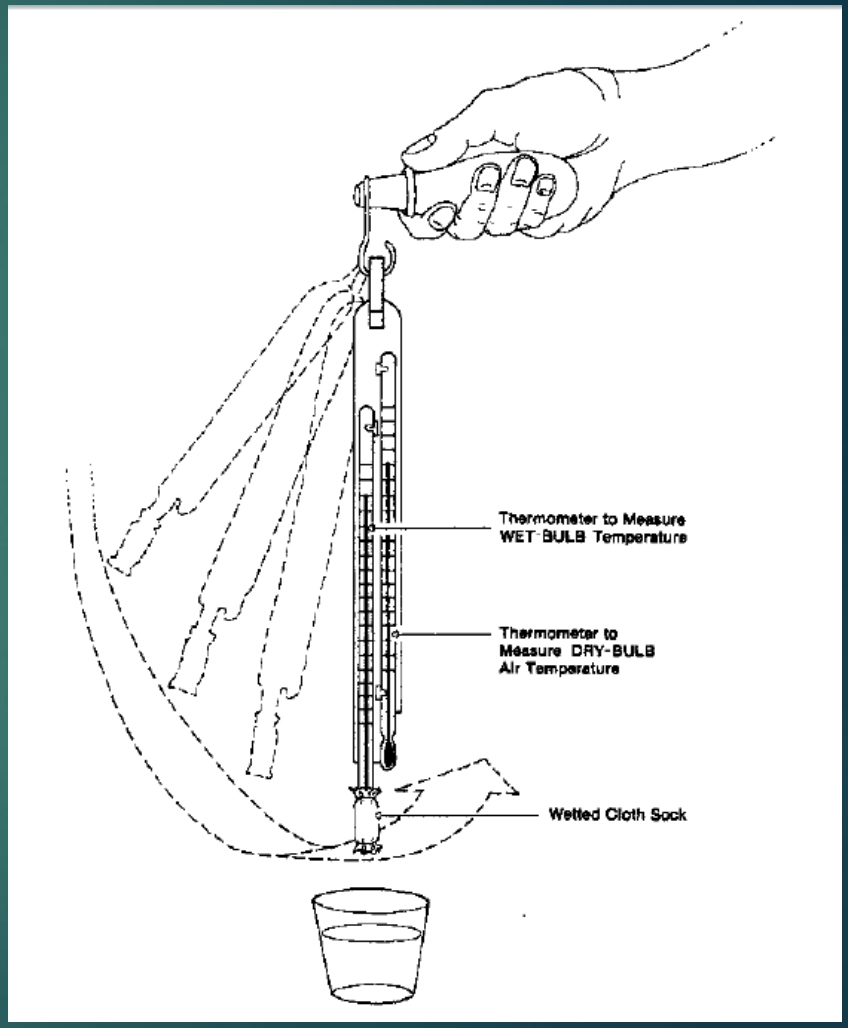


Table 1

Psychrometric chart of relative humidity (in percent)

Depression of the wet bulb (dry-bulb temperature minus wet-bulb temperature in °C)

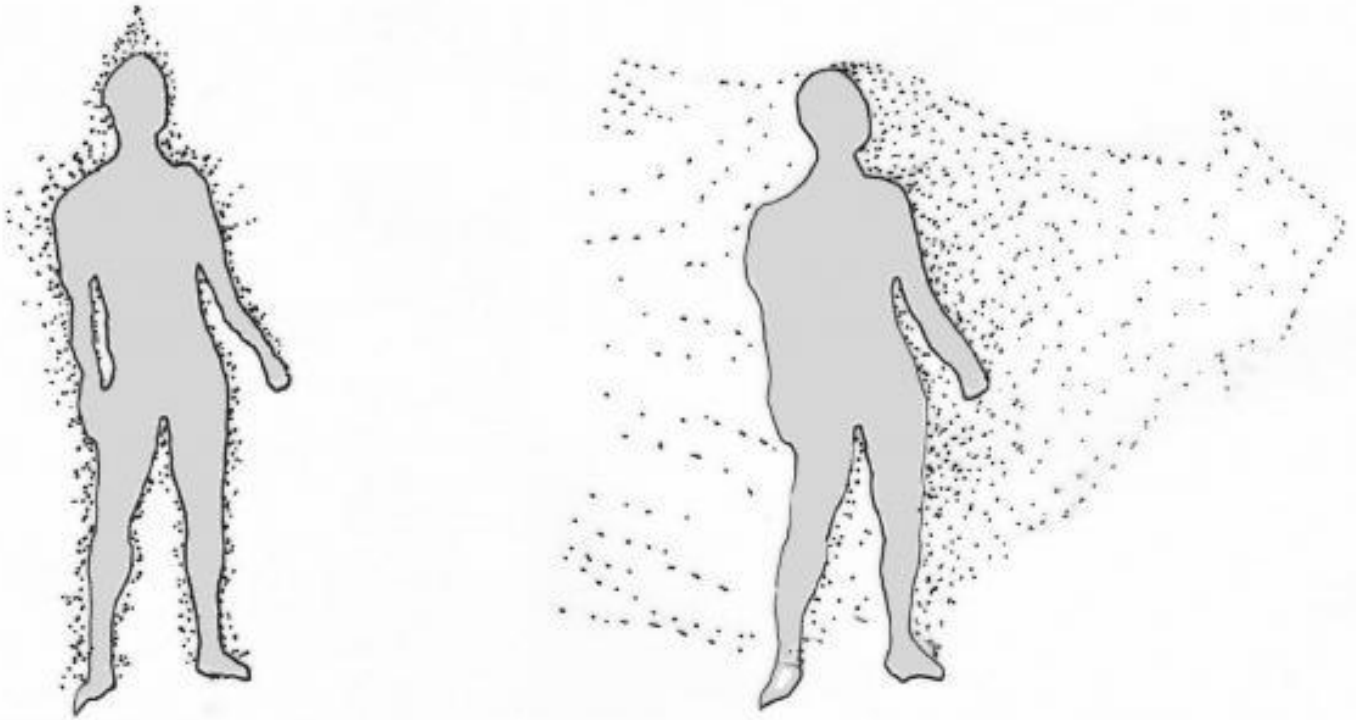
Dry-bulb temperature (air temperature °C)	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	7.5	10.0	12.5	15.0	17.5	20.0	22.5	25.0
−20	70	41	11															
−17.5	75	51	26	2														
−15	79	58	38	18														
−12.5	82	65	47	30	13													
−10	85	69	54	39	24	10												
−17.5	87	73	60	48	35	22	10											
−5	88	77	66	54	43	32	21	11	1									
−2.5	90	80	70	60	50	42	37	22	12	3								
0	91	82	73	65	56	47	39	31	23	15								
2.5	92	84	76	68	61	53	46	38	31	24								
5	93	86	78	71	65	58	51	45	38	32	1							
7.5	93	87	80	74	68	62	56	50	44	38	11							
10	94	88	82	76	71	65	60	54	49	44	19							
12.5	94	89	84	78	73	68	63	58	53	48	25	4						
15	95	90	85	80	75	70	66	61	57	52	31	12						
17.5	95	90	86	81	77	72	68	64	60	55	36	18	2					
20	95	91	87	82	78	74	70	66	62	58	40	24	8					
22.5	96	92	87	83	80	76	72	68	64	61	44	28	14	1				
25	96	92	88	84	81	77	73	70	66	63	47	32	19	7				
27.5	96	92	89	85	82	78	75	71	68	65	50	36	23	12	1			
30	96	93	89	86	82	79	76	73	70	67	52	39	27	16	6			
32.5	97	93	90	86	83	80	77	74	71	68	54	42	30	20	11	1		
35	97	93	90	87	84	81	78	75	72	69	56	44	33	23	14	6		
37.5	97	94	91	87	85	82	79	76	73	70	58	46	36	26	18	10	3	
40	97	94	91	88	85	82	79	77	74	72	59	48	38	29	21	13	6	
42.5	97	94	91	88	86	83	80	78	75	72	61	50	40	31	23	16	9	2
45	97	94	91	89	86	83	81	78	76	73	62	51	42	33	26	18	12	6
47.5	97	94	92	89	86	84	81	79	76	74	63	53	44	35	28	21	15	9
50	97	95	92	89	87	84	82	79	77	75	64	54	45	37	30	23	17	11

- 1. measure
- 2. Dry bulb C
- Wet bulb.....C -
- ----------
- Depression= C
- 3. use chart and write the result
-

Air movement

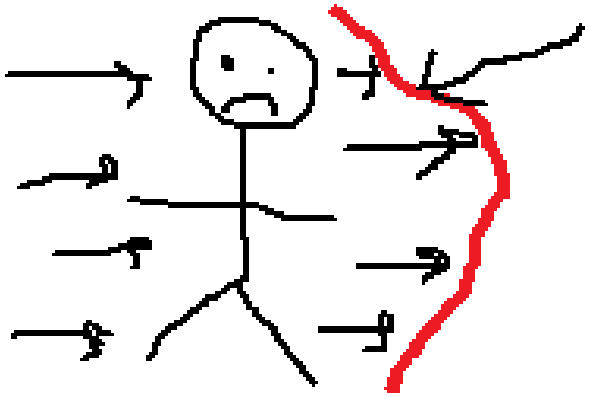
Higher air movement increases the rate of convective cooling when air blows across the body

An air movement of between 0.10 and 0.15 meters per second (m/s) provides a satisfactory air flow rate. At above about 2.0 m/s provides uncomfortable



REMOVAL OF SATURATED FILM ON BODY'S SURFACE BY EFFECT OF AIR MOVEMENT

No Wind



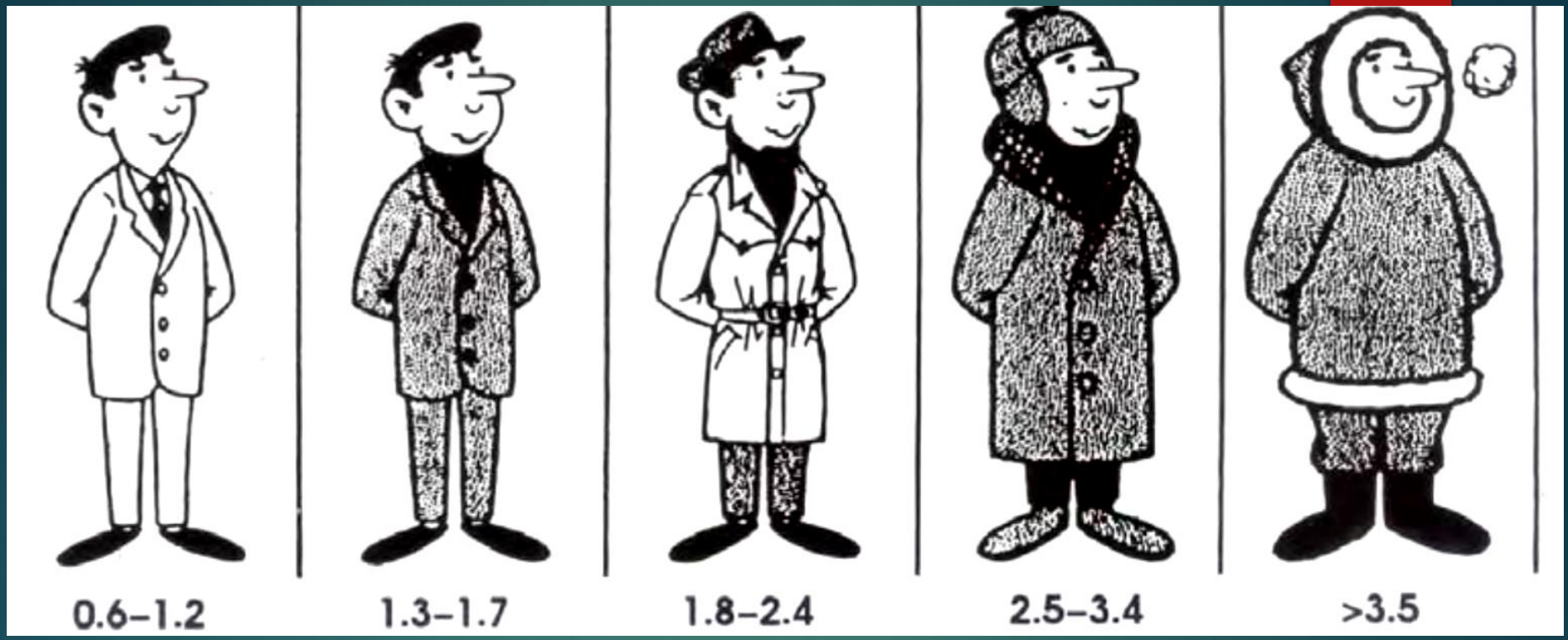
Windy

Personal Factors

Clothing

Advises that in *winter* wearing heavy clothes, a comfortable effective temperature (ET) is 20° to 24°C.

In the *summer*, wearing light clothes, the ET of 23°


0.6–1.2
1.3–1.7
1.8–2.4
2.5–3.4
>3.5

Clothing insulation

Clothes keep an air gap between our body surface and themselves that isolates us (because air is a good isolator).

During cold weather, layers of insulating clothing can help keep a person warm.

At the same time, if the person is doing a large amount of physical activity, lots of clothing layers can

Level of Adaptation

Different countries may have different comfort standards as a result of particular climate extremes and of the relative economics of providing and running heating and cooling systems

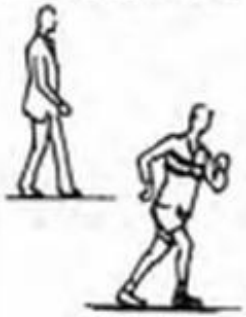
Body Metabolic Activity

These are metabolic processes which have an efficiency of only about 20%, the remaining 80% is converted into heat.

The rate of metabolic heat production is primarily controlled by the rate of body activity.

Typical metabolic heat generation for various activities

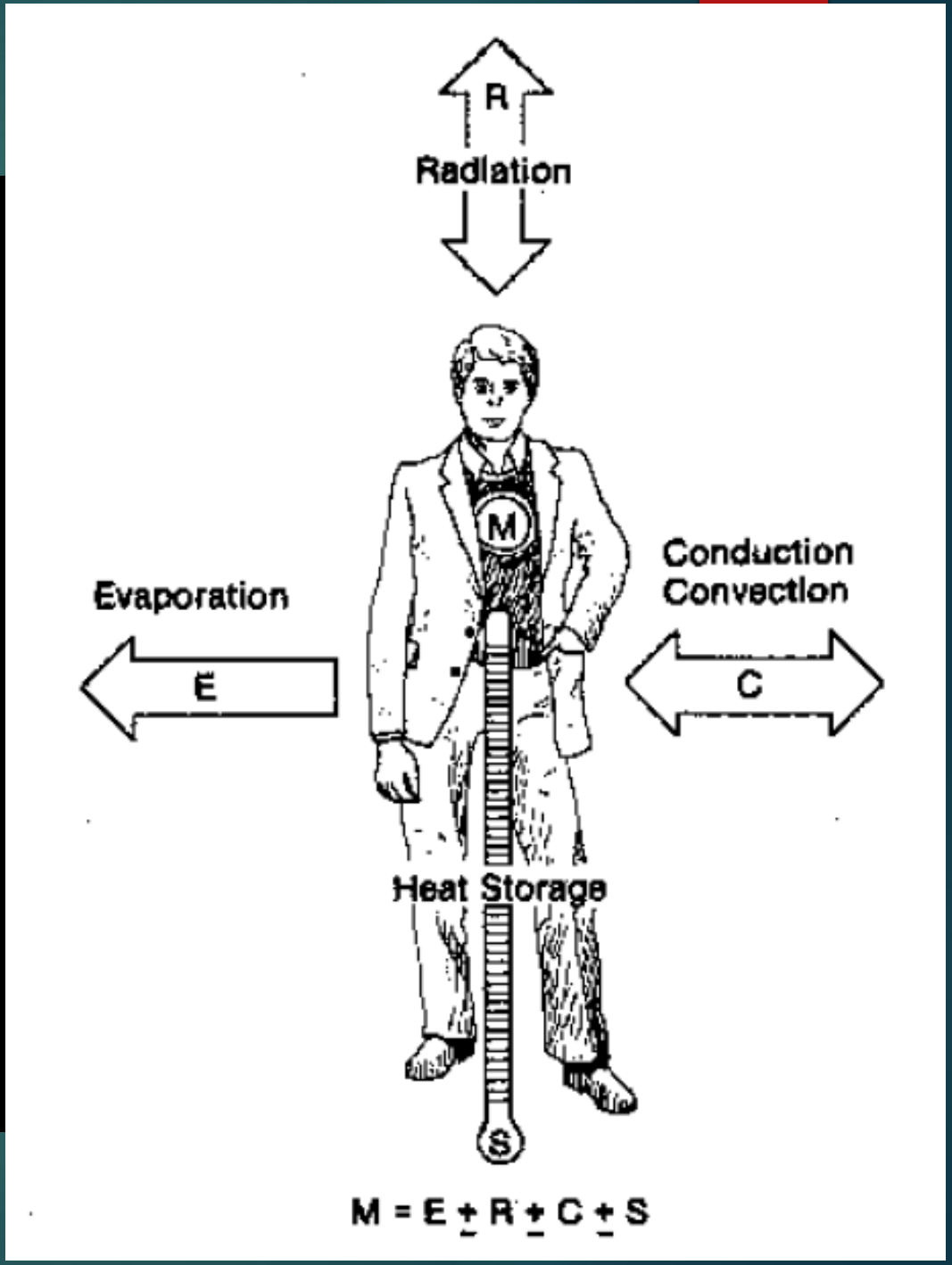
Table 4.3 Body Heat Production as a Function of Activity

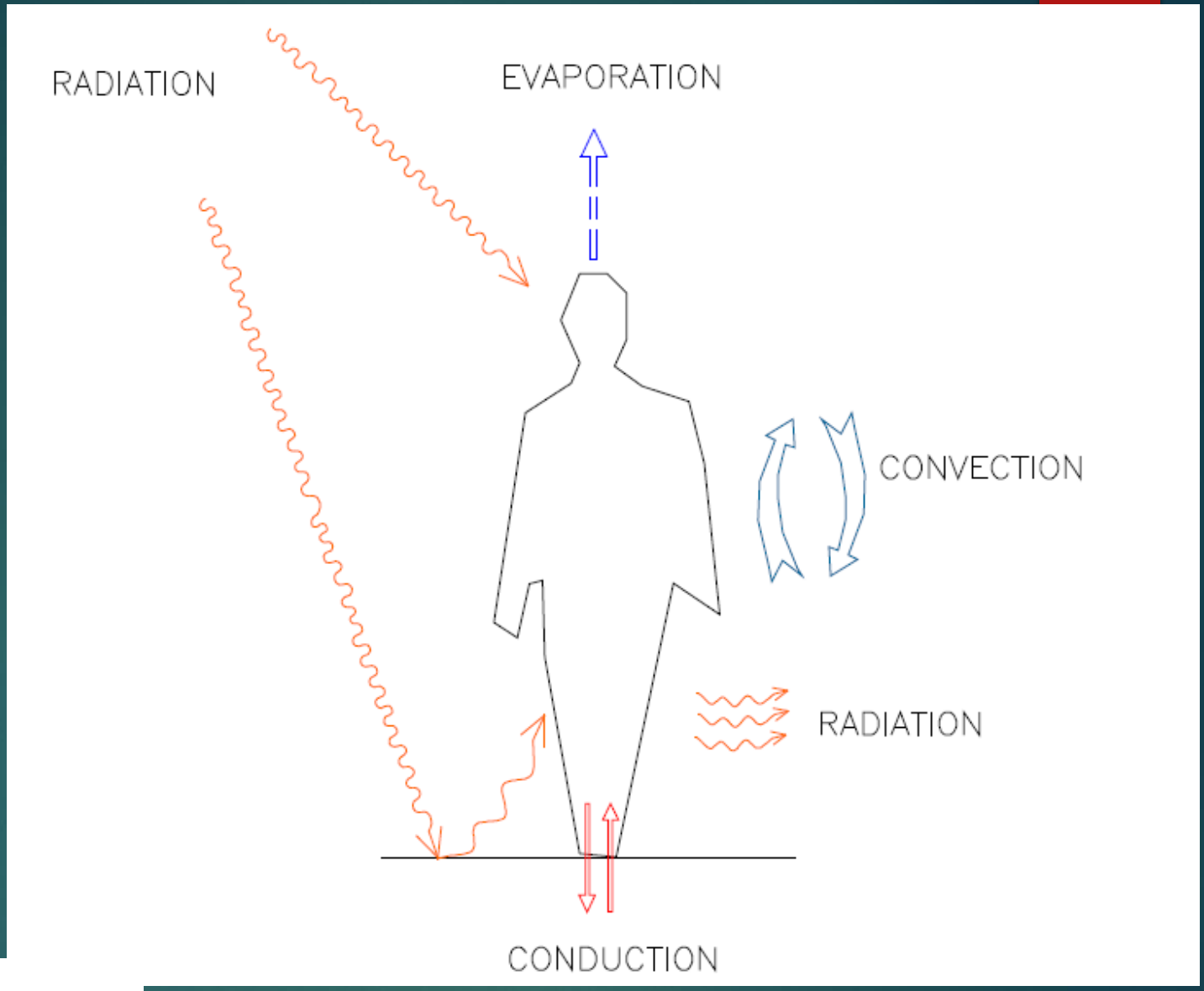
	Activity	Heat Produced (Btu/h)		Watts
	Sleeping	340		100
	Light work	680		200
	Walking	1020		300
	Jogging	2720		800

source: Lechner, "Heating, Cooling, Lighting" ch. 4

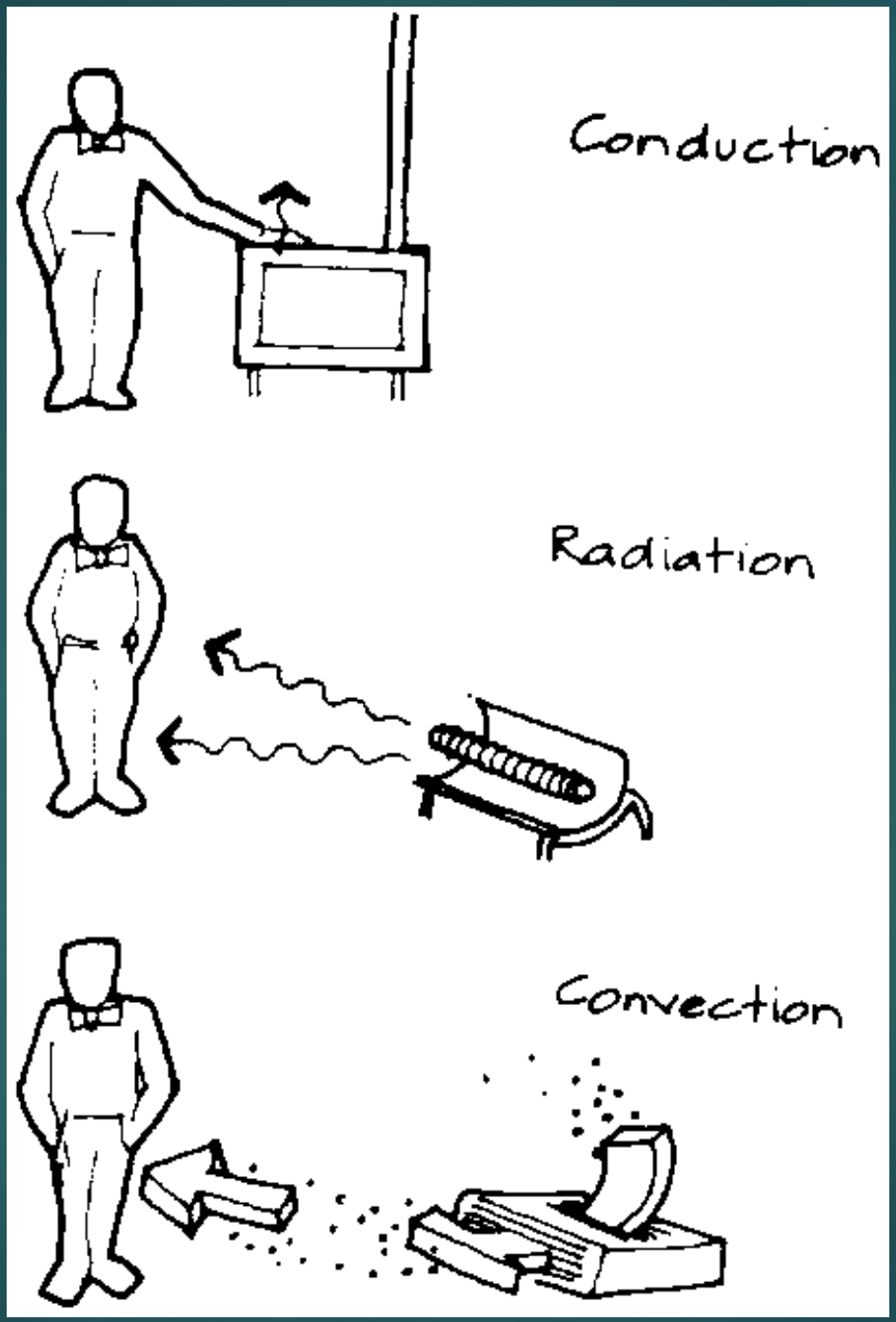
Heat transfer

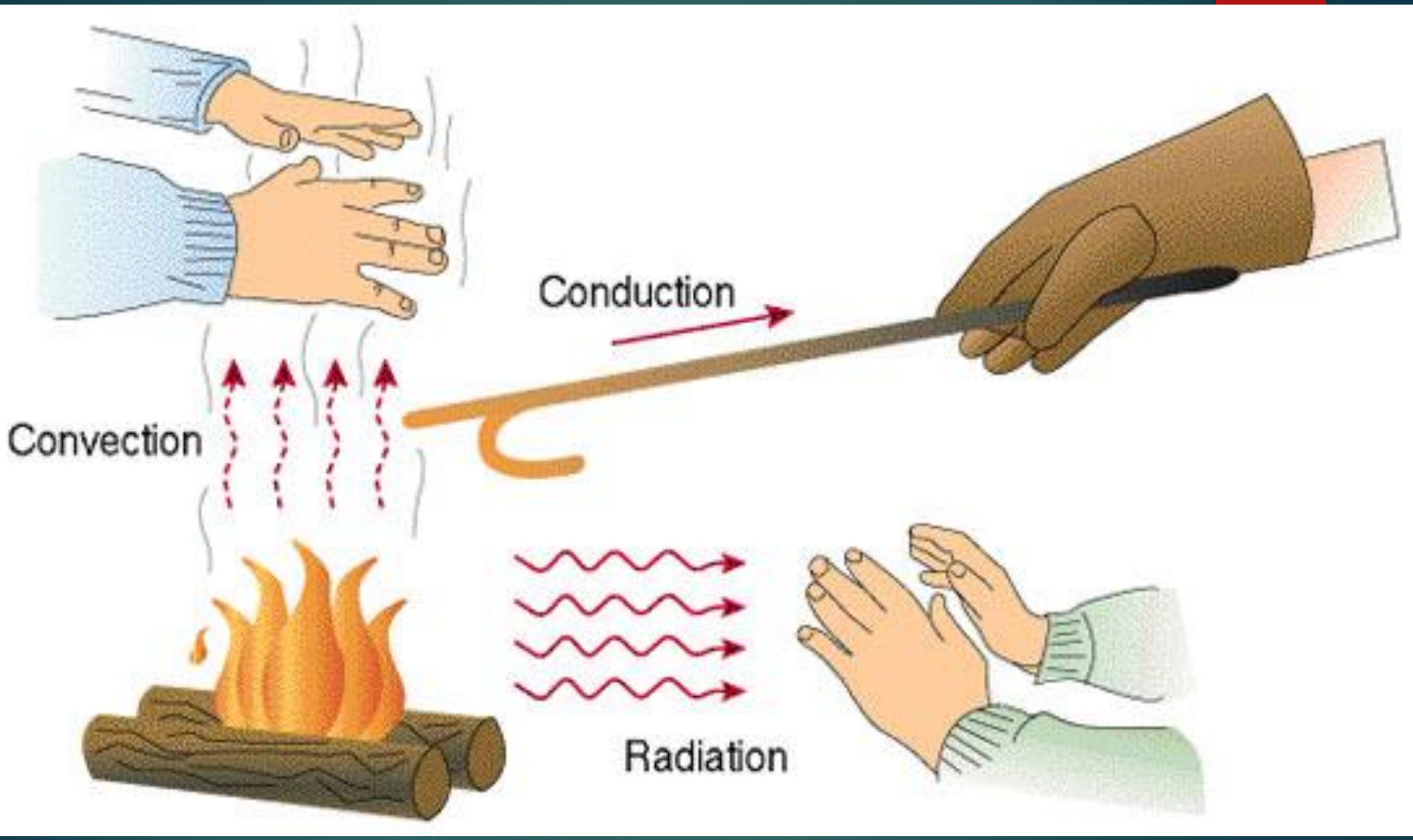
Heat is primarily transferred away from the body by one of four methods: conduction, convection, radiation or evaporative cooling.

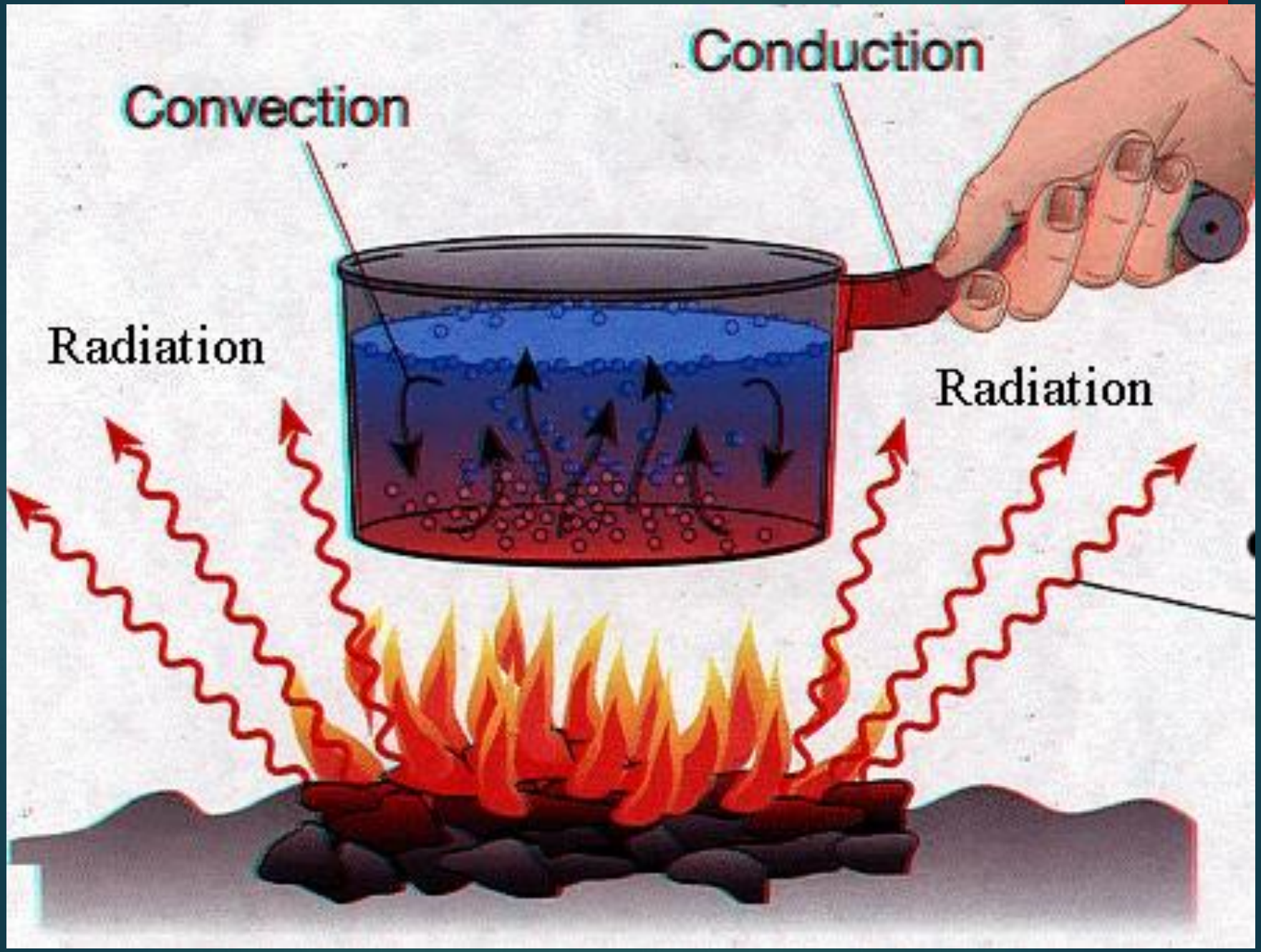




Heat exchange processes between a human body and the indoor environment


Conduction
Radiation
Convection


Conduction
Convection
Radiation

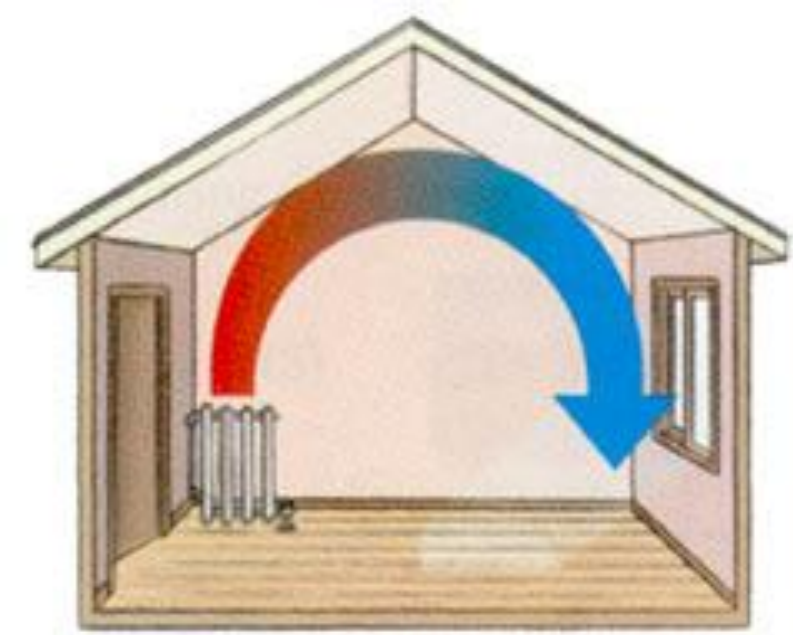

Conduction
Convection
Radiation
Radiation

Conduction

Conduction moves heat energy through a substance by transfer between molecules or atoms

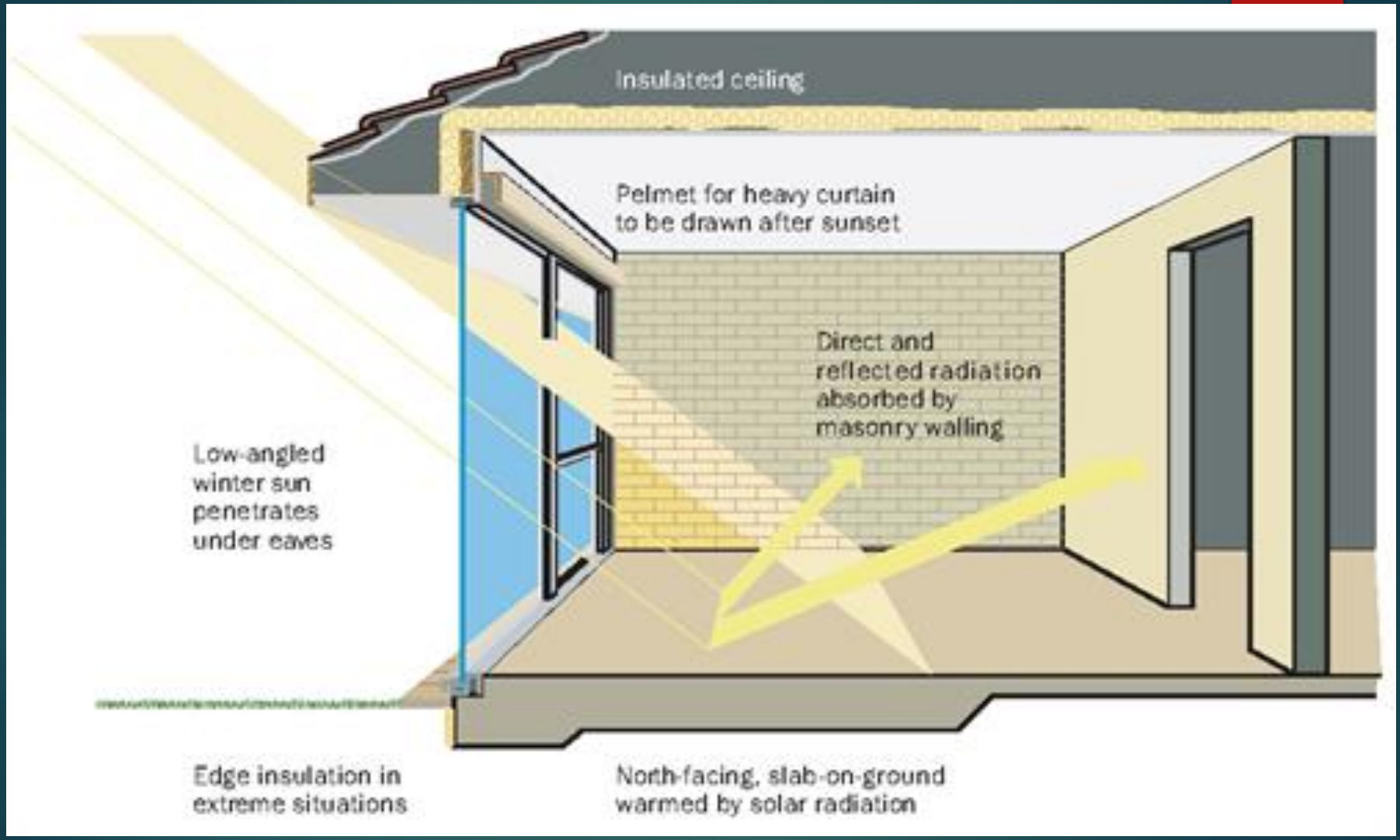
Convection

Convection moves energy by the movement of molecules or atoms in a fluid



Radiation

Radiation moves energy by electromagnetic waves

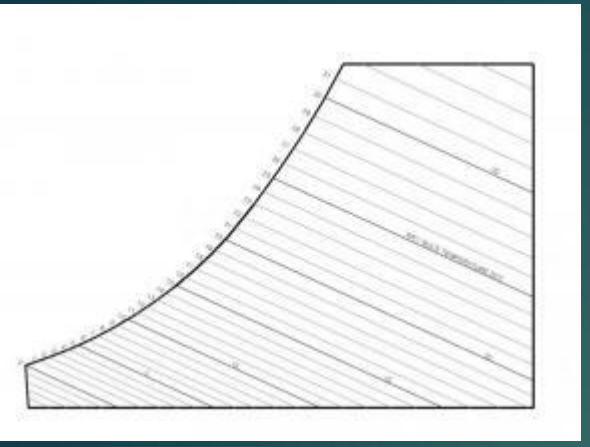

Insulated ceiling
Pelmet for heavy curtain to be drawn after sunset
Direct and reflected radiation absorbed by masonry walling
Low-angled winter sun penetrates under eaves
Edge insulation in extreme situations
North-facing, slab-on-ground warmed by solar radiation

Evaporative Heat Loss

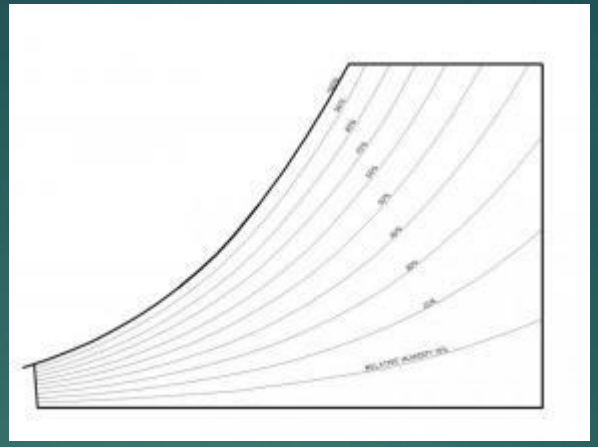
When liquid water evaporates from a surface, heat is required to change the water from the liquid to a gaseous state.

The Comfort Chart

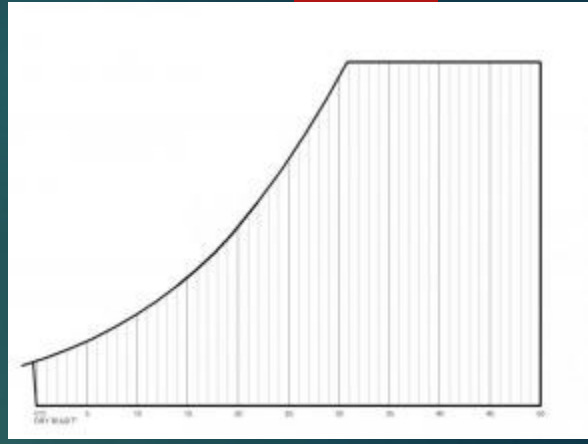
The comfort chart, shown correlates the perception of comfort with the various environmental factors



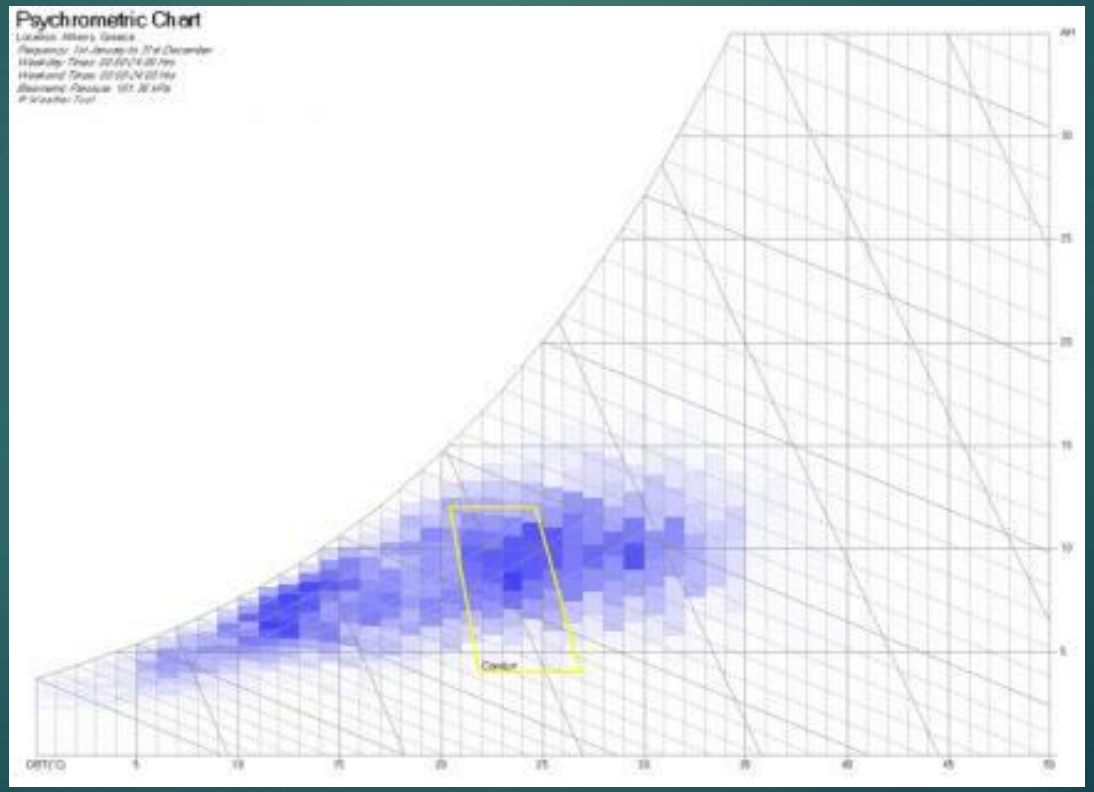
Wet bulb temperature BWT



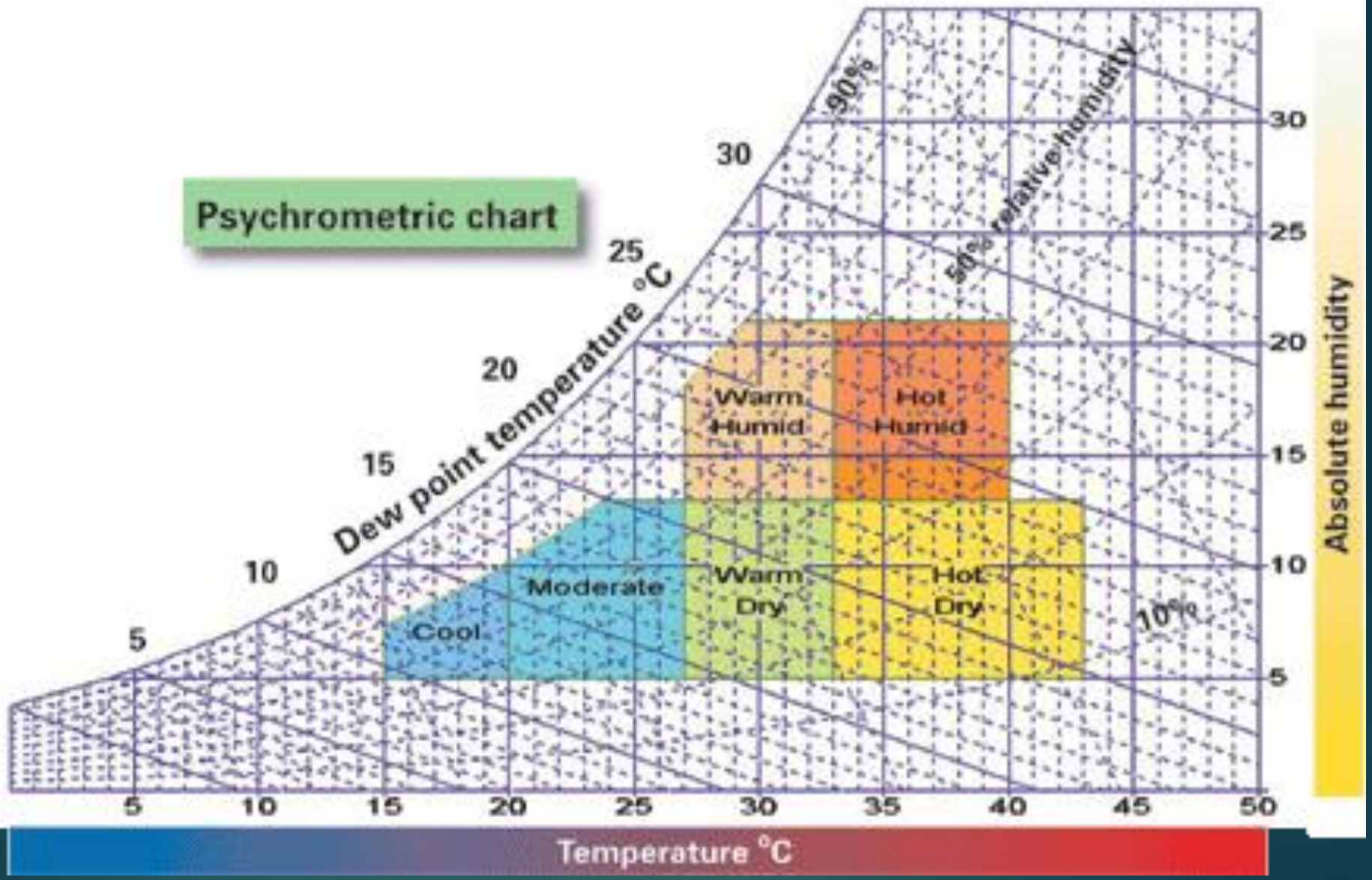
Relative humidity (RH)



Dry bulb temperature (DBT)

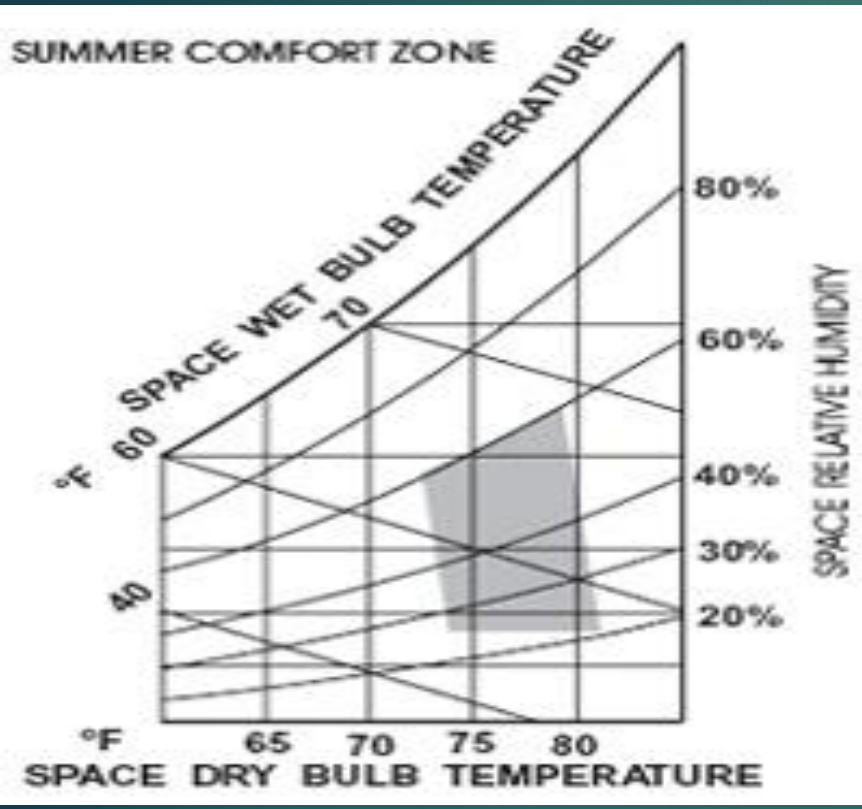


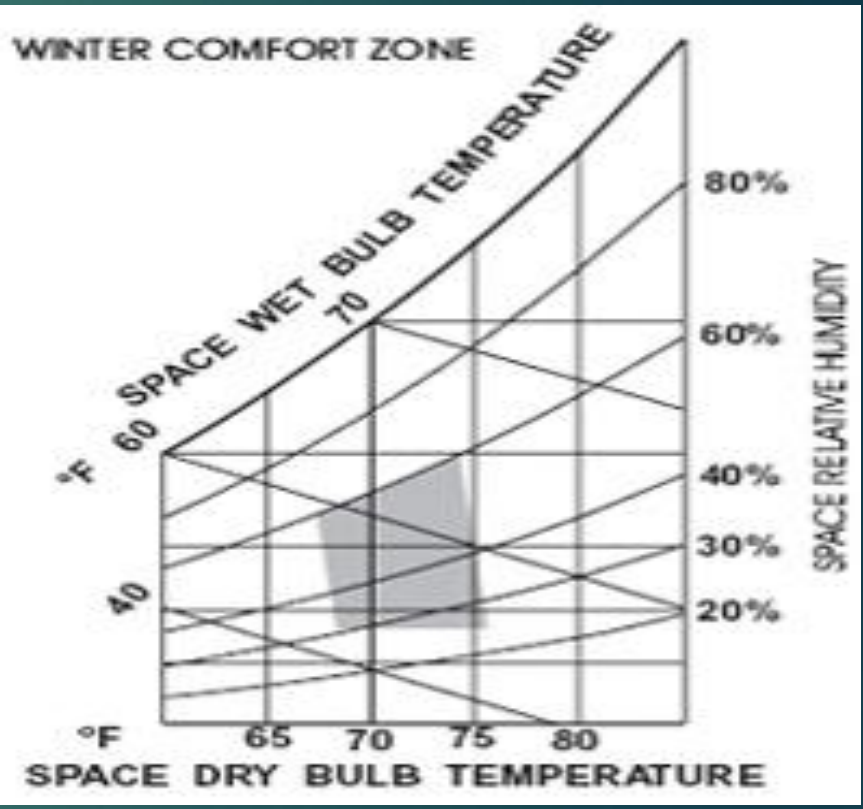
Psychrometric Chart

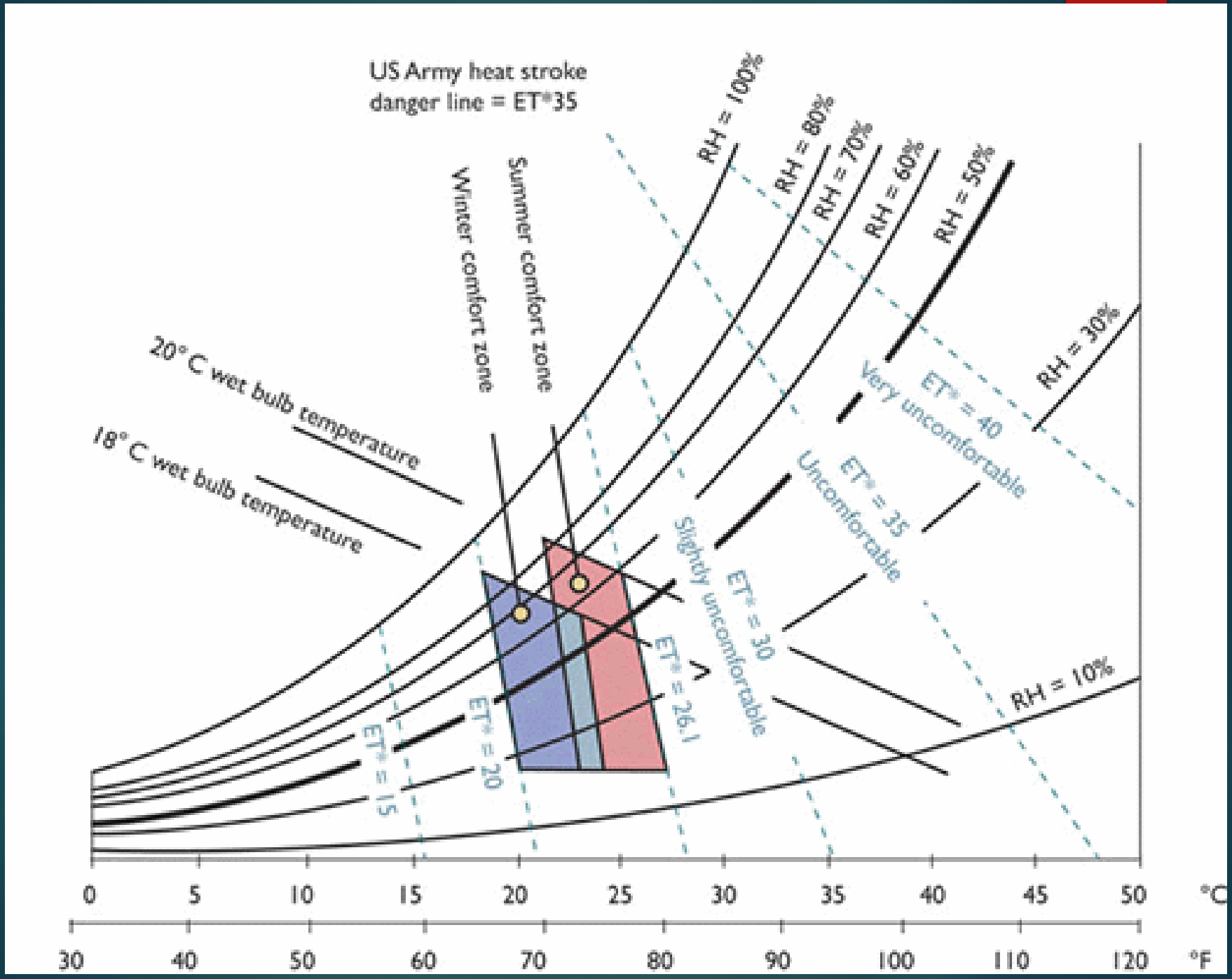


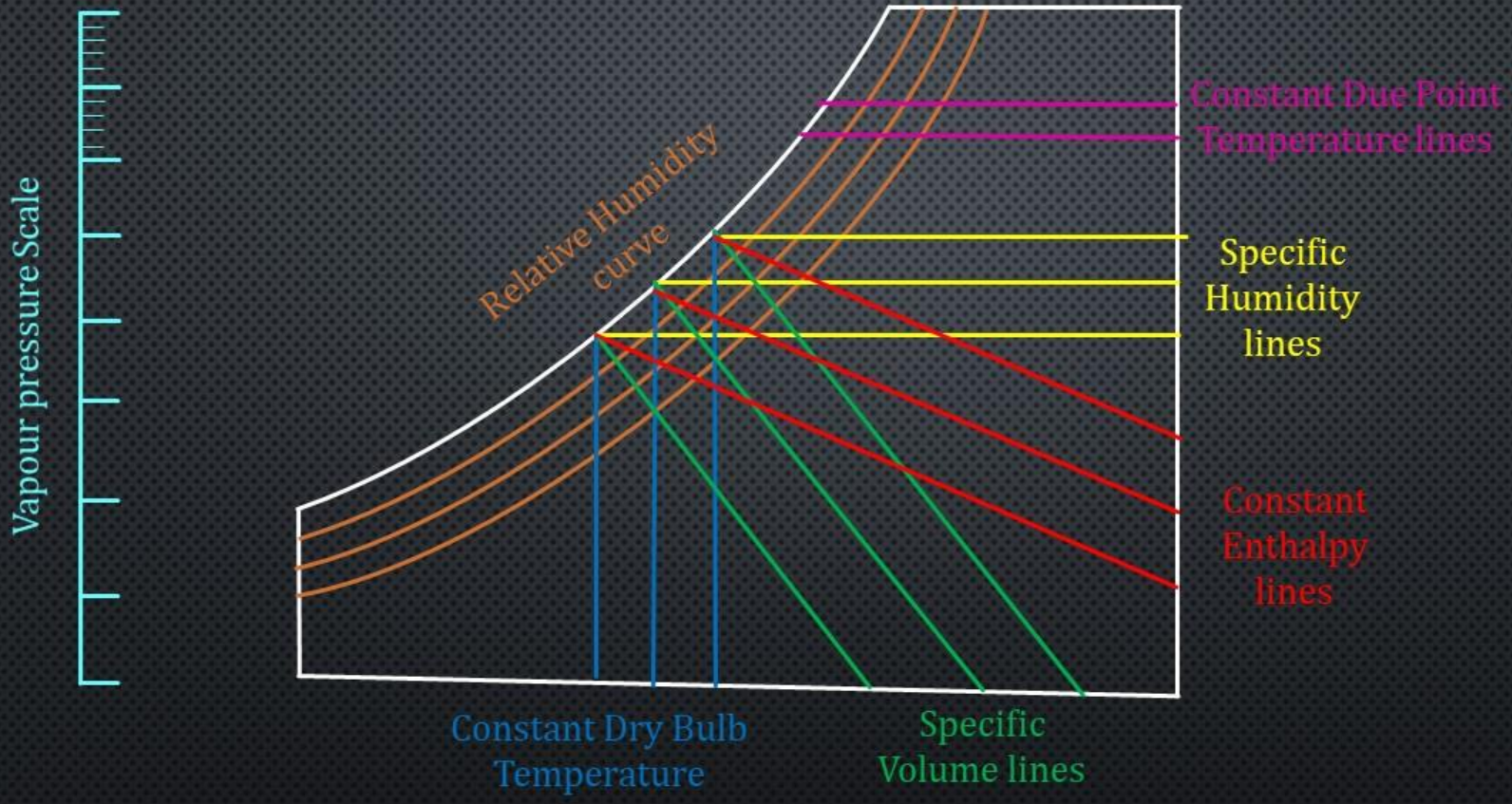
Psychrometric chart with overlaid climatic zones

The Comfort Chart



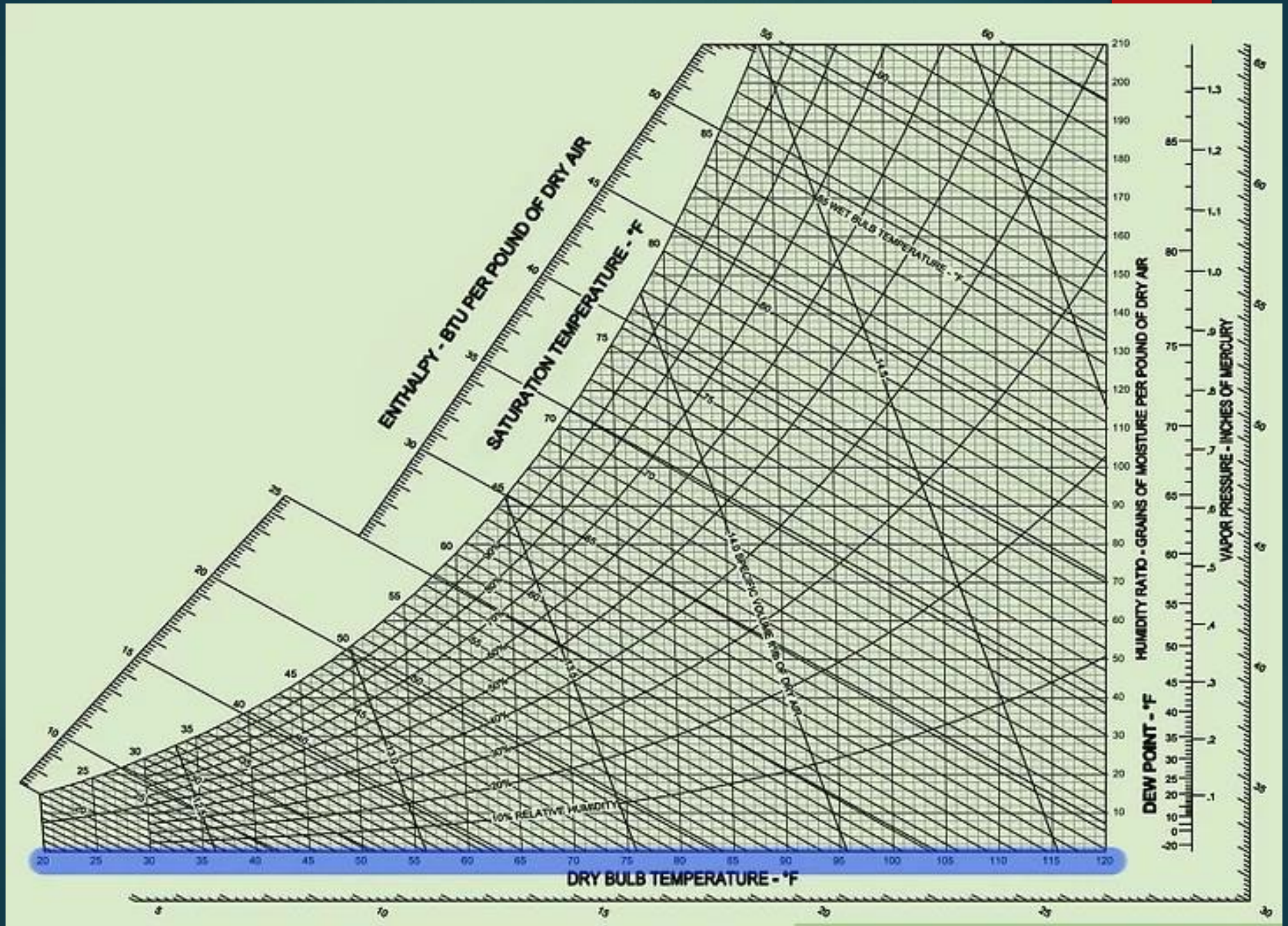



US Army heat stroke
danger line = ET*35
RH = 100%
RH = 80%
RH = 70%
RH = 60%
RH = 50%
RH = 30%
RH = 10%
Winter comfort zone
Summer comfort zone
20° C wet bulb temperature
18° C wet bulb temperature
ET* = 40
Very uncomfortable
ET* = 35
Uncomfortable
ET* = 30
Slightly uncomfortable
ET* = 26.1
ET* = 20
ET* = 15
0
5
10
15
20
25
30
35
40
45
50
°C
30
40
50
60
70
80
90
100
110
120
°F



ALLABOU REFRIGERATION

Psychrometric Chart Lines Structure



wikiHow to Read a Psychrometric Chart

Wetting W. الرطوبة النوعية	Relative volume V. الحجم النوعي	Enthalpy h. الانثالبية النوعية	Dew Point Tdp (الندى)	Relative humidity R.H الرطوبة النسبية	Wet bulb humidity Twb درجة الحرارة الرطبة	Dry bulb H humidity Tdb درجة الحرارة الجافة
Kg/Kg	M3/kg	Kj/Kg	C	%	C	C

- Ex. In Baghdad city in Jun tdb (42 c, twb 22 c) use psychometric chart to find other air attributes.

Your Homework