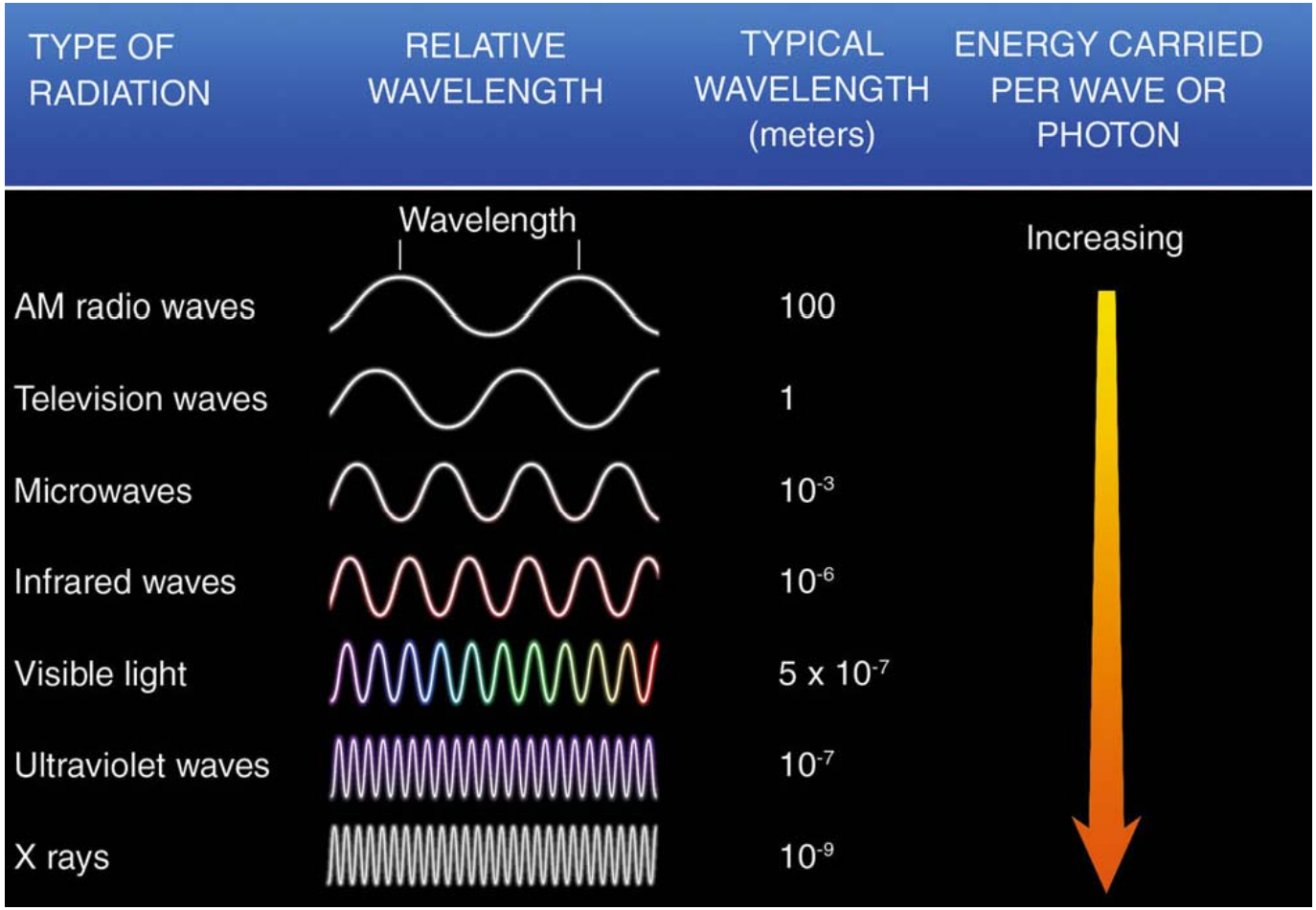
Energy: Warming the earth and Atmosphere

Chapter 2

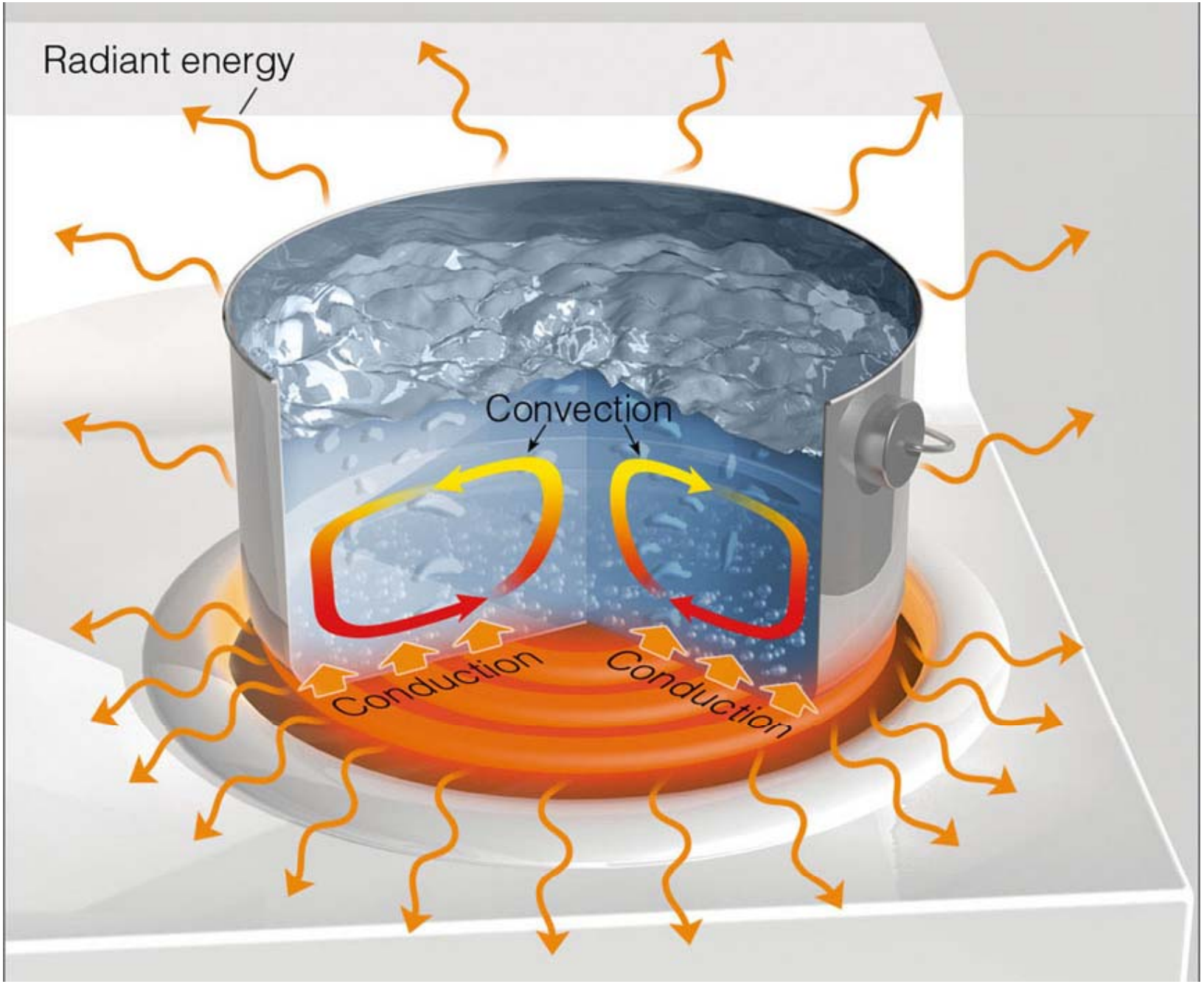
Radiation

- Energy from the sun travels through the space and the atmosphere in the form of a wave (electromagnetic waves) and is called radiation



Radiation and Temperature

- All objects with a temperature greater than 0K radiate energy
- As temperature of an object increases, the more total radiation that is emitted by an object
- $E = \sigma T^4$ where σ is the Stefan-Boltzmann constant and E is the energy emitted per square meter per second
- Sun temperature is 6000K, earth 288K, so per m^2, sun emits $(6000/288)^4$= 188,000 times the earth


Radiant energy
Convection
Conduction
Conduction

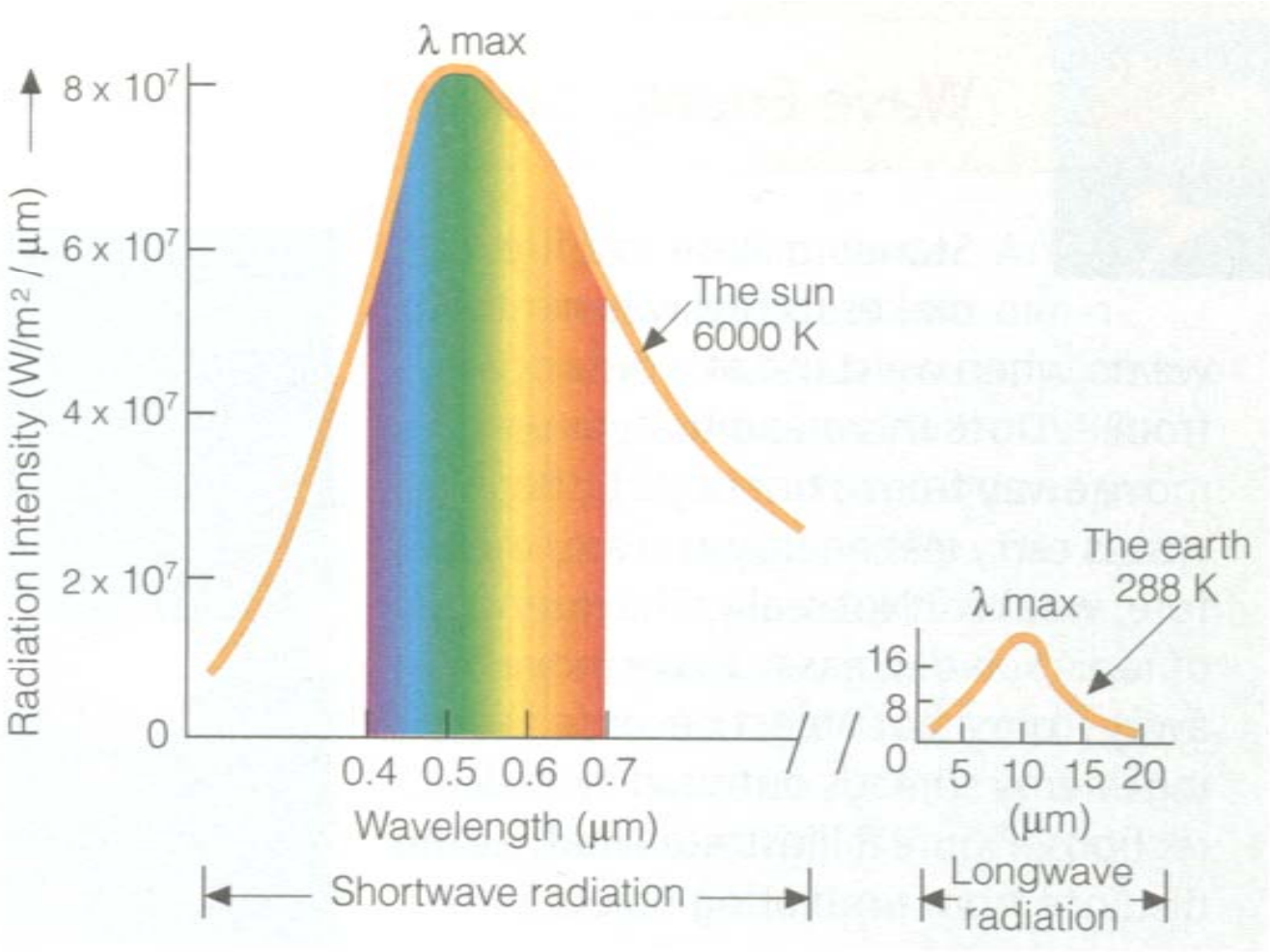
Radiation

- Radiation of the Sun and Earth
  - Sun 6000K emits radiation, electromagnetic spectrum
  - Shortwave radiation (high energy) from the Sun
  - Longwave radiation (low energy) from the Earth

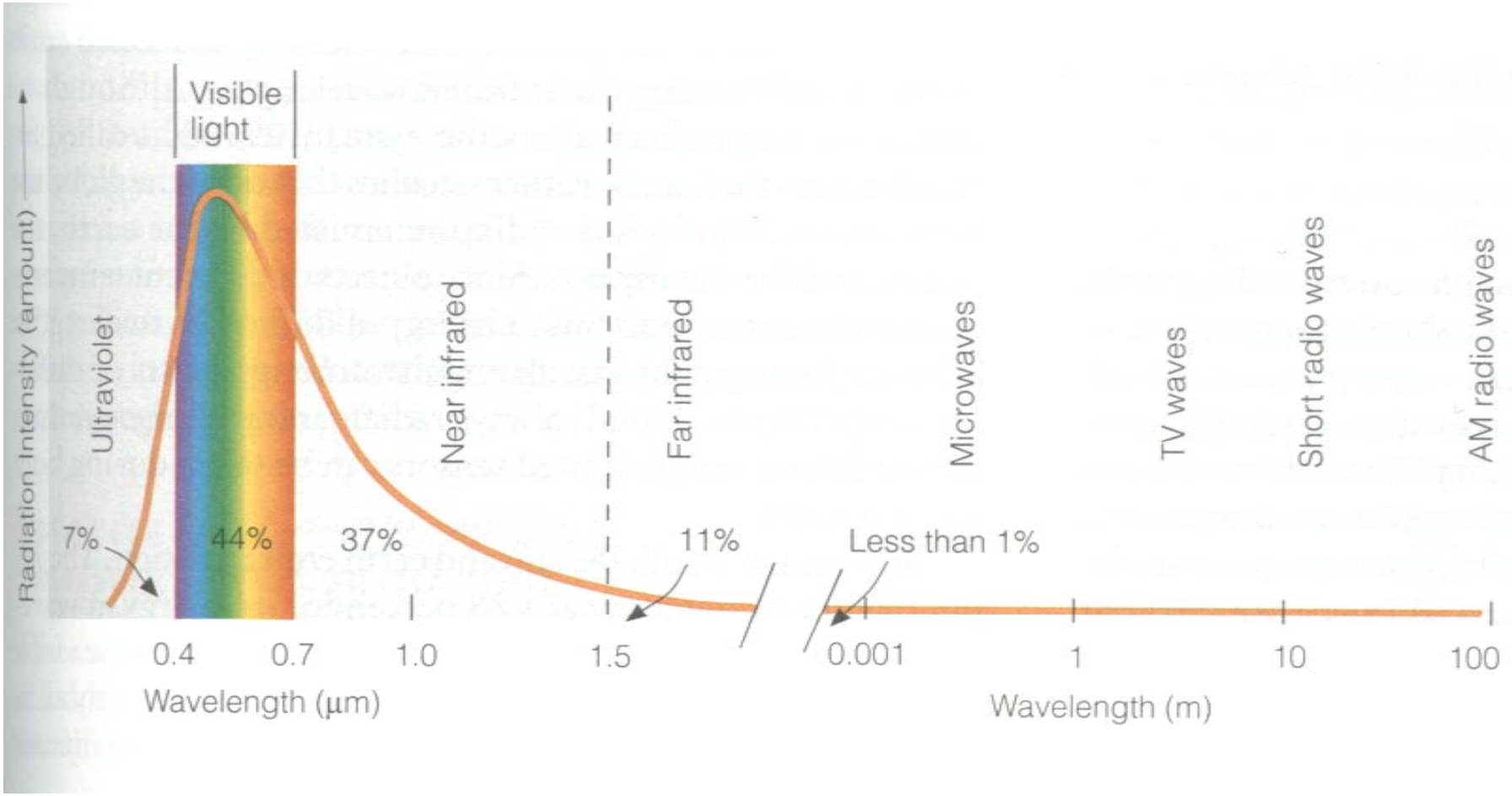
Radiation of sun and earth (solar and terrestrial radiation)

- Wien's law relates temperature of an object to the wavelength of maximum radiation λ_{max}= constant/T; constant is 2897 μm K, λ_{max} is in μm and T in K
- For the Sun, λ_{max}=2897/6000 μm ≈ 0.5 μm
- For the earth, on average λ_{max}=2897/288 μm ≈ 10 μm (infrared)
- Visible light 0.4 - 0.7 μm
- <0.4 μm, ultraviolet, >0.7 infrared

Comparison between the sun's & earth's radiant energy



The sun's spectrum



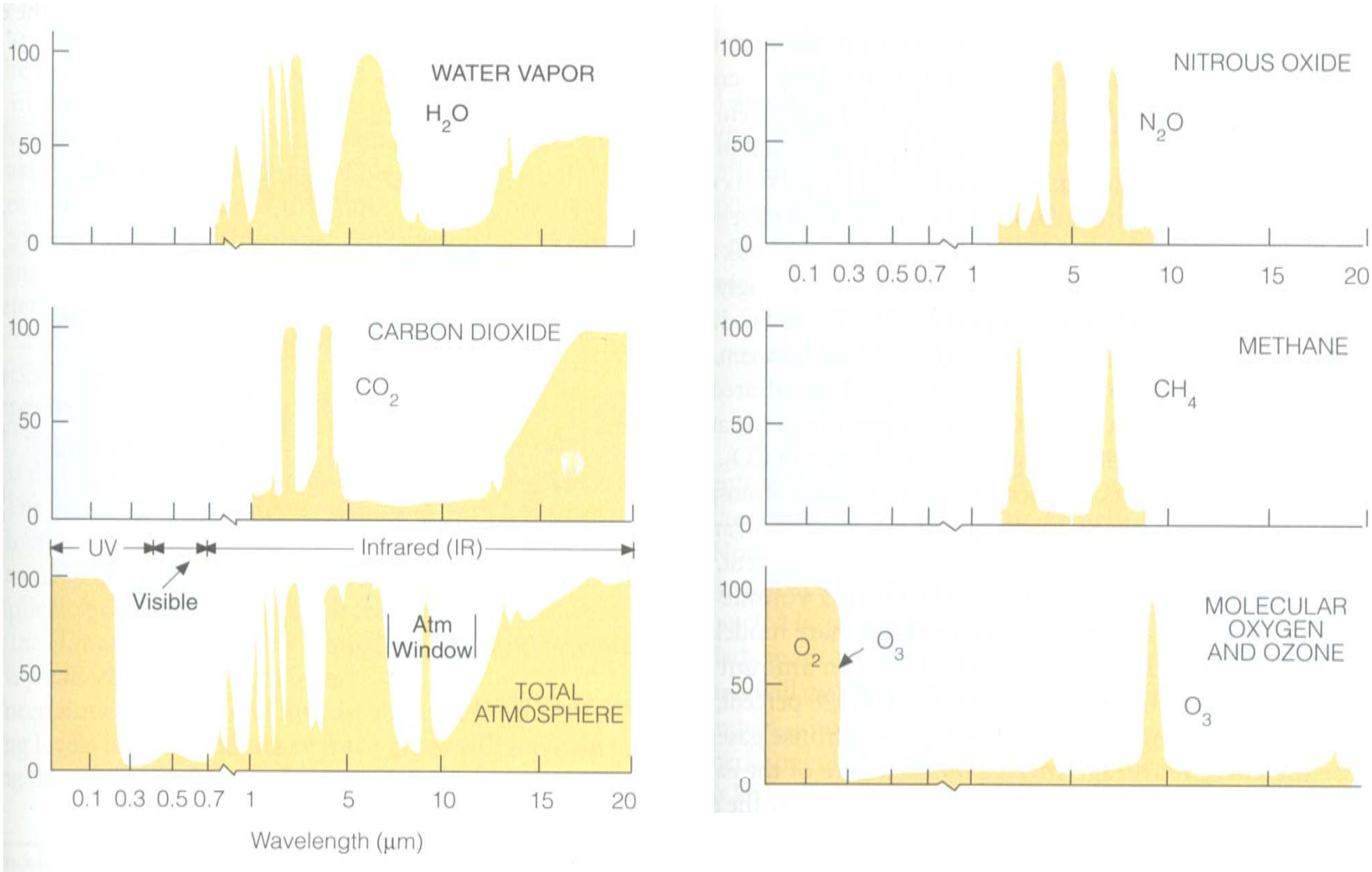
Absorption, emission, and equilibrium

- Objects absorb and emit radiation
- More energy absorbed than radiated → warming
- More energy radiated than absorbed→ cooling
- Daytime, ground warms, nighttime cools
- Dark objects good at absorbing visible light- that's why they're dark → light energy into heat
- "blackbodies" are "perfect absorbers and emitters"- absorb all radiation and emit maximum amount possible for it's temperature
- Earth and Sun behave nearly like blackbodies

Selective Absorbers

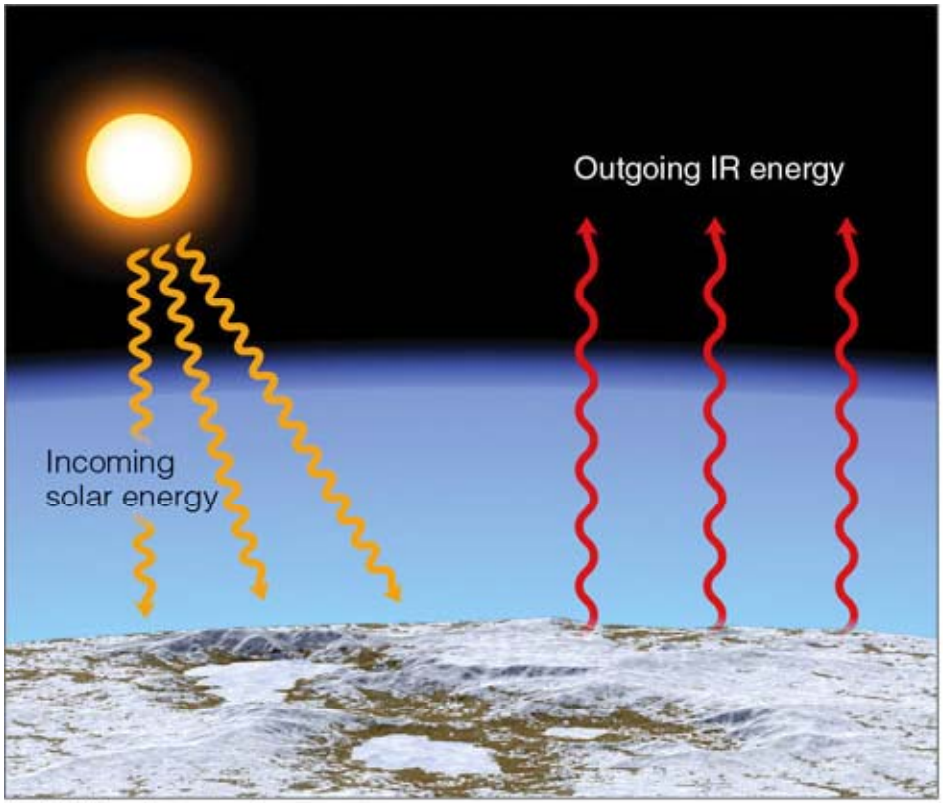
- Radiation from sun warms the earth and earth emits radiation- if no other sources of heat transfer, earth radiation equilibrium temperature would be 255 K
- But, earth's atmosphere doesn't behave like blackbody- selectively absorbs some wavelengths and transparent to others- net warming so that average temperature is 288 K
- Kirchhoff's law- good absorbers are good emitters at a certain wavelength and poor absorbers are poor emitters at the same wavelength (for gases)
- Water vapor and CO_2 most important absorbers of IR

Absorption of atmospheric gases, by wavelength

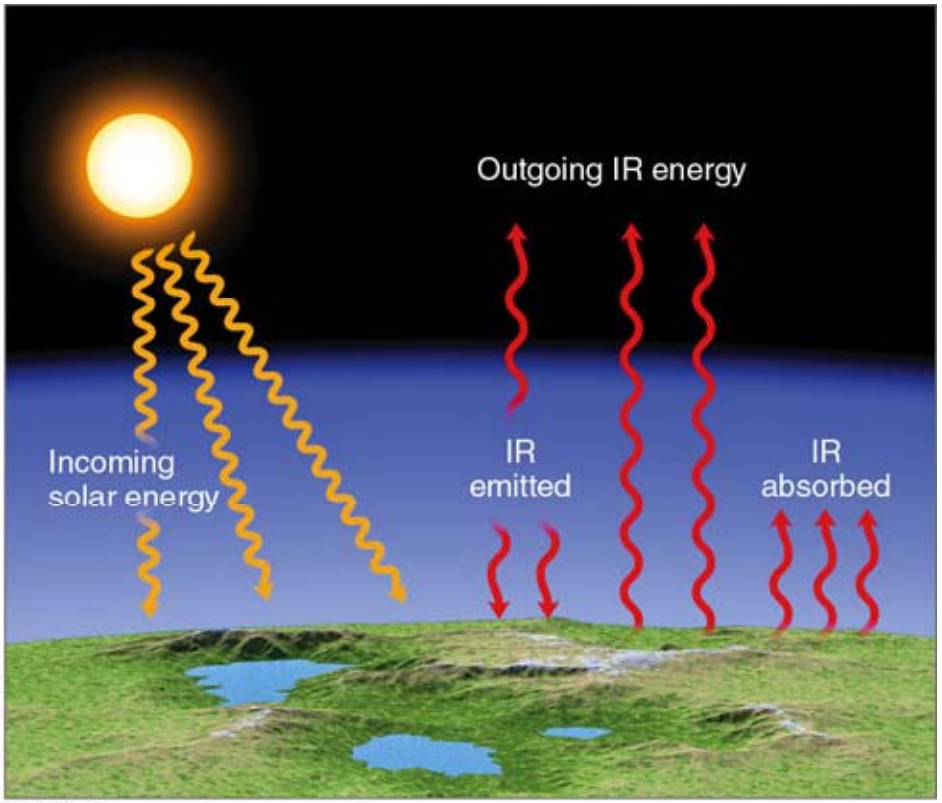


Greenhouse effect

- The atmosphere selectively absorbs infrared radiation from the Earth's surface but acts as a window and transmits shortwave radiation



(a) Without greenhouse gases



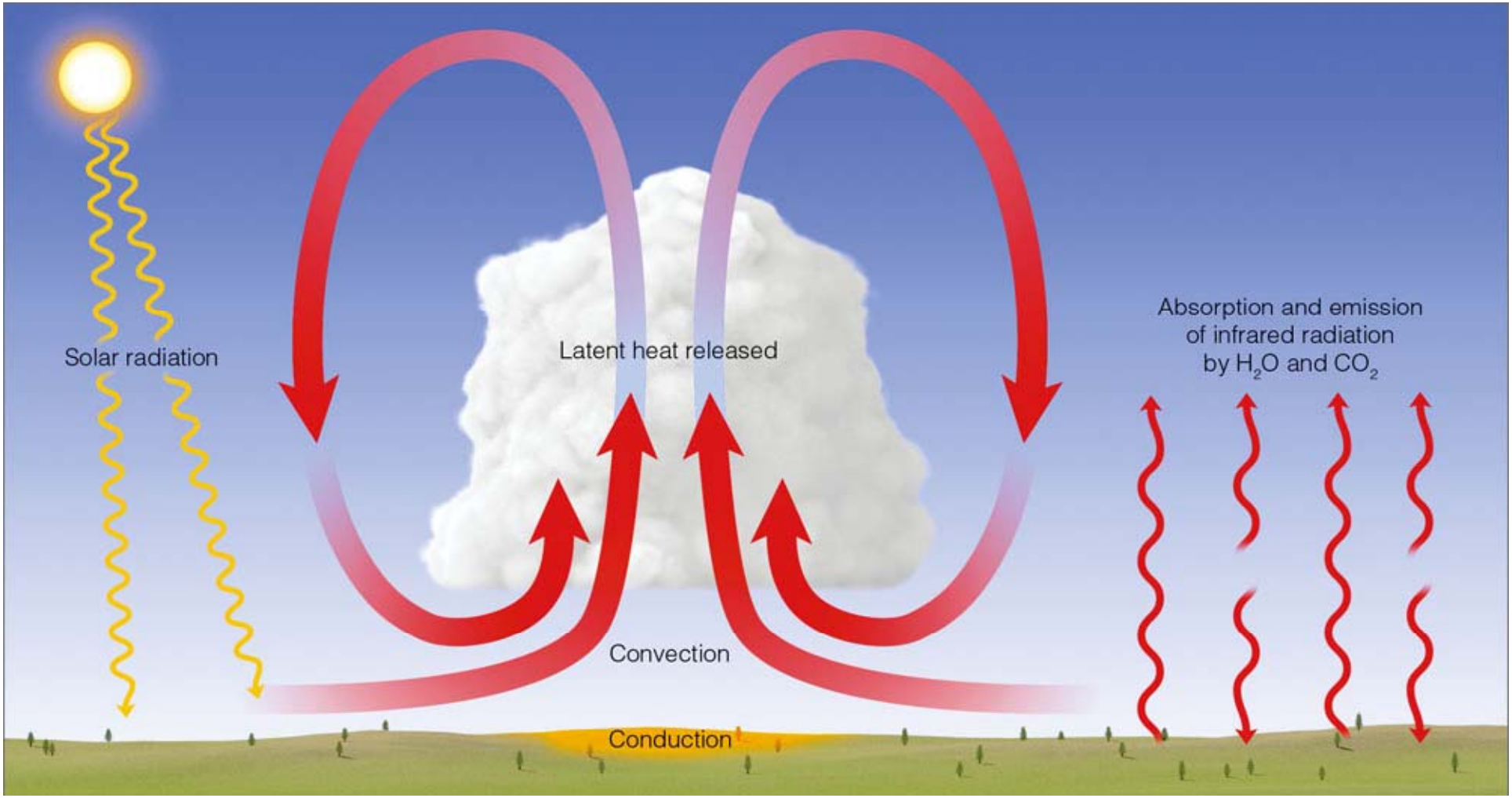
(b) With greenhouse gases

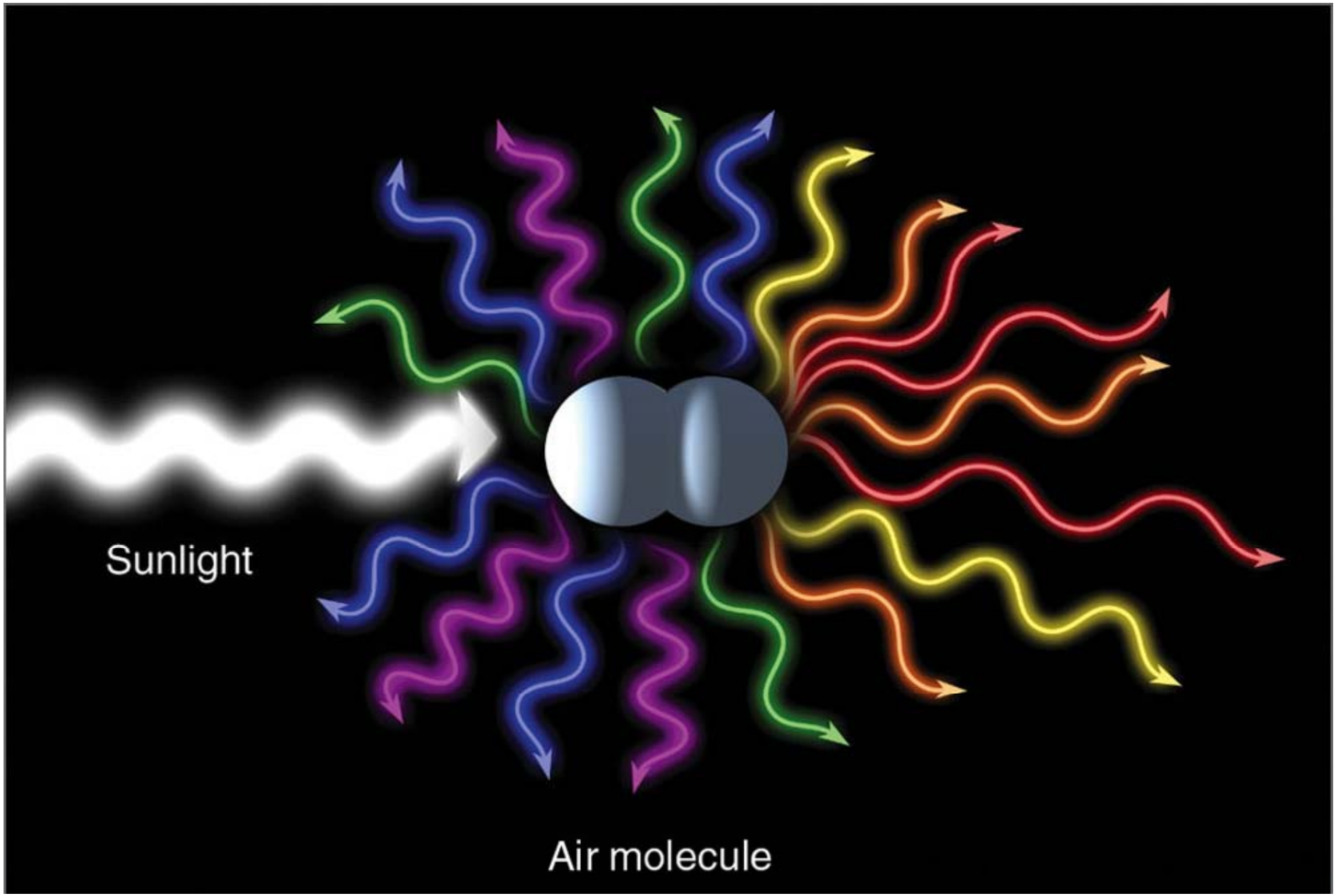
Greenhouse Enhancement

- Global warming is occurring due to an increase in greenhouse gases
  - Carbon dioxide (CO_2)
  - Methane (CH_4)
  - Nitrous Oxide (N_2O)
  - Chlorofluorocarbons (CFCs)
- Positive feedbacks continue the warming trend
- Negative feedbacks decrease warming

Incoming Solar Radiation

- Conduction, convection, and infrared radiation warm the atmosphere from below, not sunlight or insolation from above.




Sunlight
Air molecule

Incoming Solar Radiation

- Observation: Blue skies, red skies, and white clouds
  - Selective scattering of incoming solar radiation causes reflectance in portion of the electromagnetic spectrum that correspond with the colors our eyes detect
  - Sky is blue because air molecules preferentially scatter short wavelength blue light

Radiation balance

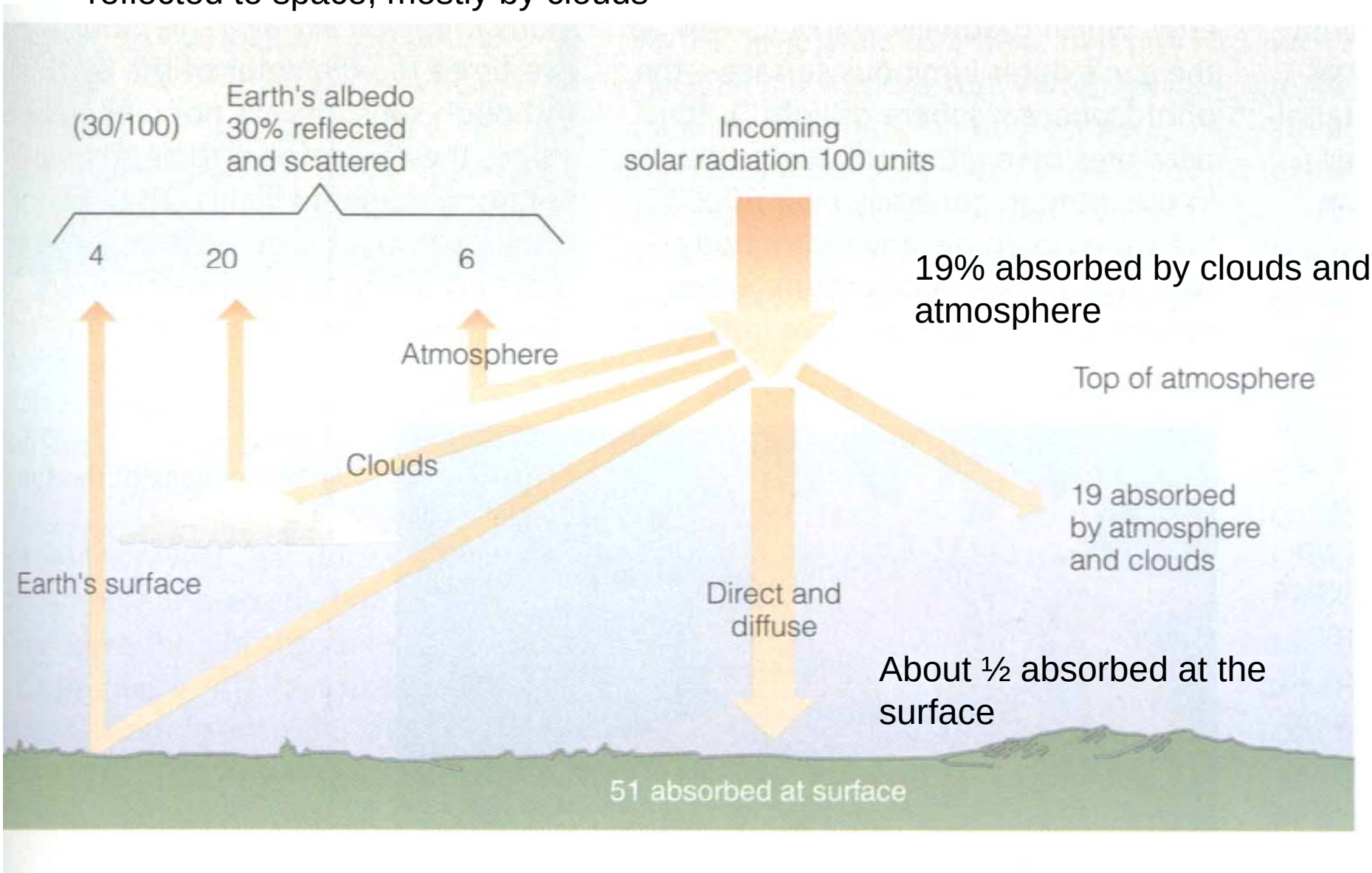
- Clouds emit IR as well as absorb- cloud tops radiate to space, cloud bases emit back toward ground
- Clouds also reflect sunlight back to space- cloud cover keeps temperatures near the ground more even throughout the day- warmer nights, cooler days
- Albedo= ratio of radiation reflected from a surface to amount falling on surface 1-albedo= absorption

Table 2.3 Typical Albedo of Various Surfaces

SURFACE	ALBEDO (PERCENT)
Fresh snow	75 to 95
Clouds (thick)	60 to 90
Clouds (thin)	30 to 50
Venus	78
Ice	30 to 40
Sand	15 to 45
Earth and atmosphere	30
Mars	17
Grassy field	10 to 30
Dry, plowed field	5 to 20
Water	10*
Forest	3 to 10
Moon	7

*Daily average.

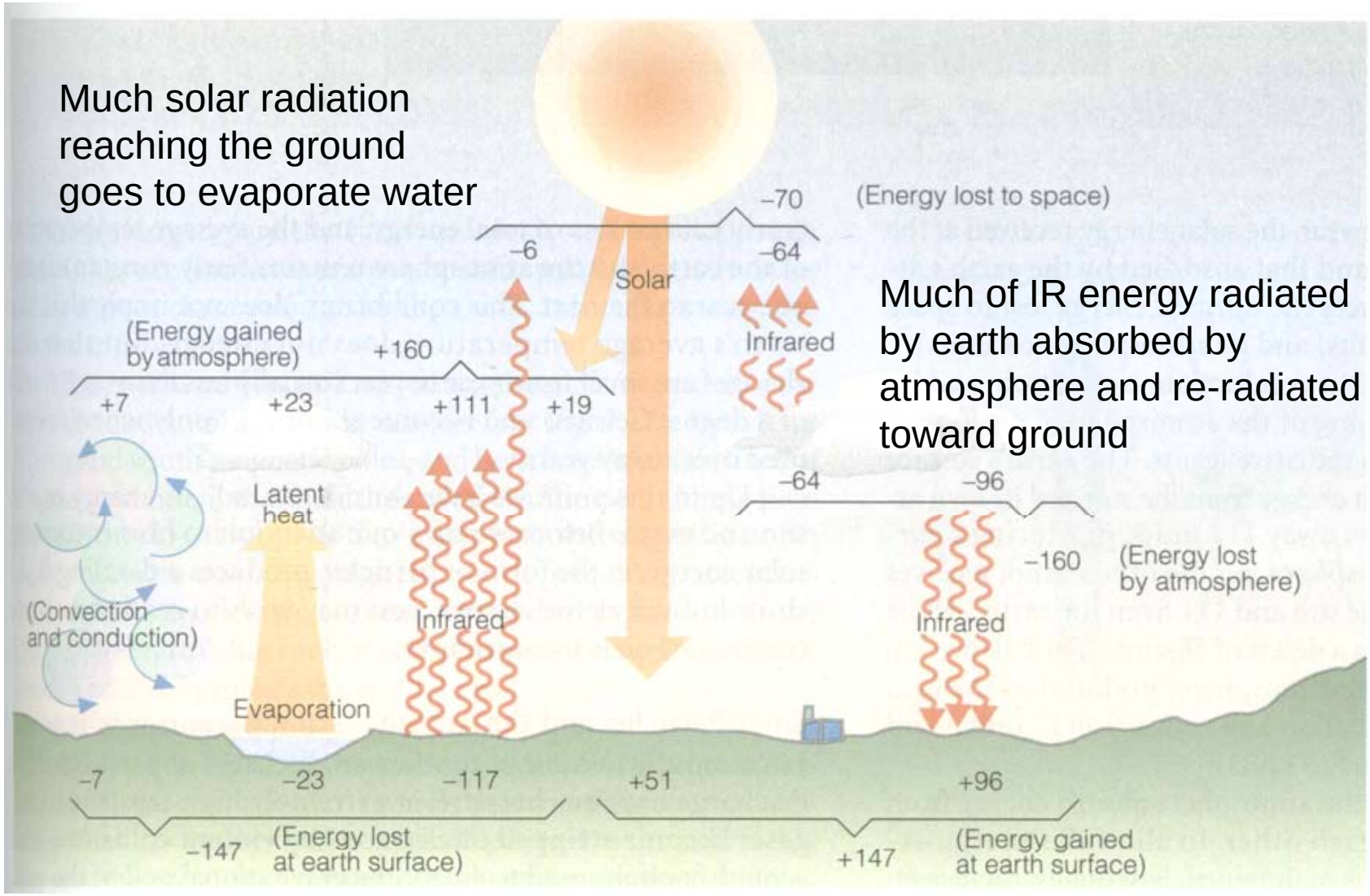
30% of incoming solar radiation
reflected to space, mostly by clouds



19% absorbed by clouds and atmosphere

About ½ absorbed at the surface

Much solar radiation reaching the ground goes to evaporate water



Much of IR energy radiated by earth absorbed by atmosphere and re-radiated toward ground

Annual Energy Balance

- 50% of insolation reaches the Earth's surface
- Earth absorbs 147 units, radiates 117 units, 30 unit surplus, warm
- Atmosphere absorbs 130 units, radiates 160 units, 30 unit deficit, cool
- Tropics have a surplus of energy