

# What is Heat

Fall 2026 class date: March 4, 1:00 PM (in class)

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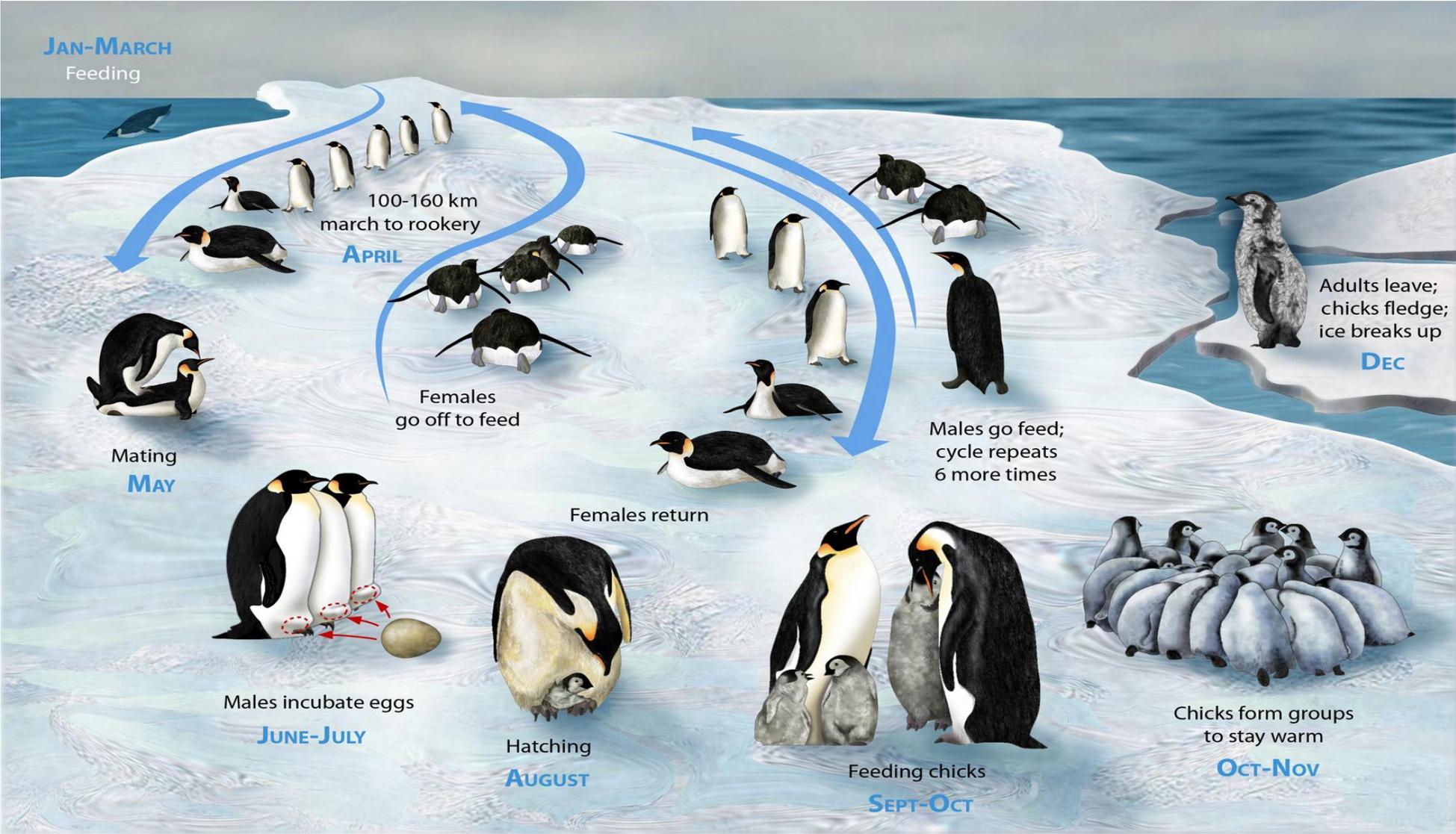
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A copy of this presentation can be found in the web site:  
*danielray.site* Under presentations click on: *What is Heat*

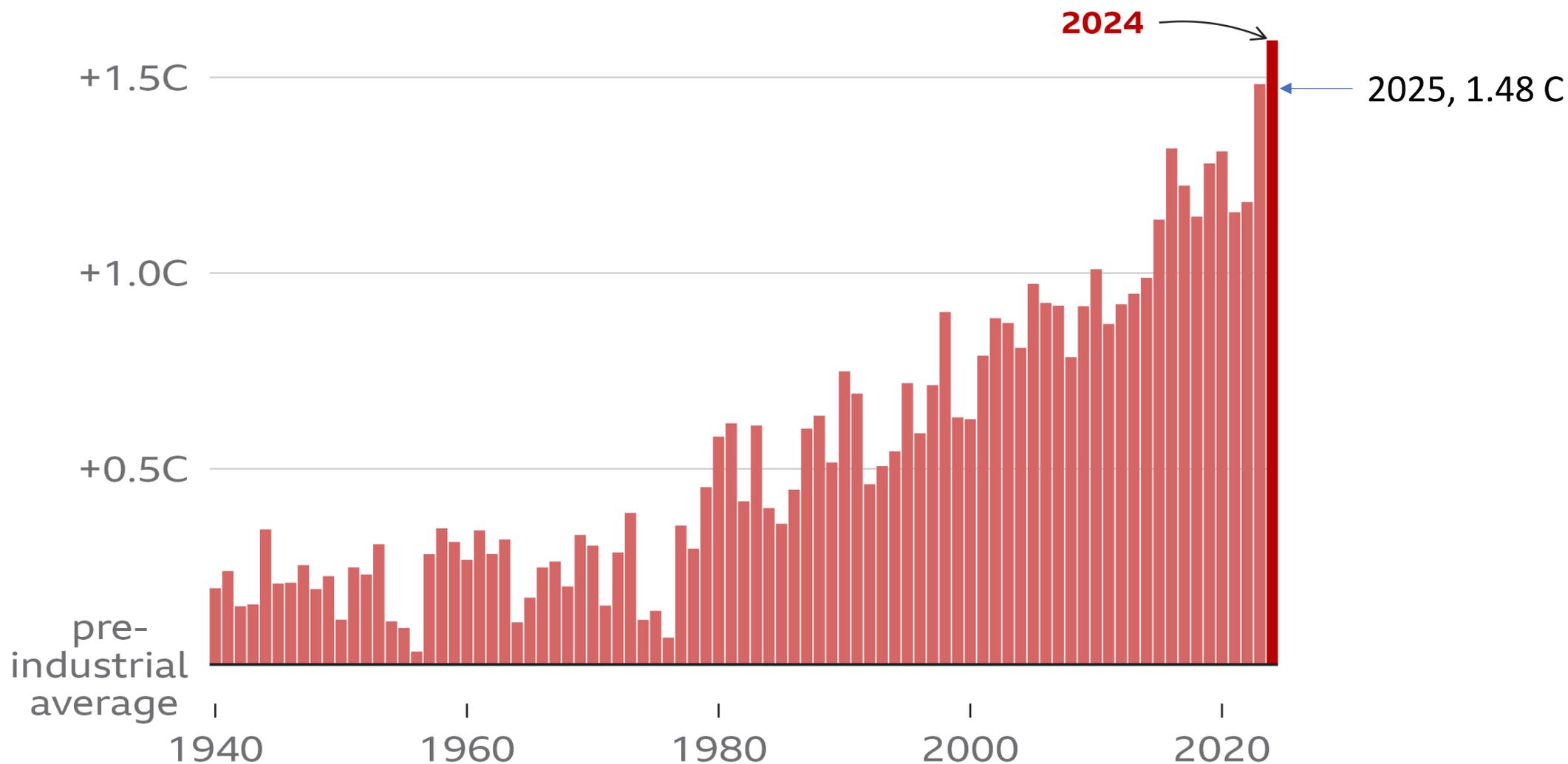
Additionally, an essay titled *What is Heat* can be found at  
the same web site under essays.

# Caution! This presentation may be more about penguins than you really wanted to know.



# 2024 set to be hottest year on record

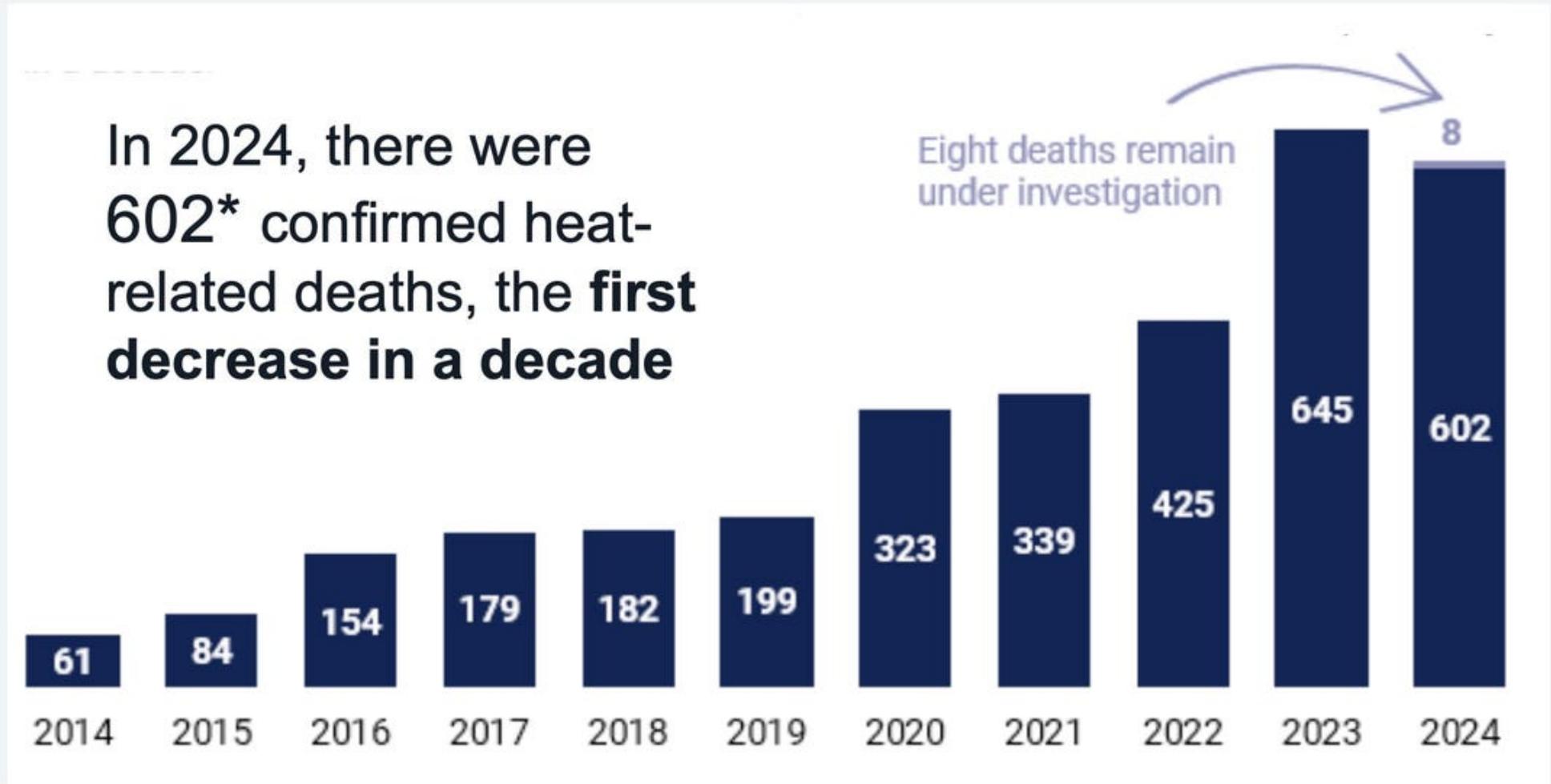
Global average temperature by year, compared with the pre-industrial average, 1850-1900



Provisional estimate for 2024, based on January to October temperatures

Source: ERA5, C3S/ECMWF

# Heat-Related Deaths Over Time



# What is Heat

Sir Isaac Newton (1642 – 1727)

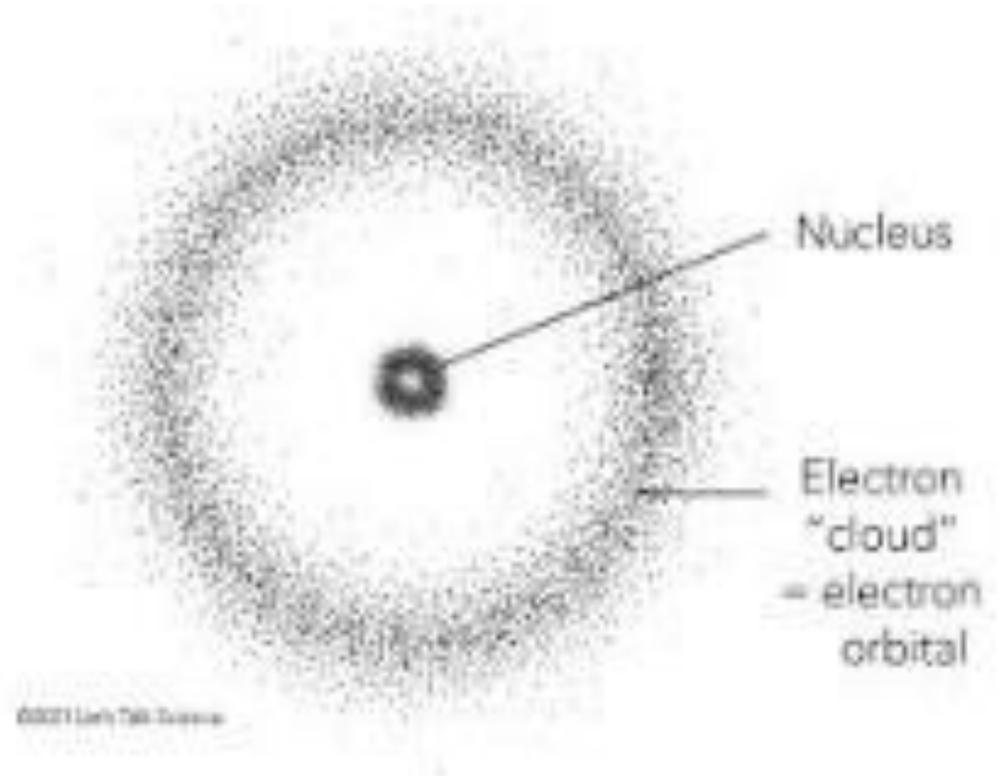
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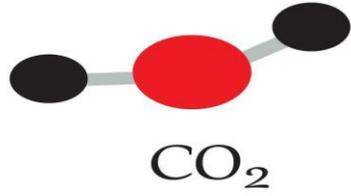


Heat is generated by: *“the trembling agitation of the smallest parts of all bodes”*

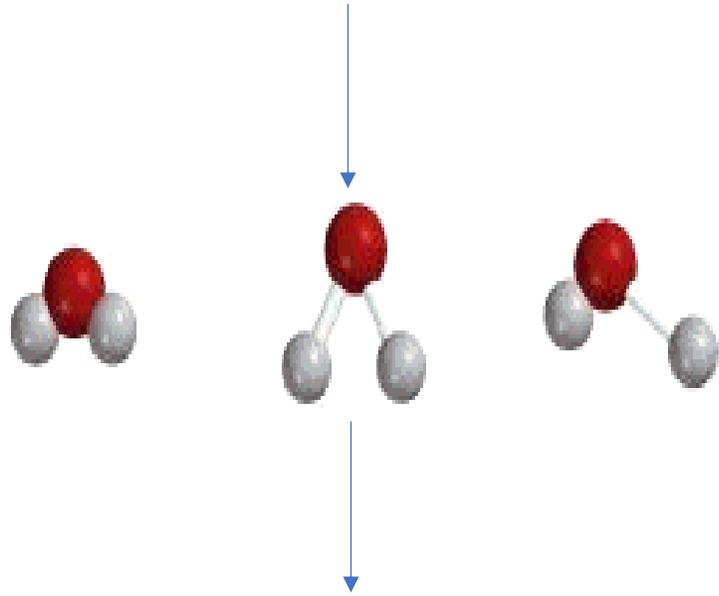
What we now understand as the vibration of atoms within molecules.

Electrons spinning around the nucleus of an atom  
causes the atom to vibrate



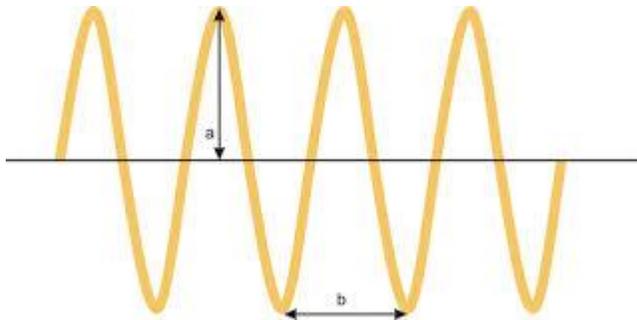


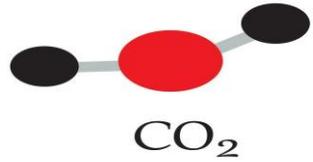
carbon dioxide



atomic vibration causing  
molecular motion

Heat (thermal radiation)





at absolute zero  
(-459.67 deg F)  
no molecular motion



at any temp above  
absolute zero  
molecules are in  
motion producing  
thermal radiation



As motion increases  
the temperature of  
thermal radiation  
increases

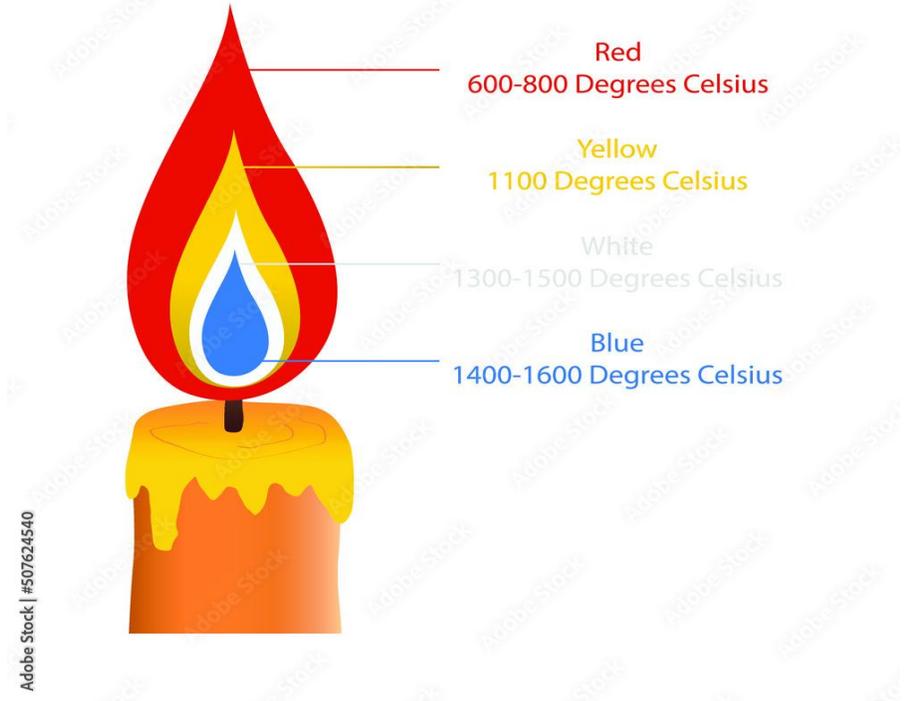
When temperature reaches about 80 deg F, thermal radiation consists of infrared rays which we feel as heat.

Our main source of infrared radiation comes from the sun

Thermal radiation that we can feel is emitted from all warm objects.

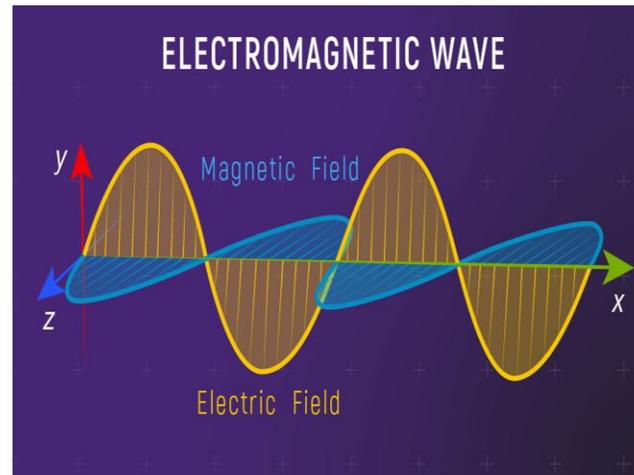
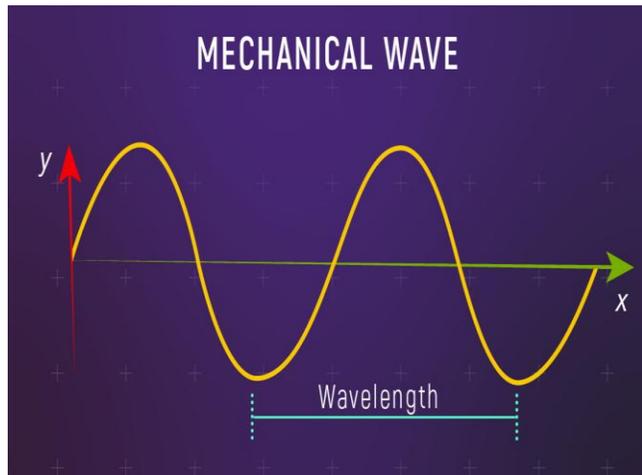
Which radiation depends on the temperature of the heat source:

80 F– infrared  
1112 F – red  
2012 F – yellow  
2552 F - blue



→ infrared

Radiation from the sun and other heat sources are components of the electromagnetic spectrum

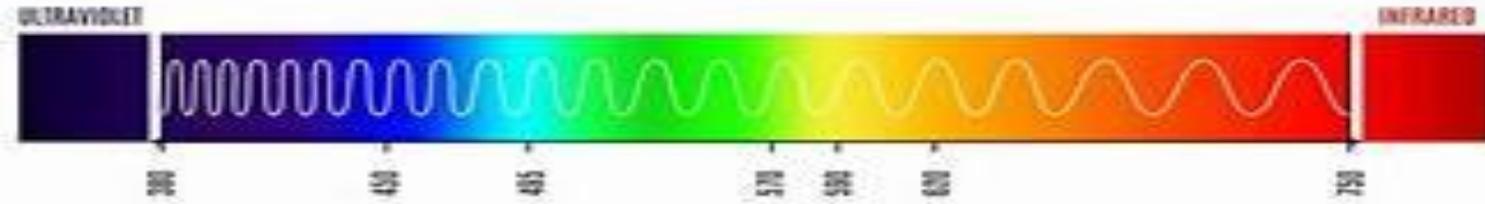


James C Maxwell (circa 1870) Scotland physicist.  
Derived the mathematical relationship between  
electrical and magnetic components of electromagnetic forces.

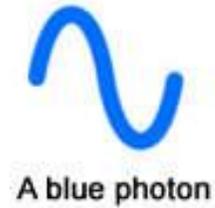
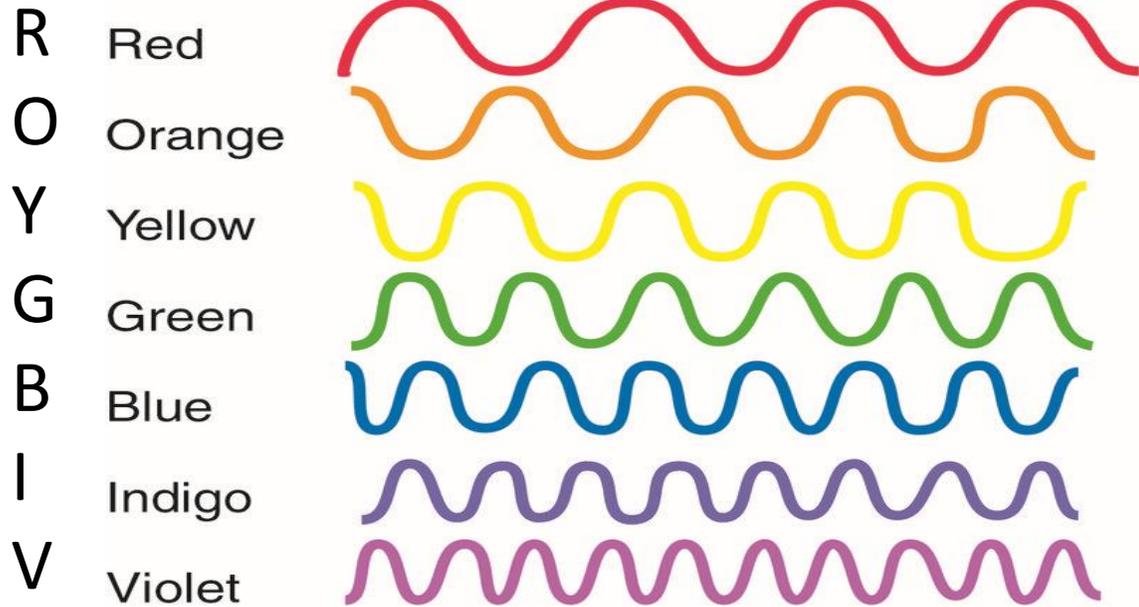




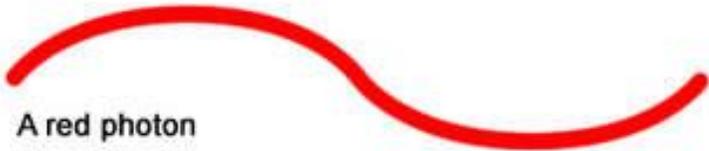
# VISIBLE SPECTRUM



## Visible Light - Wavelength



A blue photon



A red photon

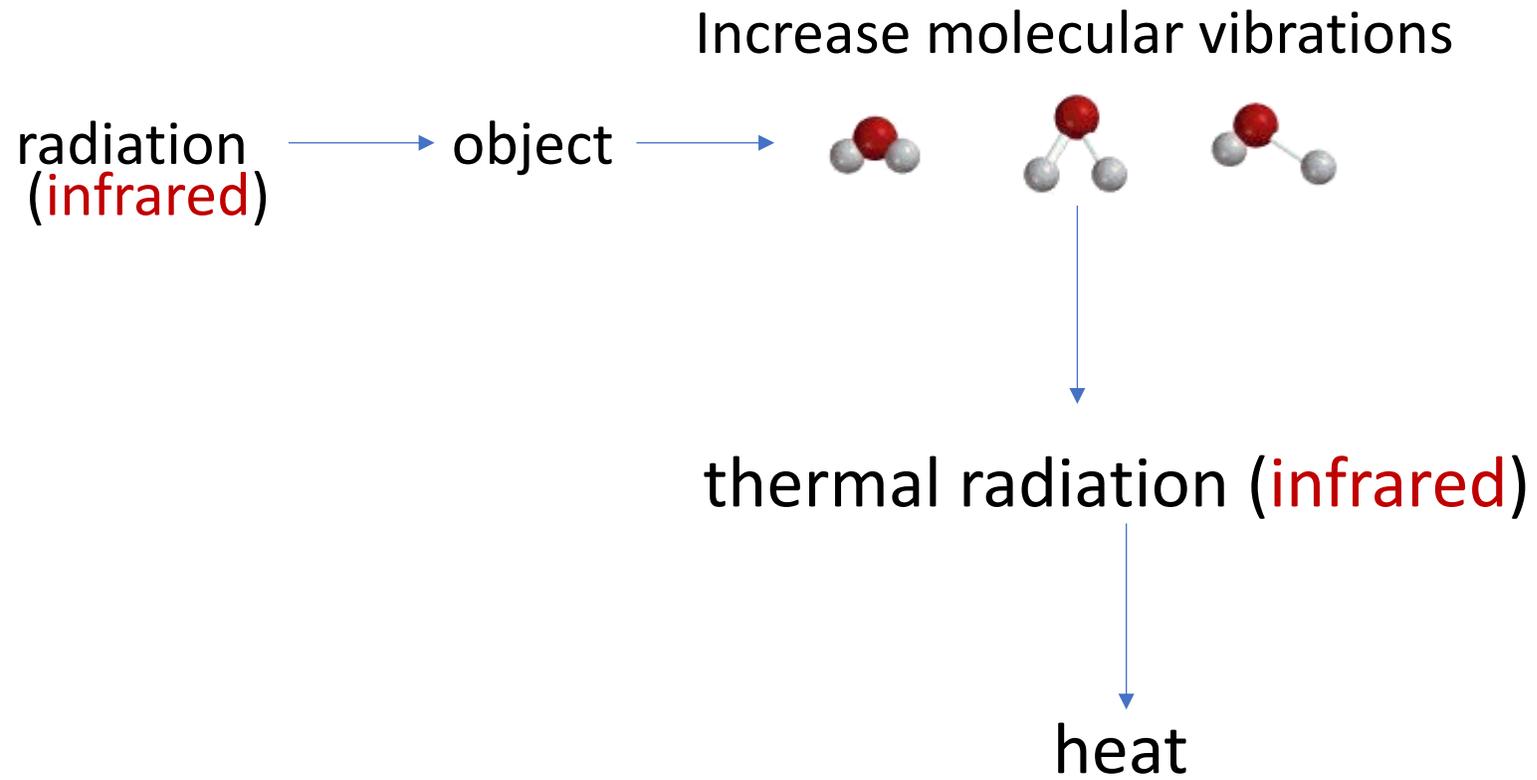
Max Planck German physicist (circa 1900)



Energy of electromagnetic waves

$$E = hf$$

$h$  = Planck's constant,  
 $f$  = wave frequency

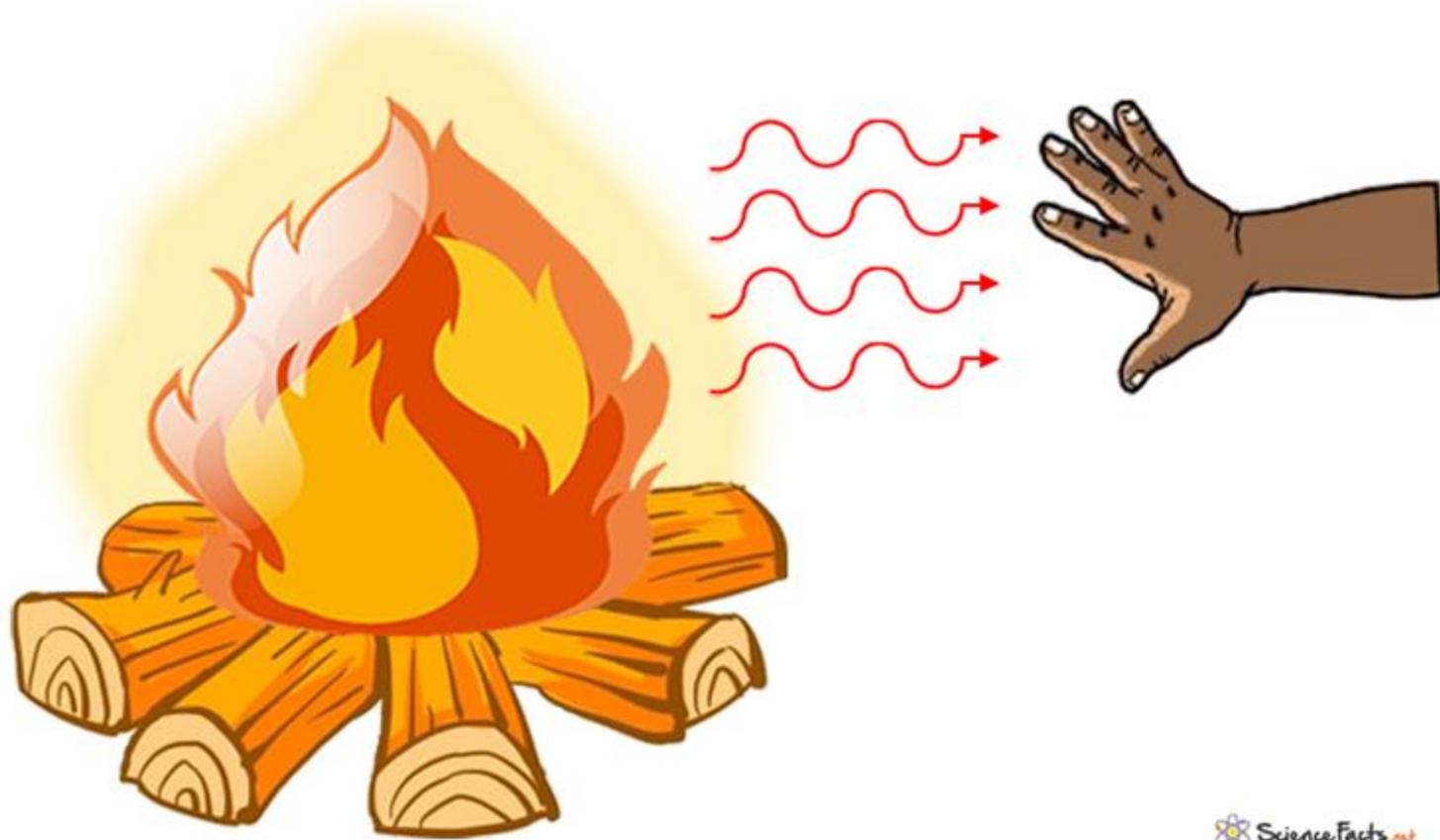


Infrared rays are invisible to our eyes.

But not to those of snakes, in particular rattle snakes,  
who use infrared vision to locate prey or the leg of a hiker!

# Thermal Radiation

Campfire



The intensity (energy) of radiation decreases as the square of the distance from the source

$$X \propto \frac{1}{d^2}$$

Where:

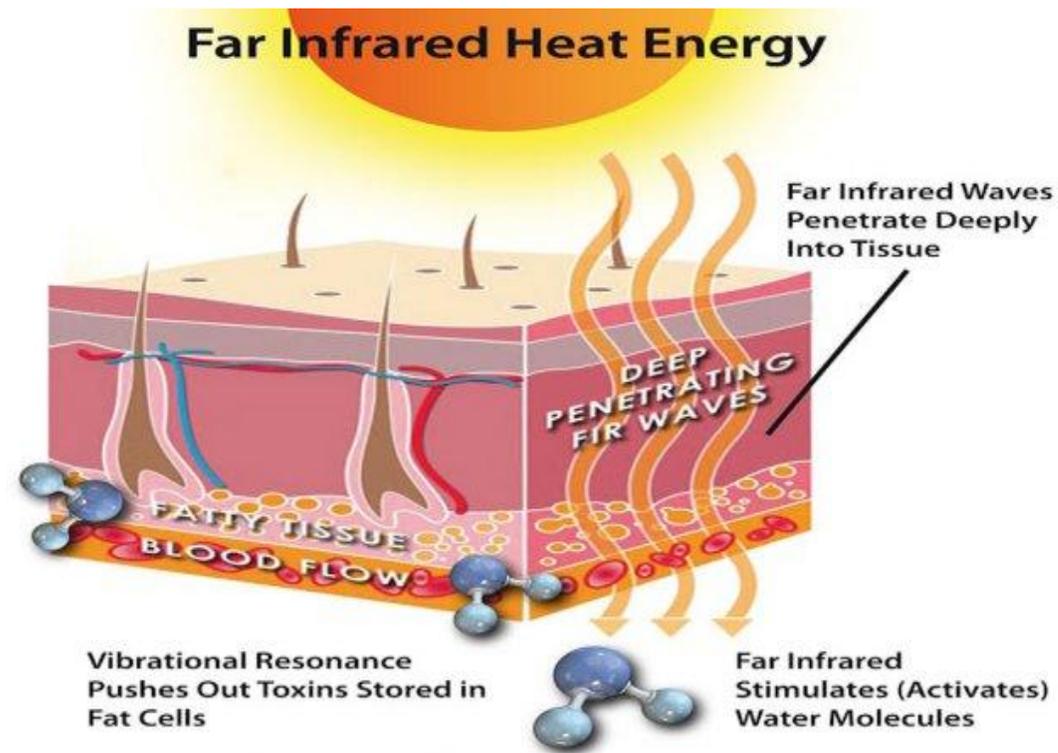
$X$  is the quantity or intensity

$\propto$  stands for proportional to

$d$  is the distance from the center of the source (usually measured in meters)

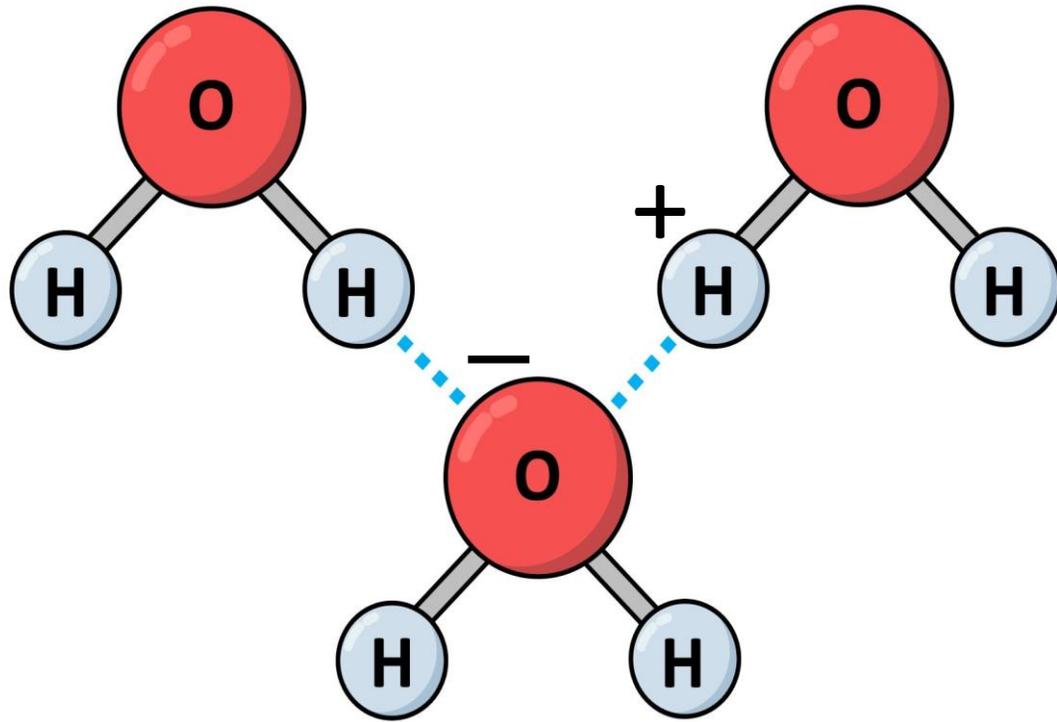


Regardless of source, infrared rays easily penetrate skin



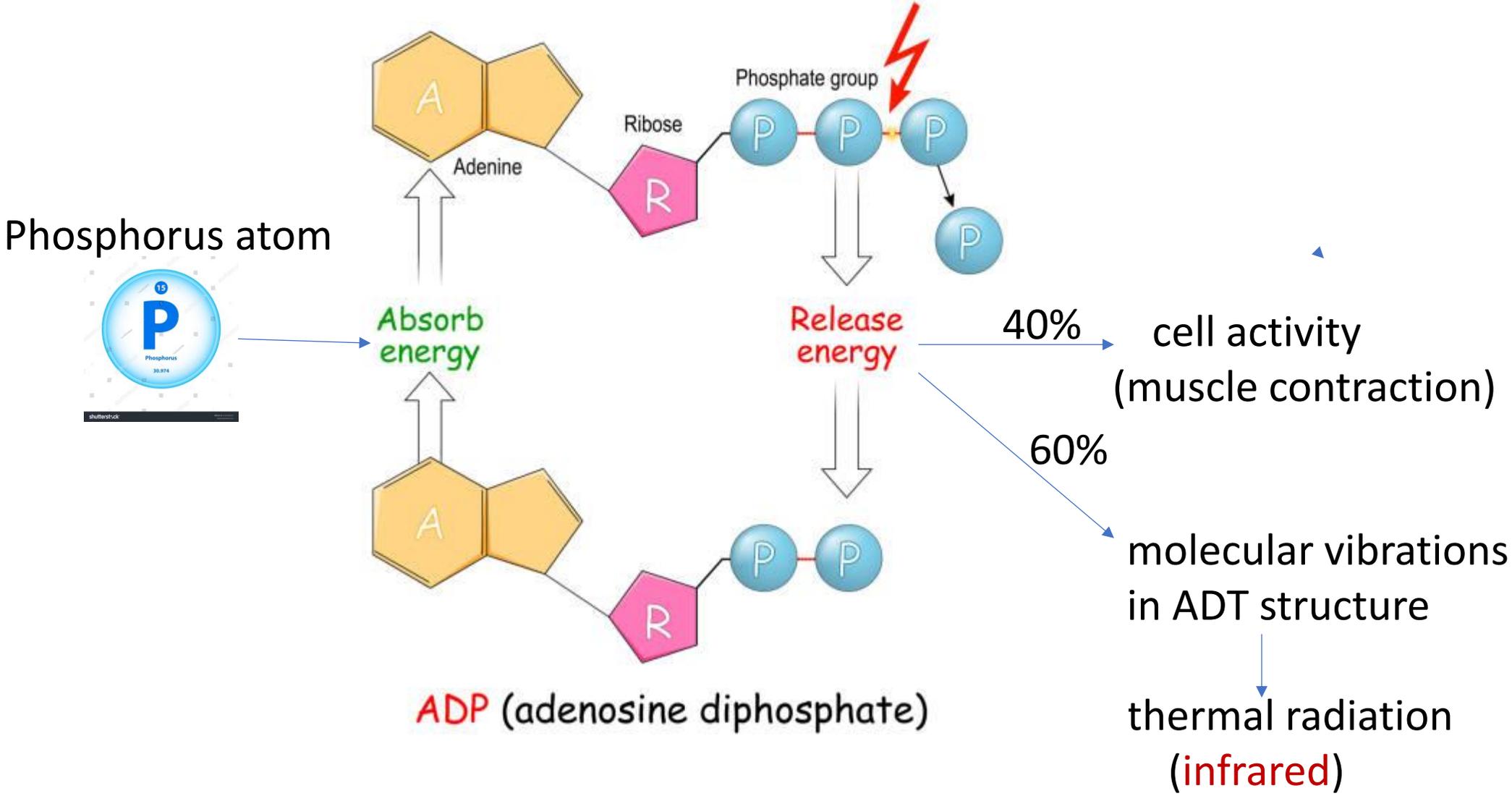
**Infrared rays** penetrate water molecules in skin causing molecular vibration which produces thermal radiation in the form of **infrared rays**.

Individual water molecules bond together to form liquid water



# Heat from body metabolism

**ATP** (adenosine triphosphate)



Body metabolism, our main source of internal heat, increases with activity



In warm weather

or



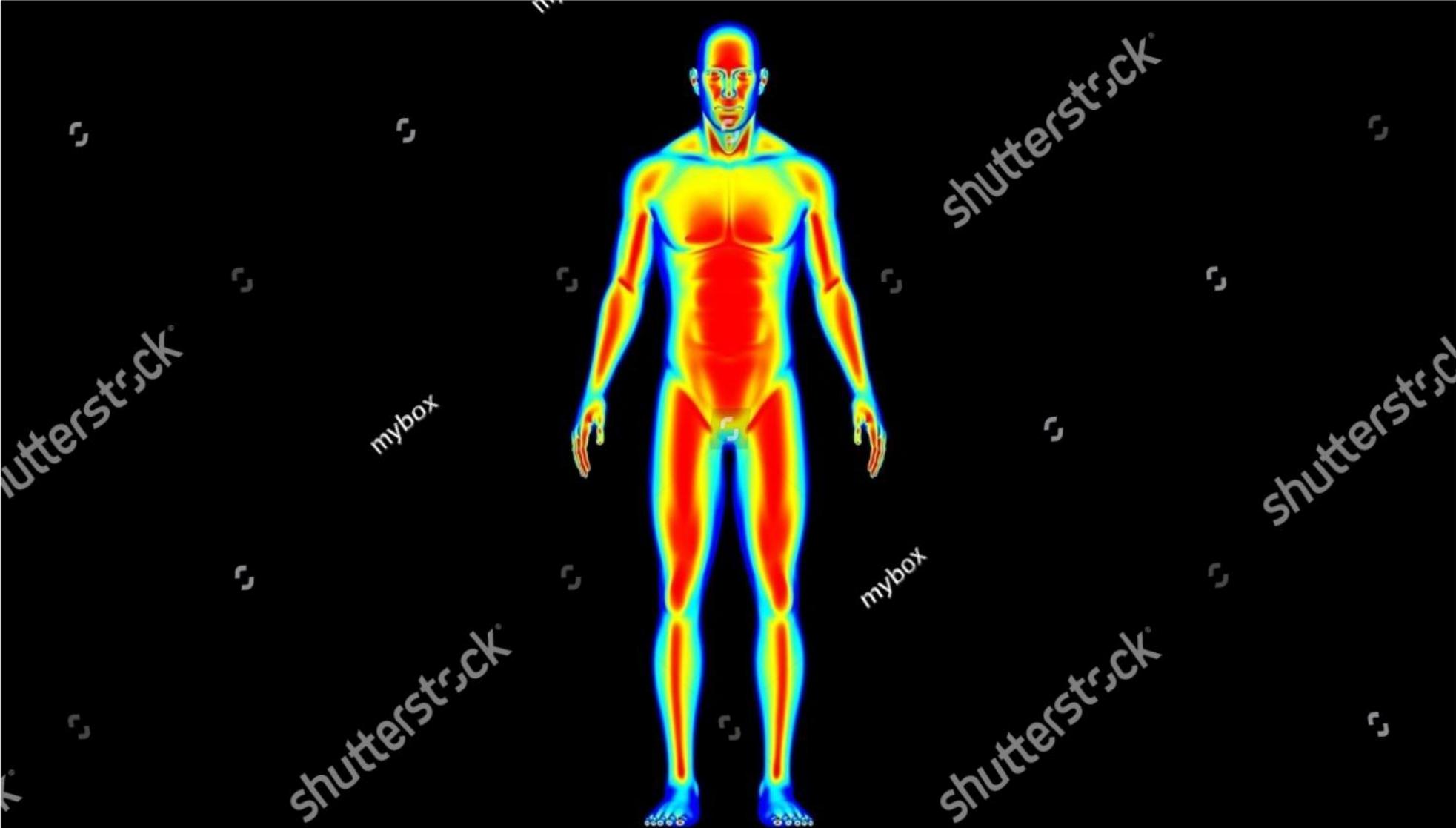
Cold weather

If infrared rays are invisible to us,  
then how do we know they  
exist as part of thermal radiation?

Valentina and Semyon Kirlian (circa 1955), Soviet scientist developed photography that would capture infrared light rays. Now known as “Kirlian photography”.



Infrared (Kirlian) photography of human body (aka thermal imaging)



# How is Heat Transferred From Warm to Cool Objects



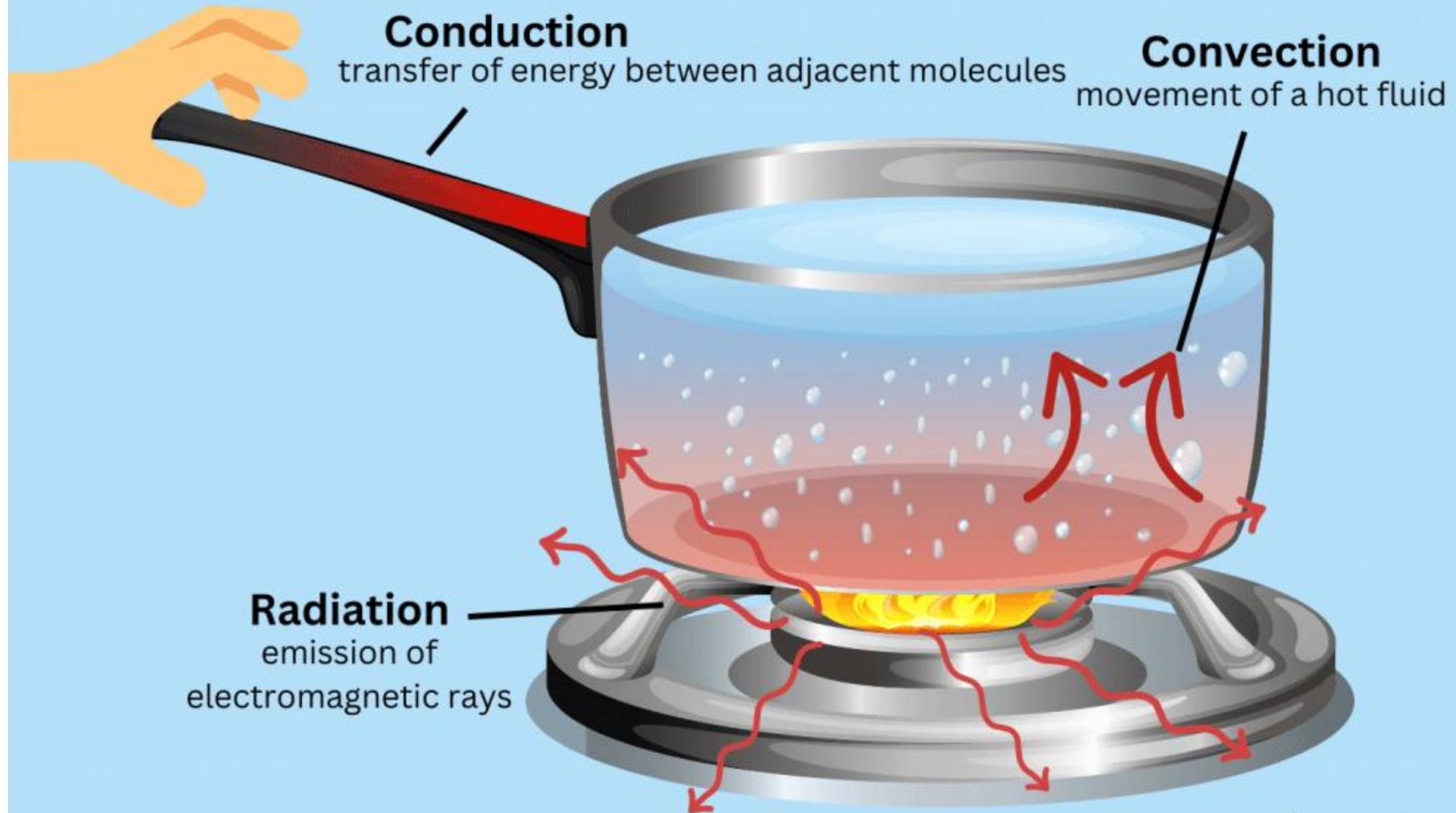
Antoine Lavoisier (circa 1780)

French nobleman and chemist

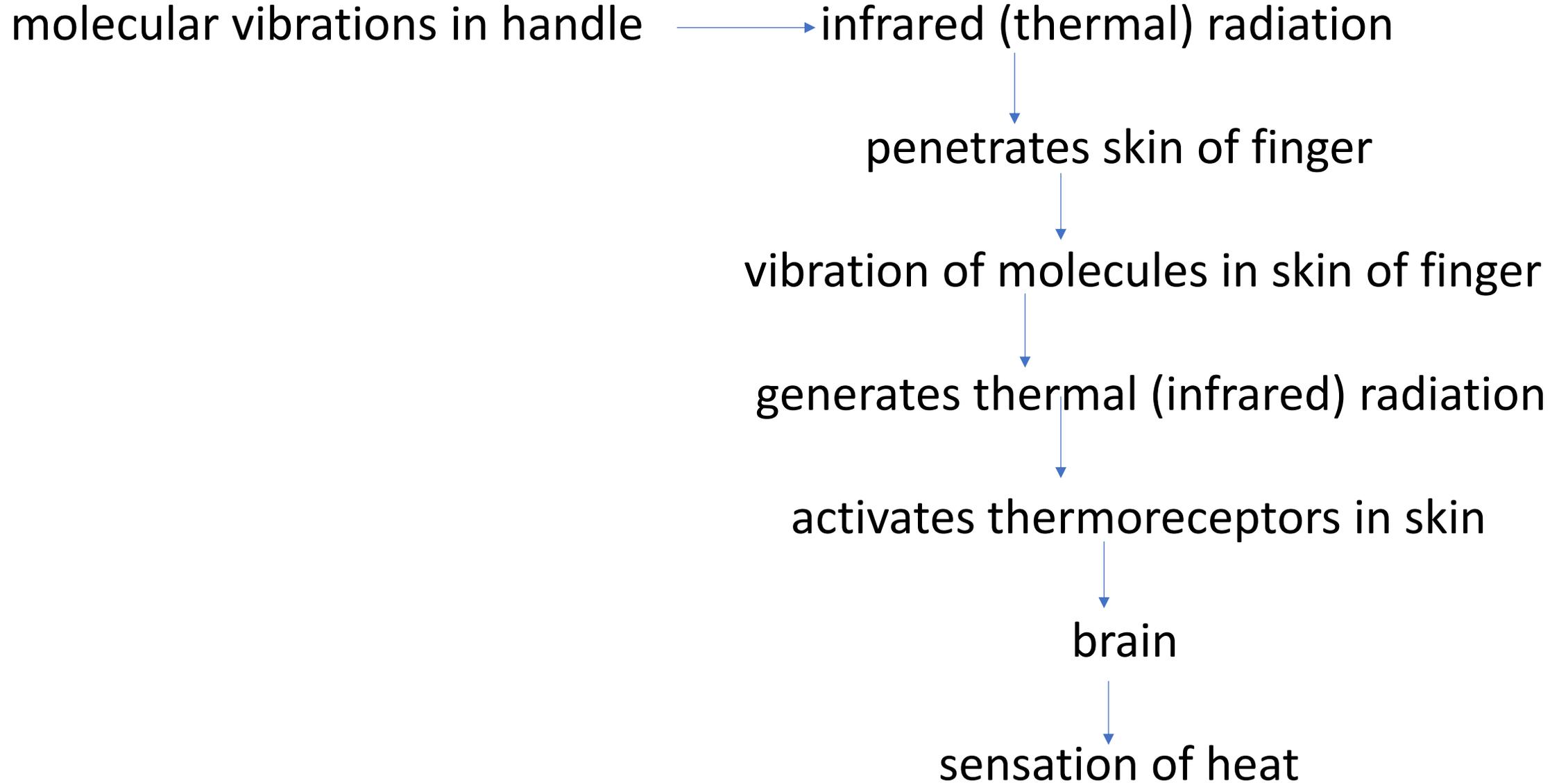
Published "*The Caloric Theory of Heat*" in 1783:

This theory held that heat is a substance that flows from warm to cool objects much like water flowing down hill.

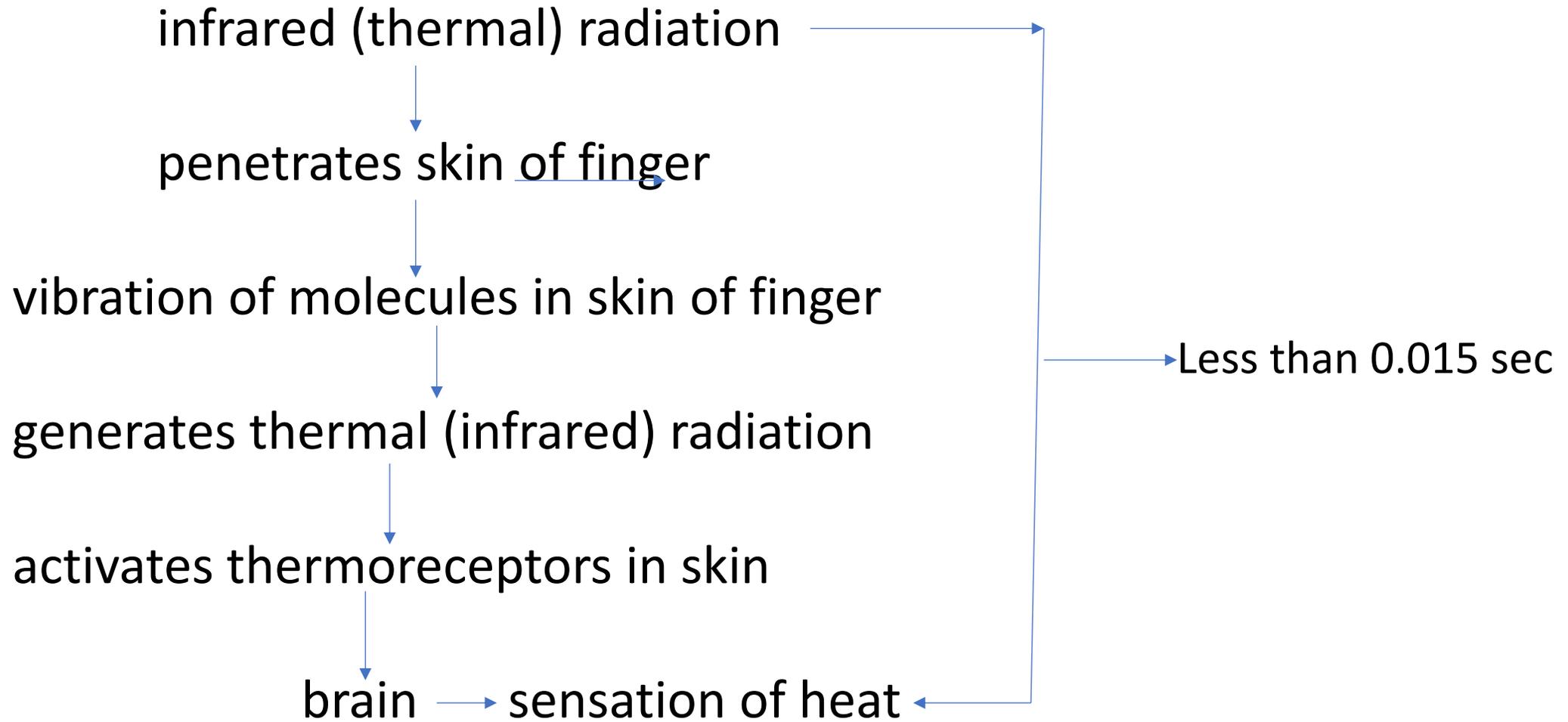
# Heat Transfer



# Heat transfer into the fingers when touching a hot object (pan handle)

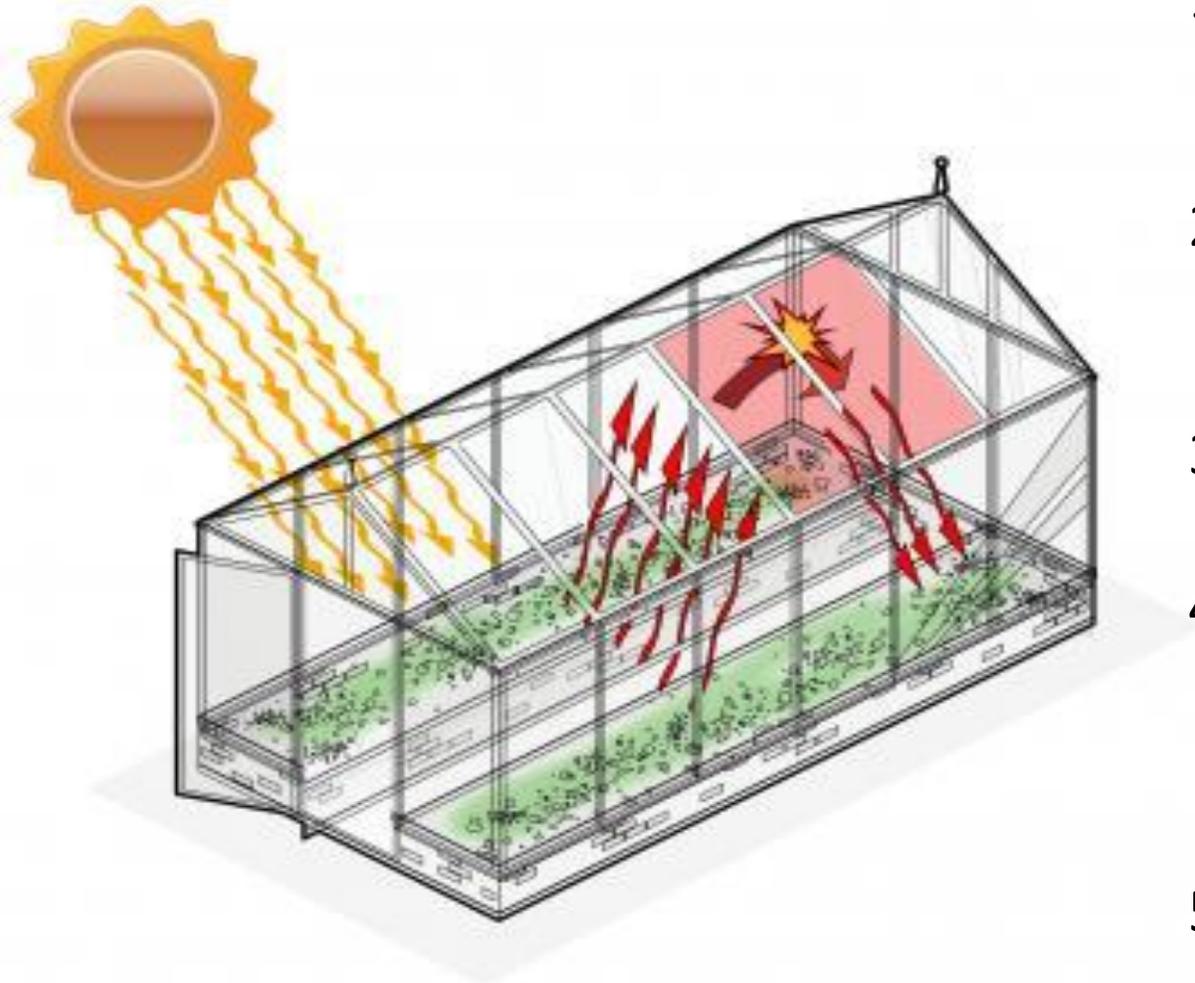


# Why does a hot object feel hot as soon as you touch it?



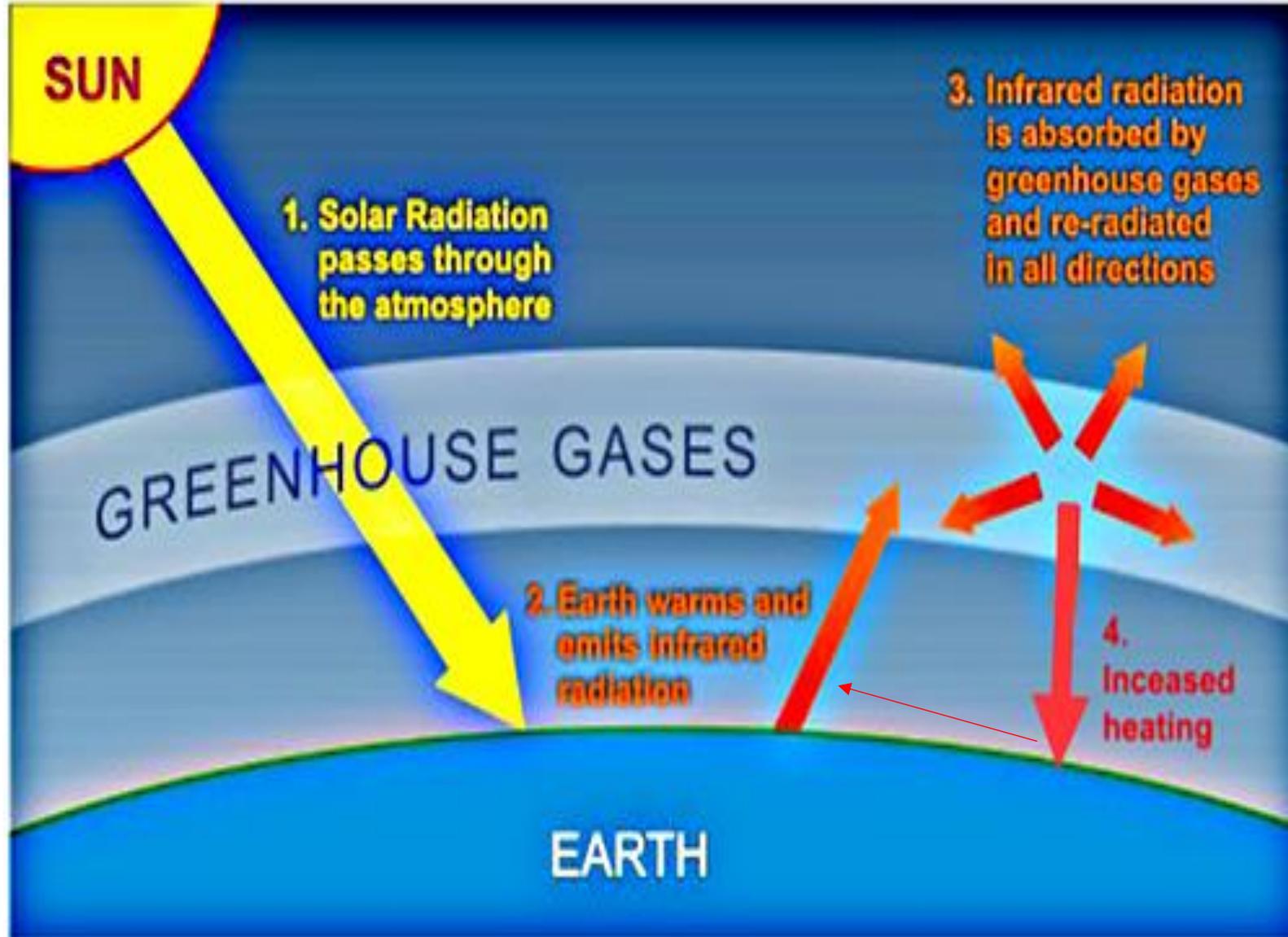
*Since we can not detect such a short time interval, the heat feels instantaneous.*

# The Greenhouse Effect: How Thermal Radiation Warms the Earth

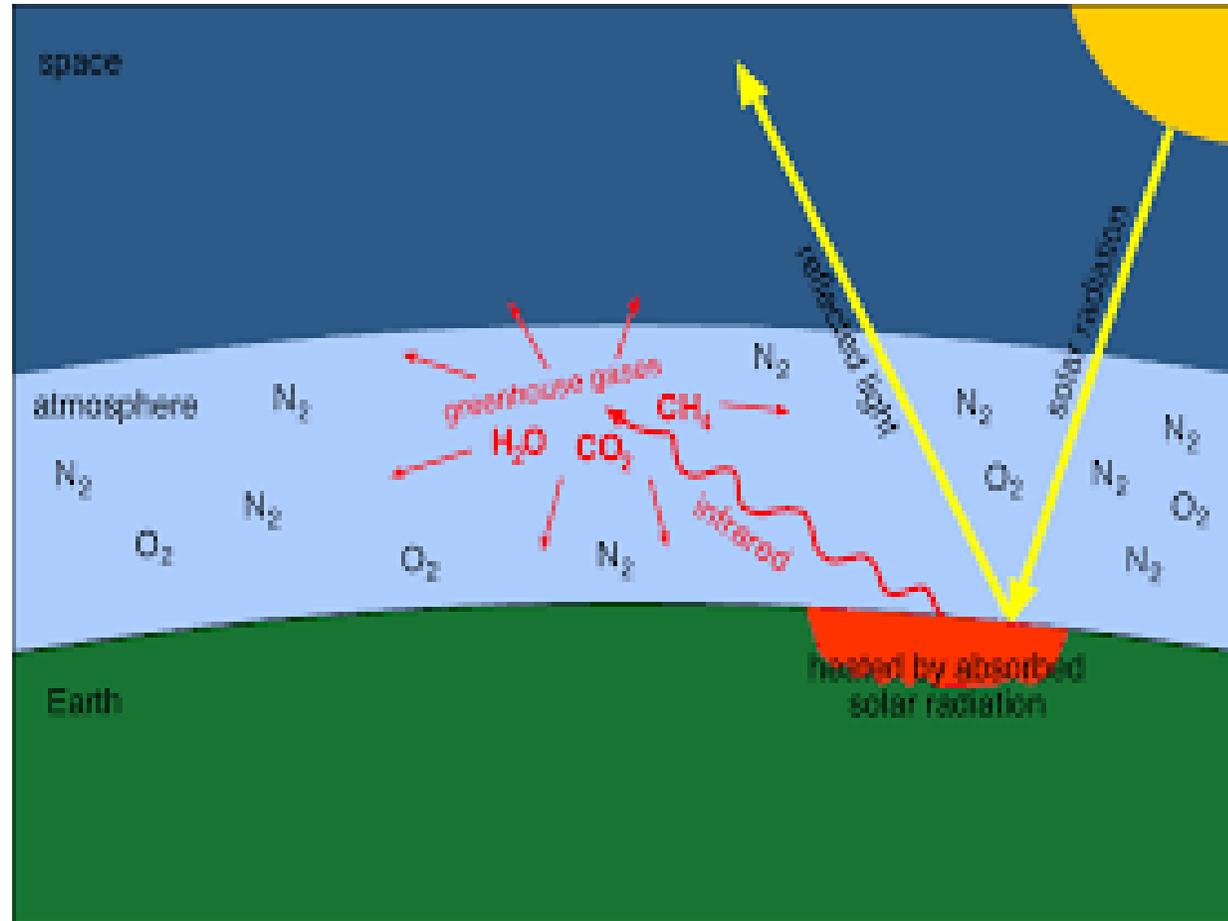


- 1) Solar radiation penetrates greenhouse glass striking the plants
- 2) Molecular vibration in plants generates thermal radiation (infrared rays)
- 3) Radiation absorbed by greenhouse glass
- 4) Some of the radiation absorbed by the glass is sent back into the greenhouse and absorbed by the plants.
- 5) Cycles back to step 2

To warm the earth, our atmosphere has greenhouse gases which act like greenhouse glass.



Greenhouse gases:  
 $\text{CO}_2$  - carbon dioxide  
 $\text{H}_2\text{O}$  - water vapor  
 $\text{CH}_4$  - methane  
 $\text{N}_2\text{O}$  - nitrous oxide

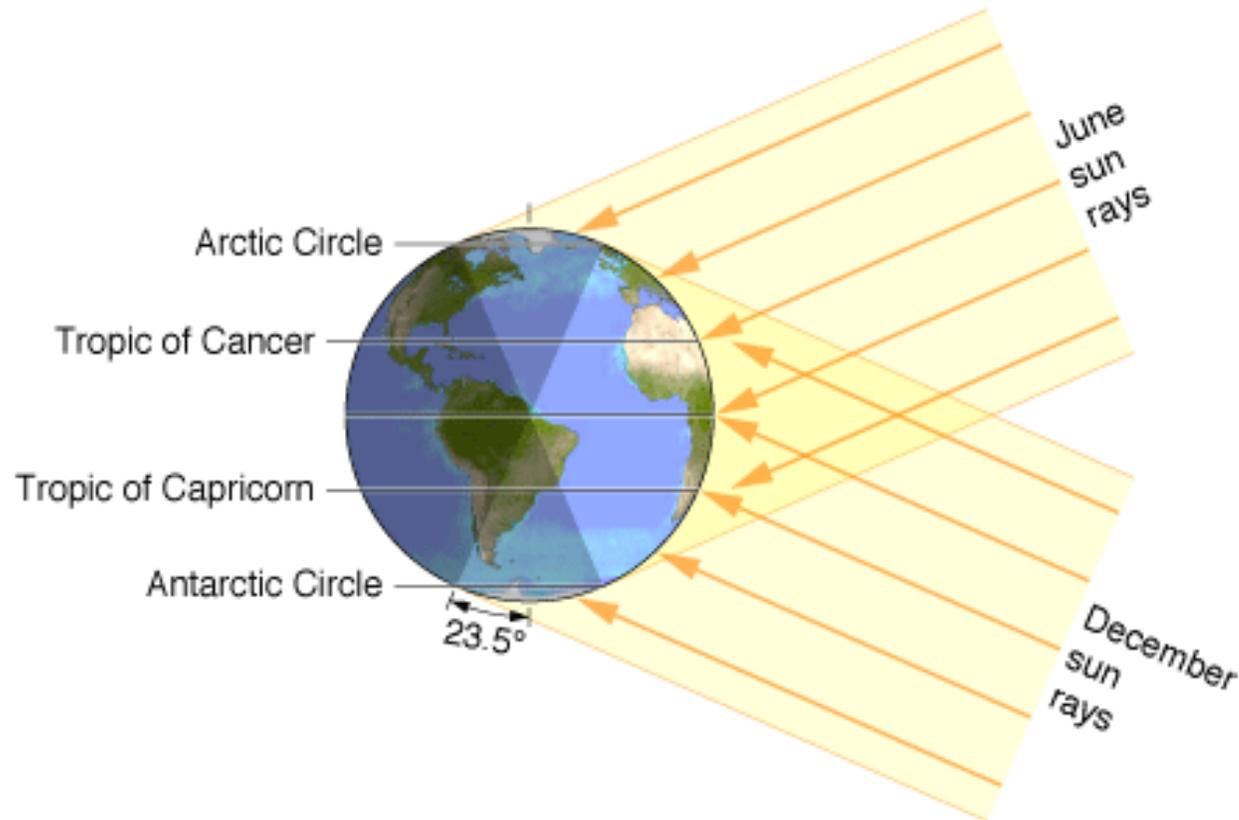


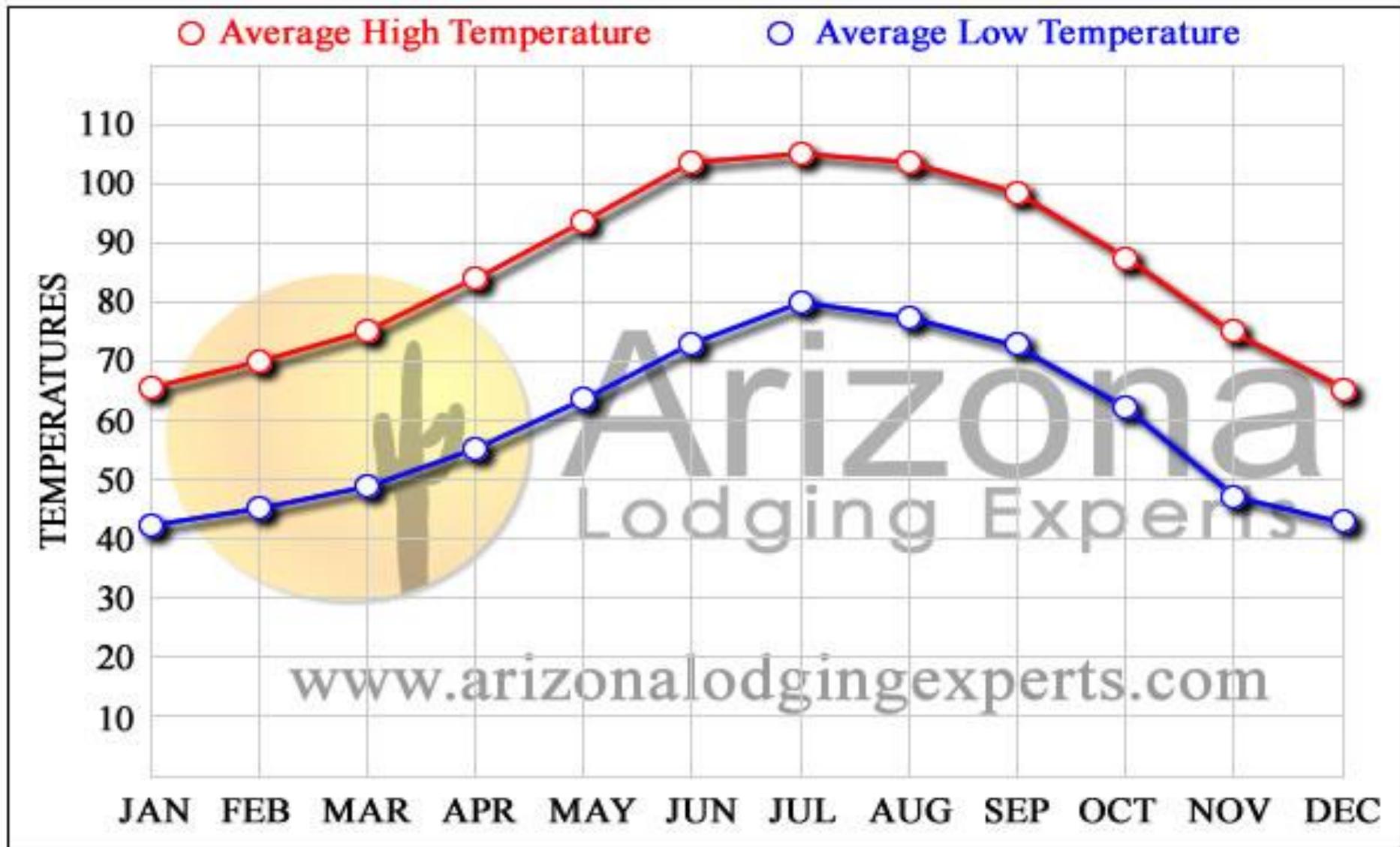
# Daily variations in greenhouse effect basis of daily temperature variations

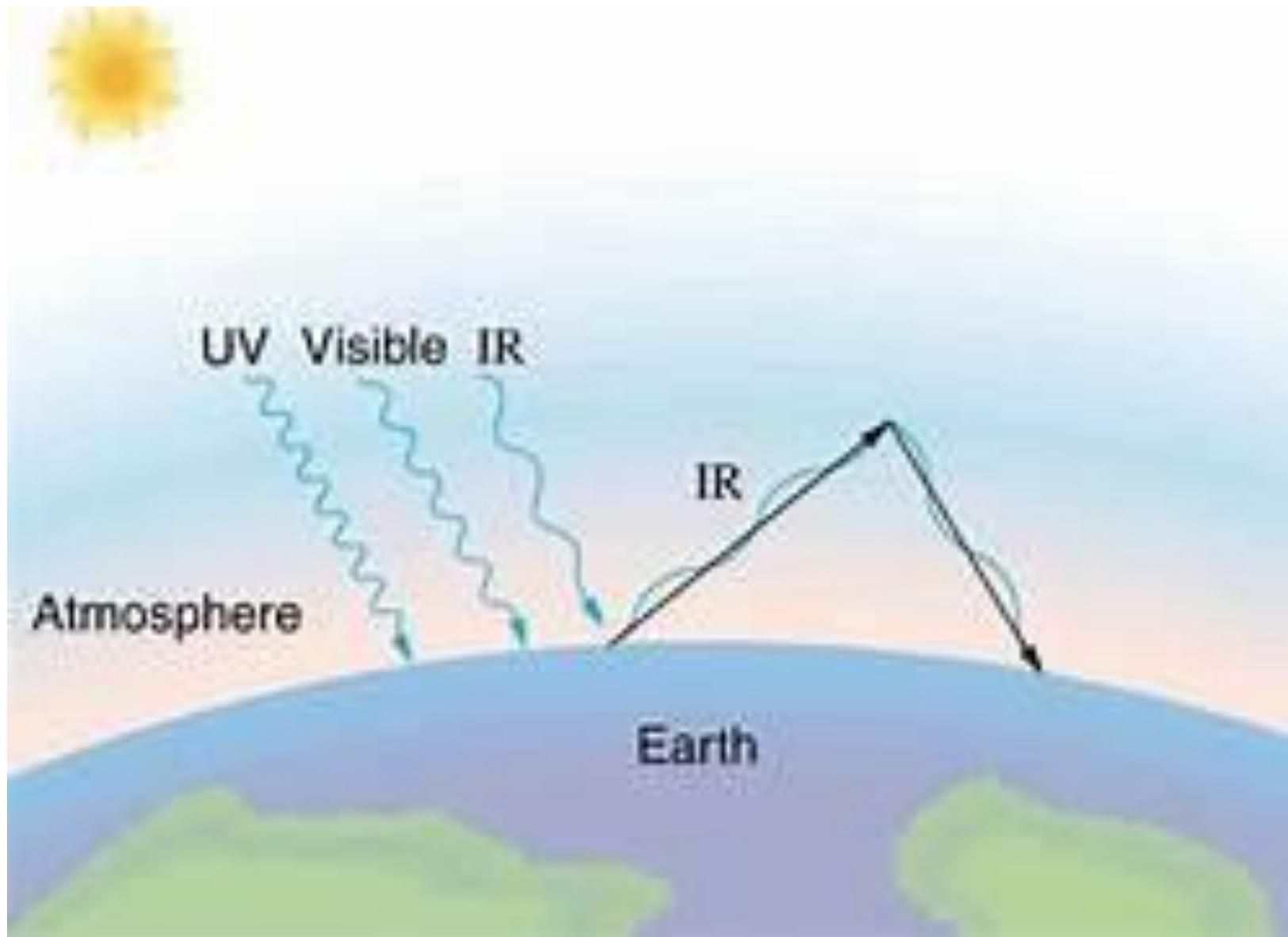
Time of Day	Typical Summer Temp Range
5:00 AM - 7:00 AM	80°F - 90°F (Low)
10:00 AM	95°F - 100°F (Rapid rise)
3:00 PM - 5:00 PM	105°F - 115°F+ (Peak)
10:00 PM	90°F - 100°F (Slow cooling)

Source: National Weather Service for Sky Harbor Phoenix, AZ

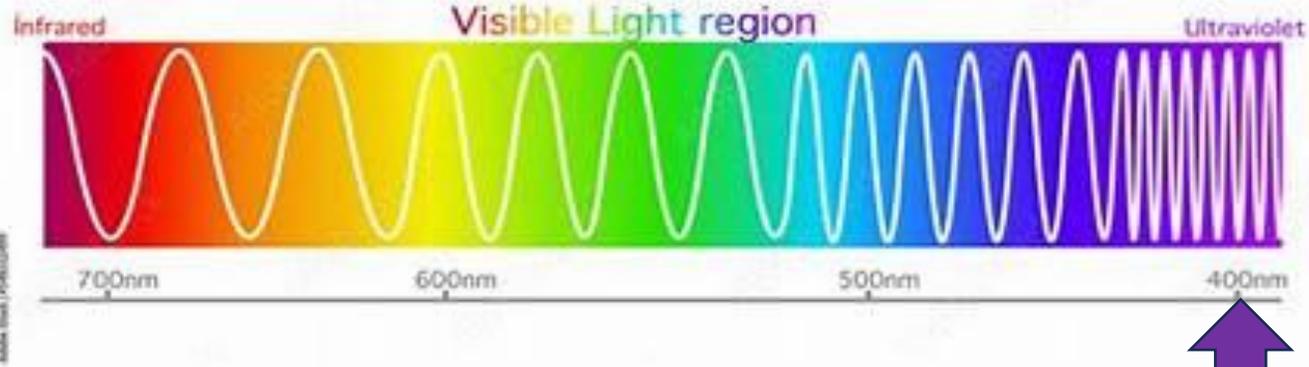
In northern hemisphere the greenhouse effect results in higher temperatures in summer because the sun is more direct.







# Electromagnetic Spectrum



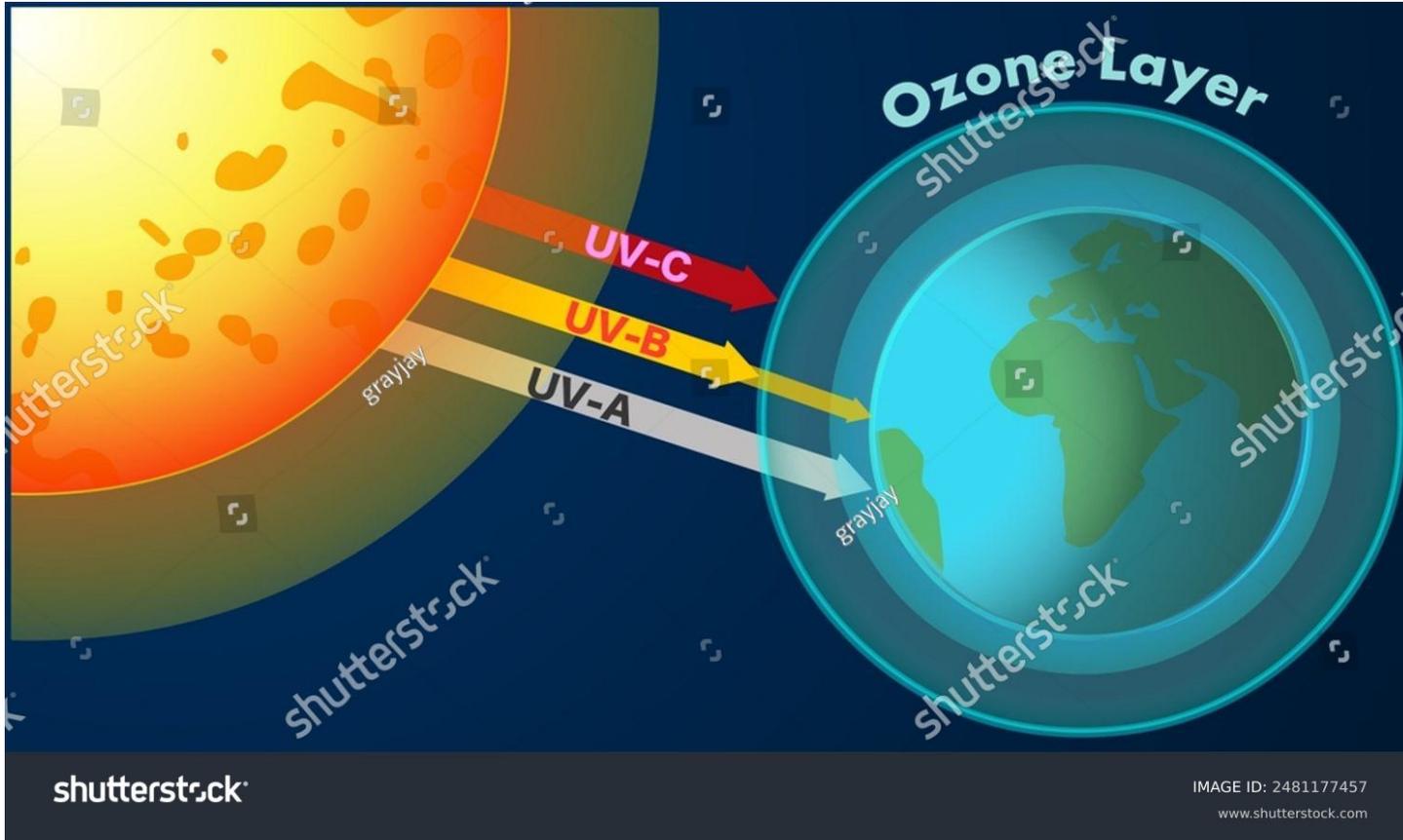
Ultraviolet (UV) rays

Can elicit thermal radiation but are less effective than infrared rays

Main concern about UV rays is their effects on human skin

Which effect depends on the type of UV ray:

Three types of UV rays: UVA, UVB, and UVC

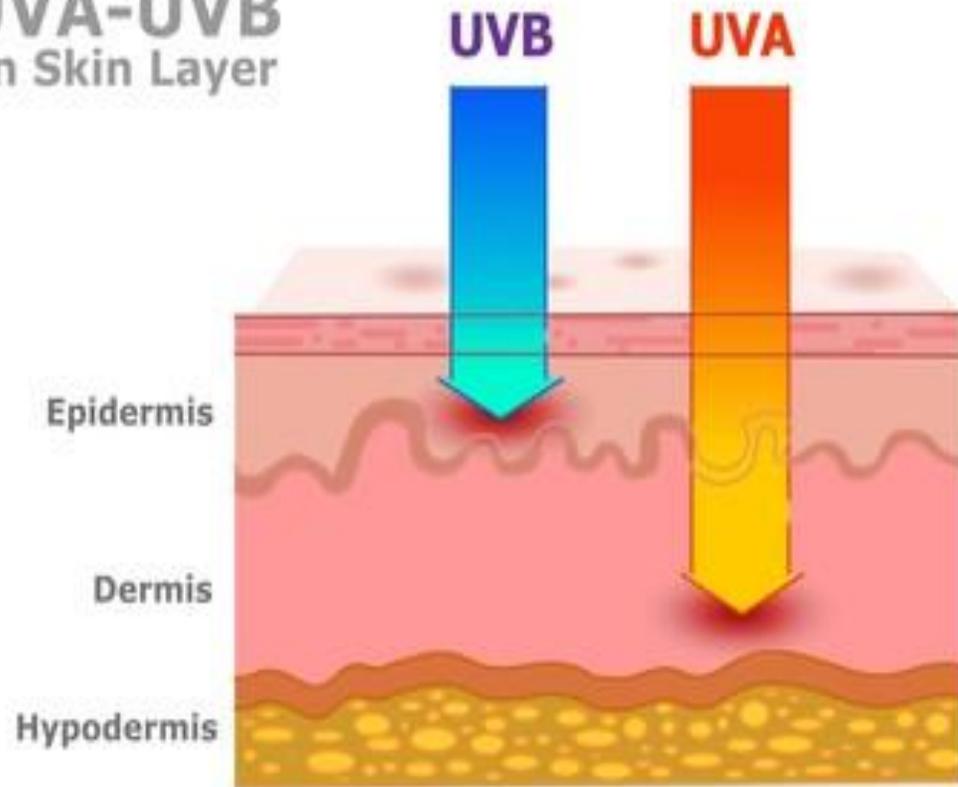


UVA – 95% reach earth

UVB - 15% reach earth

UVC – none reach earth  
100% absorbed by Ozone

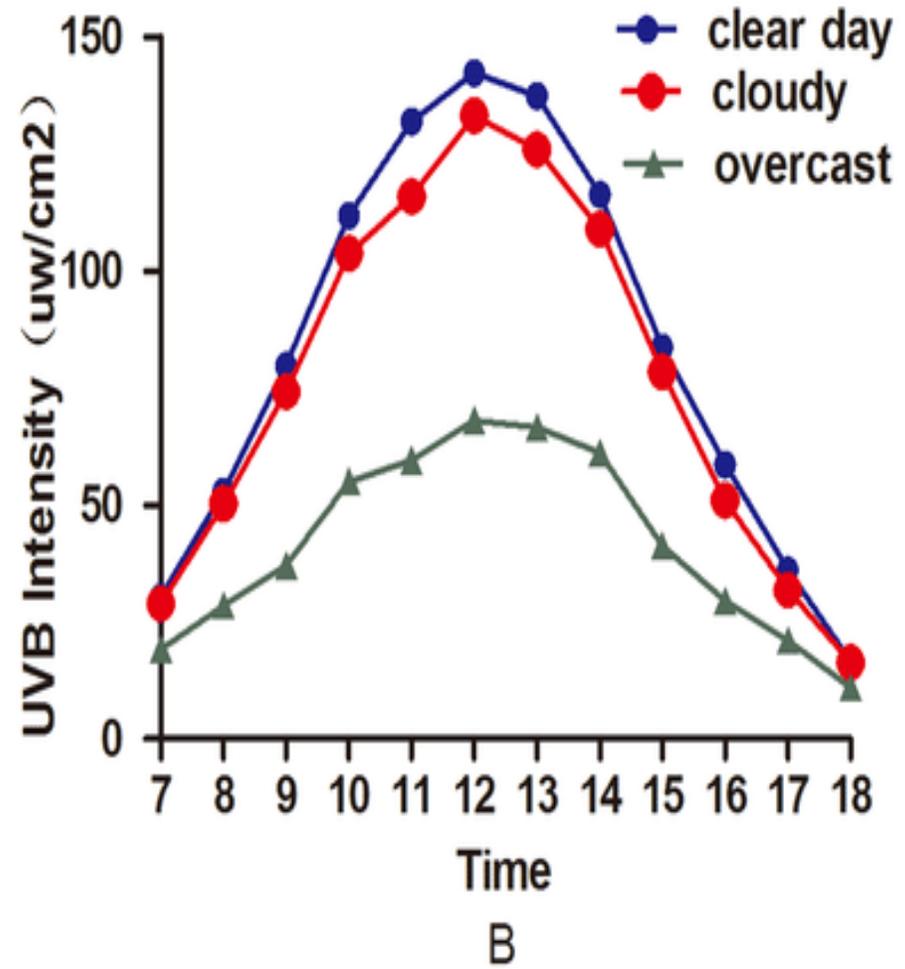
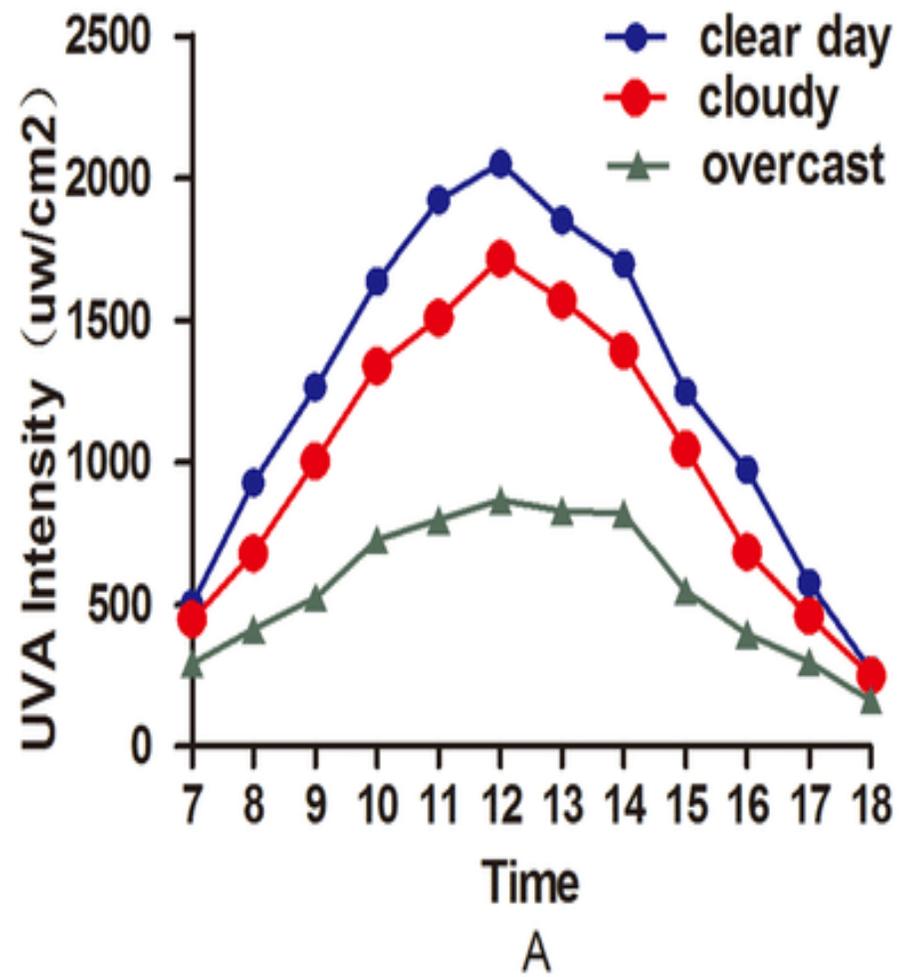
## UVA-UVB on Skin Layer



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UVA rays penetrate deep into dermis of skin  
Cause wrinkling and loss of elasticity with age

UVB rays penetrate epidermis  
Small amount stimulates melanin secretion  
causes tanning  
Large amount can cause sun burn  
and can lead to skin cancer (melanoma)



Web site to look up hourly UV index in your zip code  
(<https://chromedomecaps.com/uv-index-today/>)

## **UV scale**

**0-2 Low**

**3-5 Moderate**

**6-7 High**

**8-10 Very High**

**11 or more: Extreme**

Caution: UV index and temperature don't always match.

On October 31, 2023, 11:30 AM

In Tempe, AZ, elevation 1,180 ft

Air Temp – 76

UV index – 3.8

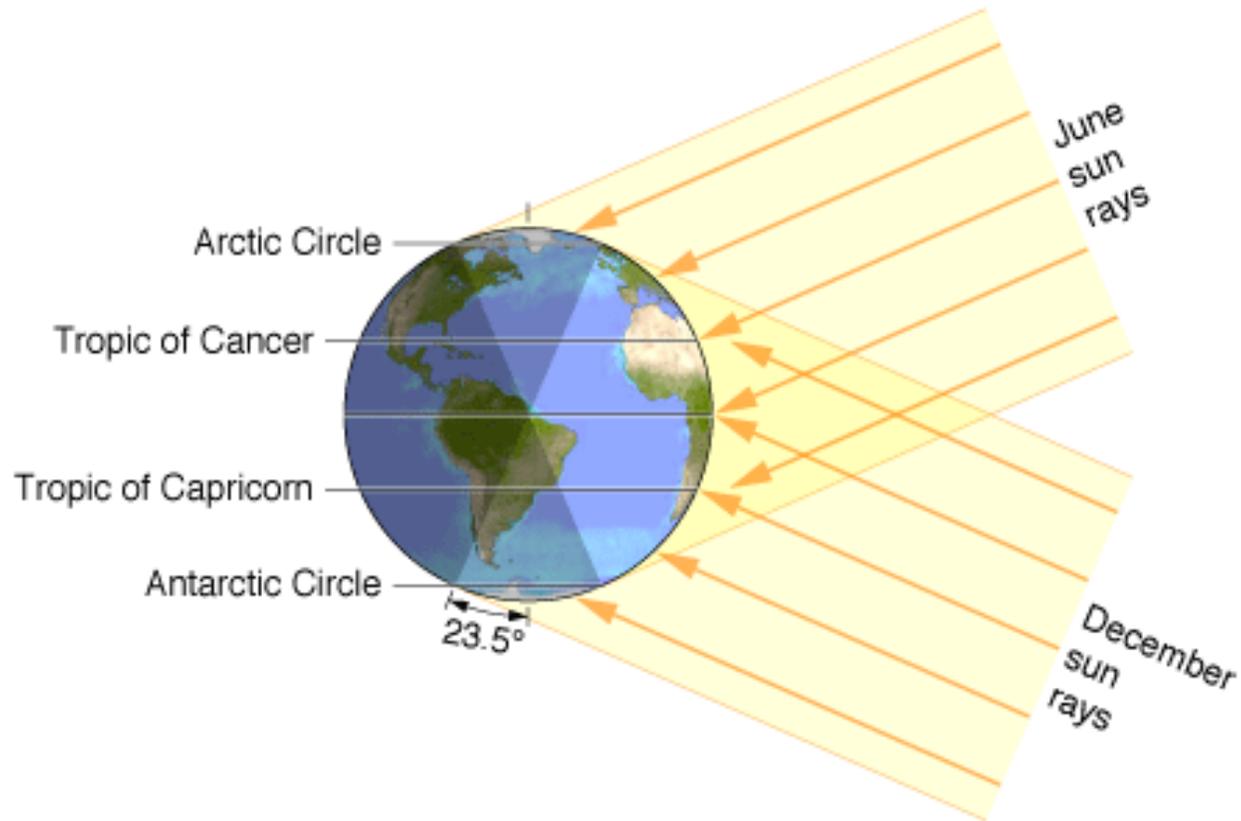
In Tonto Village, AZ, elevation 5,700 ft

Air Temp – 62

UV index - 4.0

(On average air temp decreases 3.5 F per 1,000 ft increase in elevation)

Like temperature, in the northern hemisphere UV rays are higher in summer because the sun is more direct.





# UV MONTHS INDEX

# Sun Screen: Developed to block UVB rays



The number on the tube (55) is the *Sun Protection Factor* (SPF)  
 $1/\text{SPF} = \text{fraction of UVB rays that penetrate the skin.}$   
 $1/55 = 0.018$  ( over 98% of UVB rays are blocked)