Goals for today:

- ***Begin Ch 2 "Solar Radiation & the Seasons"***

14 Sept., 2011

The sorts of concepts/questions covered in Chapter 2:

- What energy source "drives" the atmosphere (& climate system)?
- How is energy transported in the atmosphere?
- How does "terrestrial" radiation differ from solar radiation?
- What (in the technical sense) is a "gray body"?

Energy Transfer Mechanisms in the natural environment

- **Radiation**. Emission-flight-absorption of “photons” (energy packets). Ultimately, radiative energy transfer “drives” circulation of the atmosphere.

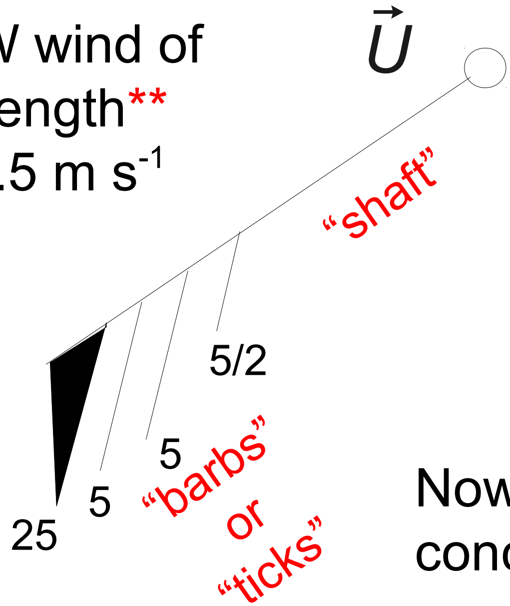
- **Conduction**. Local exchange of energy by inter-molecular collisions (in gas or liquid) or via inter-atomic forces (in solid). Not very important in atmosphere except at boundaries, where bulk motion of the air is impeded – e.g. a thin layer near Earth’s surface.

- **Convection**. Transport (of *anything* – not just heat) due to “bulk motion” ie. “mass movement” of the air (a coordinated motion of vast numbers of molecules). Rate of transport is proportional to air velocity... and transport flux vector is parallel to velocity vector. Convective fluxes of “sensible” and “latent” heat are enormously important in the atmosphere. [A nuance: in general, convective transport refers to transport by bulk fluid or gas motion in *any* direction; however in meteorology/oceanography the term is often used in the narrower sense of buoyancy-driven vertical transport. Which interpretation is intended can usually be deduced from the *context* in which the word is used.]

In Ch. 2 we focus on radiative energy…

Map symbol for wind; the wind vector; the convective flux carried by the air

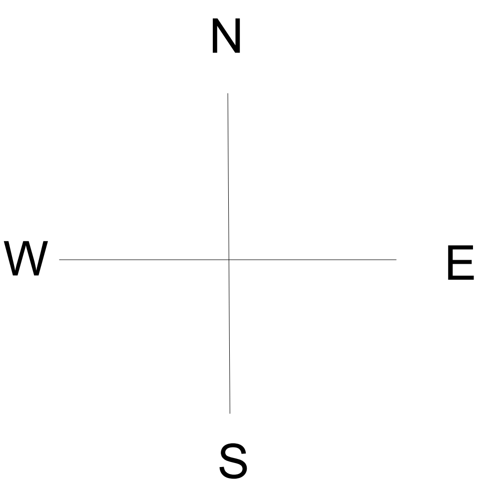
This is a SW wind of strength** 37.5 m s^{-1}



The map symbol pictorially represents the "wind vector," say $\vec{U}$, giving the "magnitude" of the vector (the wind "speed") and the direction of the vector.

Now suppose the air were loaded with dust, present with concentration C kg m^{-3}. The "flux" of dust is a vector parallel to the wind vector:

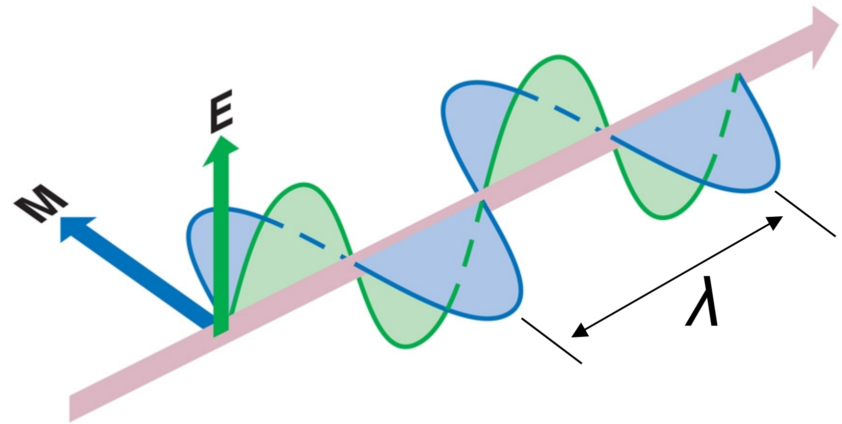
$$\vec{F} = \vec{U} \; C \quad [\text{kg} \;\; \text{m}^{-2} \;\; \text{s}^{-1}]$$



**Textbook Fig. 1-14 uses mph and kph. We'll use m s^{-1} which makes the scale easier to remember. (Scale will be given on any quiz/exam question)

Electromagnetic radiation

… generated by the acceleration of charges in matter at any temperature above absolute zero (thermal motion guarantees such accelerations are occurring continuously)



(a)

wavelength λ [μm]

Black body

Object or medium that perfectly absorbs all radiation striking it (need not be visually black) and emits radiation at the maximum possible rate for a given temperature

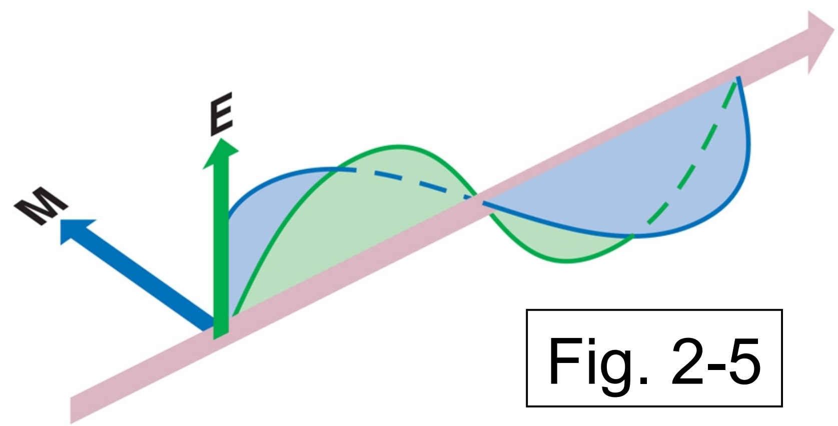
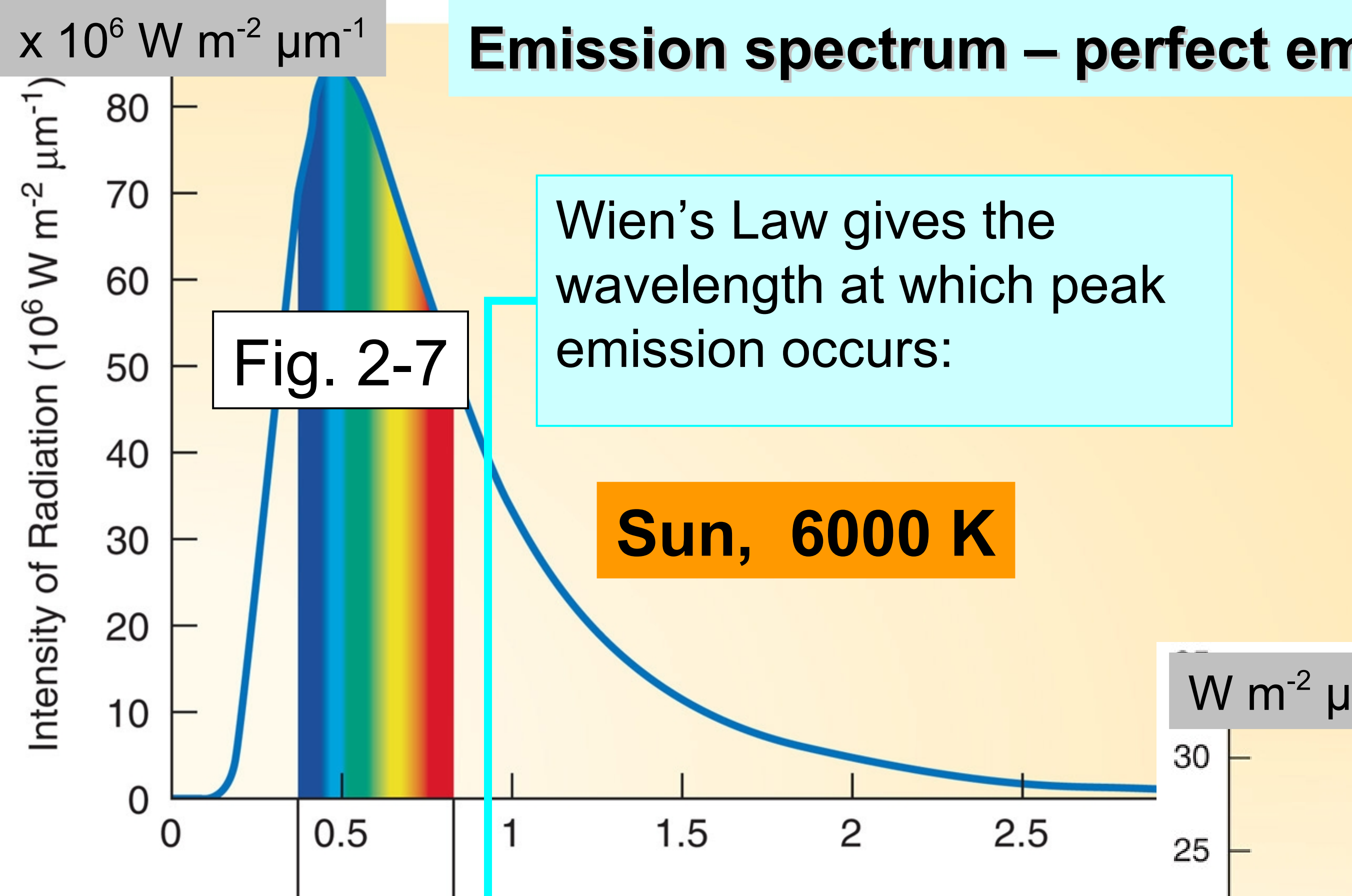


Fig. 2-5

(b)

Emission spectrum – perfect emitter**

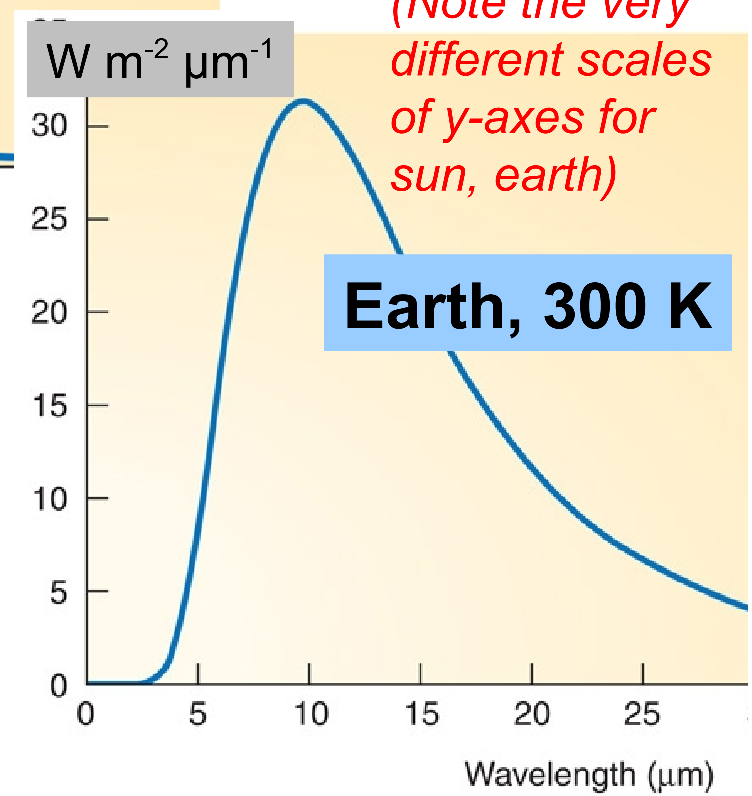


Wien's Law gives the wavelength at which peak emission occurs:

$$\lambda_{\max}[\mu m] = \frac{2900}{T[K]}$$

Wien (Germany, 1864-1928; experimentalist)

(Note the very different scales of y-axes for sun, earth)



****The "perfect emitter" (or black body) is an idealization, but near-perfect radiation emitters do exist. A perfect emitter is also a perfect absorber**

Black body emission spectrum

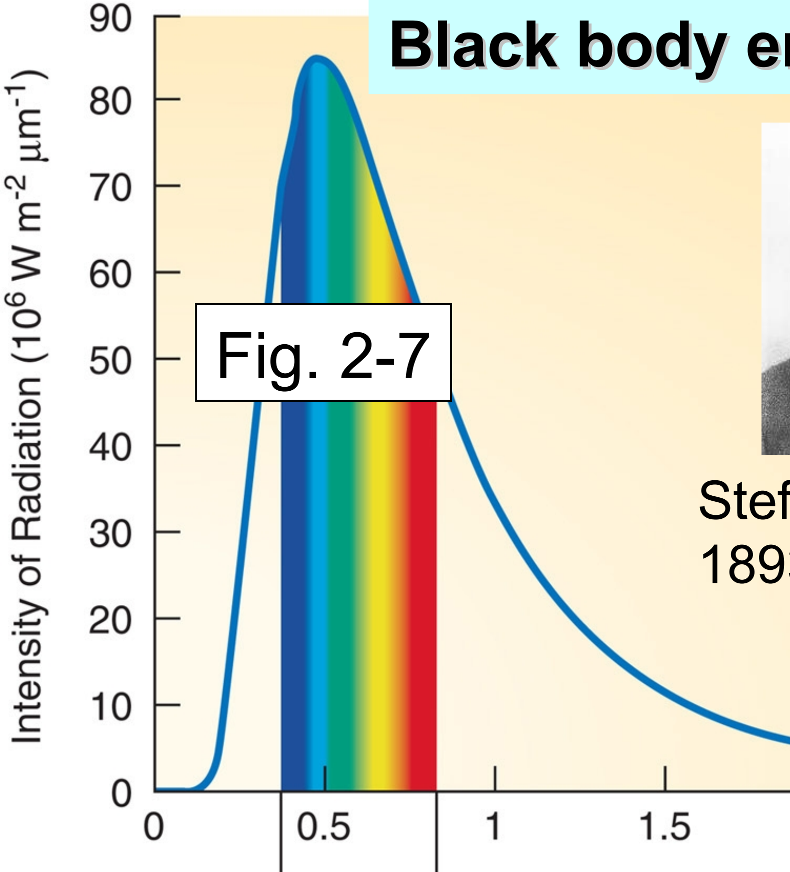
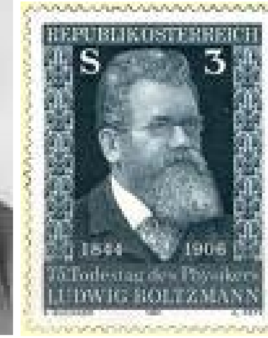
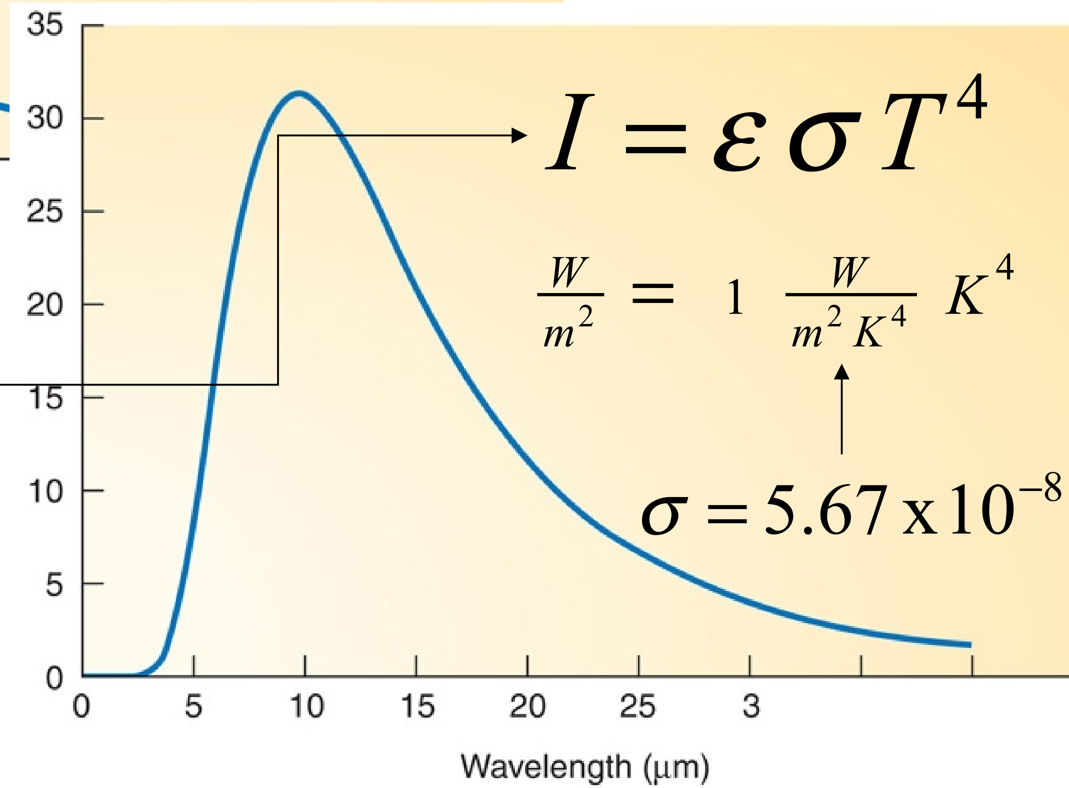


Fig. 2-7

Stefan (Austria, 1835-1893; experimentalist)



Boltzmann (Austria, 1844-1906; theoretician)



Stefan-Boltzmann Law gives the area I under the curve, the total energy emitted per second per square metre of emitter surface:

$$I = \varepsilon \sigma T^4$$

$$\frac{W}{m^2} = 1 \; \frac{W}{m^2 K^4} \; K^4$$

$$\sigma = 5.67 \times 10^{-8}$$

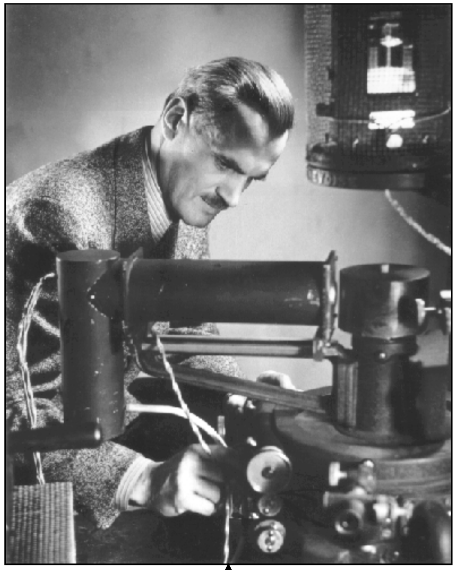
Emissivity ε equals 1 for a "black body"… for most terrestrial surfaces $\varepsilon > 0.9$

Interaction of radiation and matter

• individual atoms and molecules of a gas are "selective" emitters and absorbers, whereas solids and liquids emit and absorb over a wide and continuous range of wavelengths (see Sec. 2-1, p40)

• emission and absorption of photons by atmospheric gases is confined to just those wavelengths that cause the participating molecule (or atom) to move between allowed energy states. Thus the atmosphere is not a black (or gray) body – and so the Stefan-Boltzmann law and Wien's law do not apply

• later we'll come back to interaction of radiation with the atmosphere



A.H. Compton, Nobel prize winner (1927), interaction of light and matter (USA)

Two-band decomposition of environmental radiation (p41) commonly used in earth science…

Solar (= shortwave) radiation band

$$\lambda \leq 4\ \mu m$$

- the Near Infrared ("NIR") $0.7\ \mu m \leq \lambda \leq 4\ \mu m$

Longwave (= terrestrial = thermal infrared) radiation band

$$\lambda \geq 4\ \mu m$$

- together NIR+longwave total about half sun's energy emission

Solar constant (S_0)

Strength (ie. intensity) of the solar (shortwave) beam measured outside the atmosphere.

Seen from planets, sun is a distant point source: so

$$S_0 \propto \frac{1}{r^2}$$

On earth,

S_0 =1367 W m^{-2}

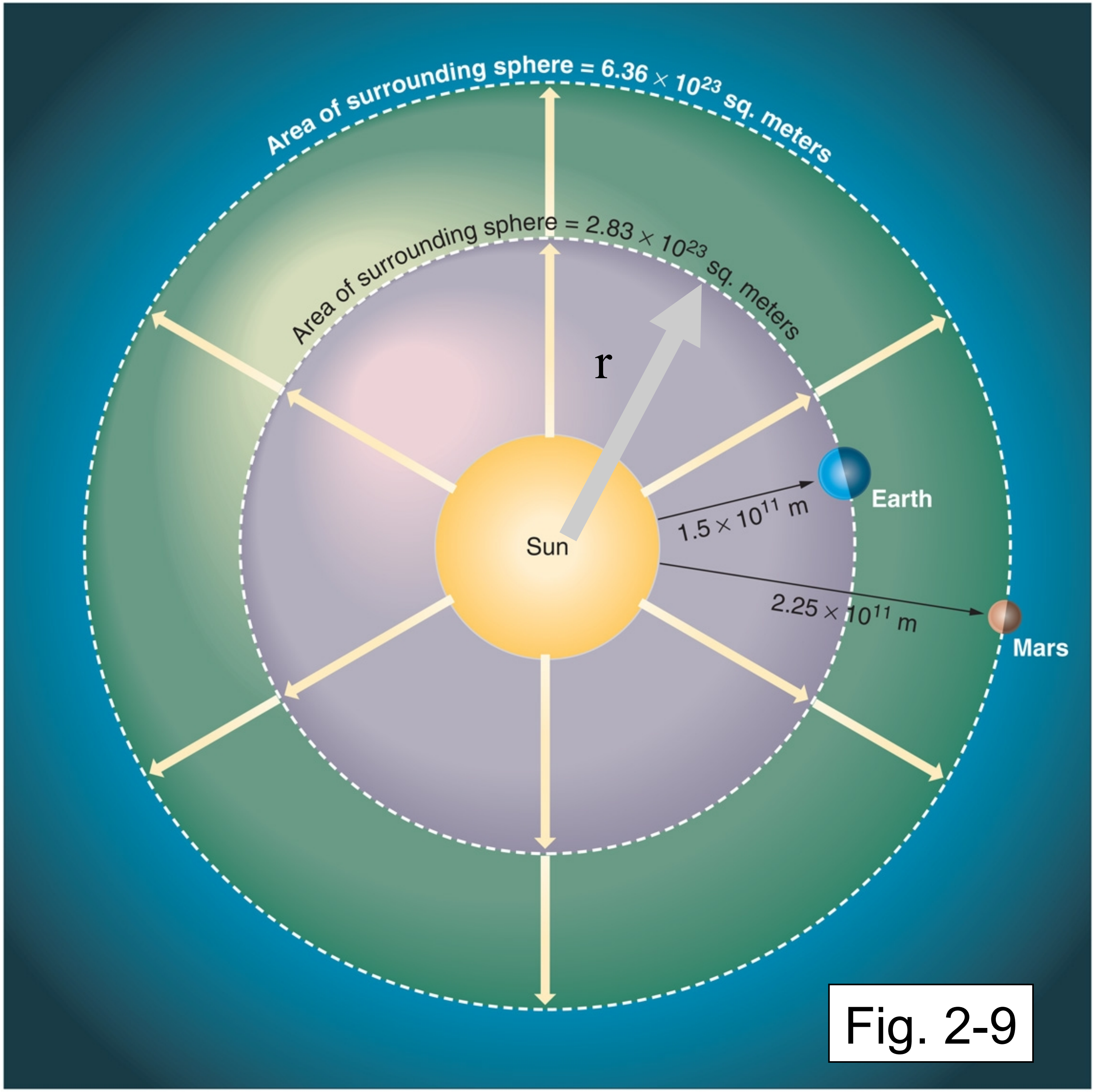
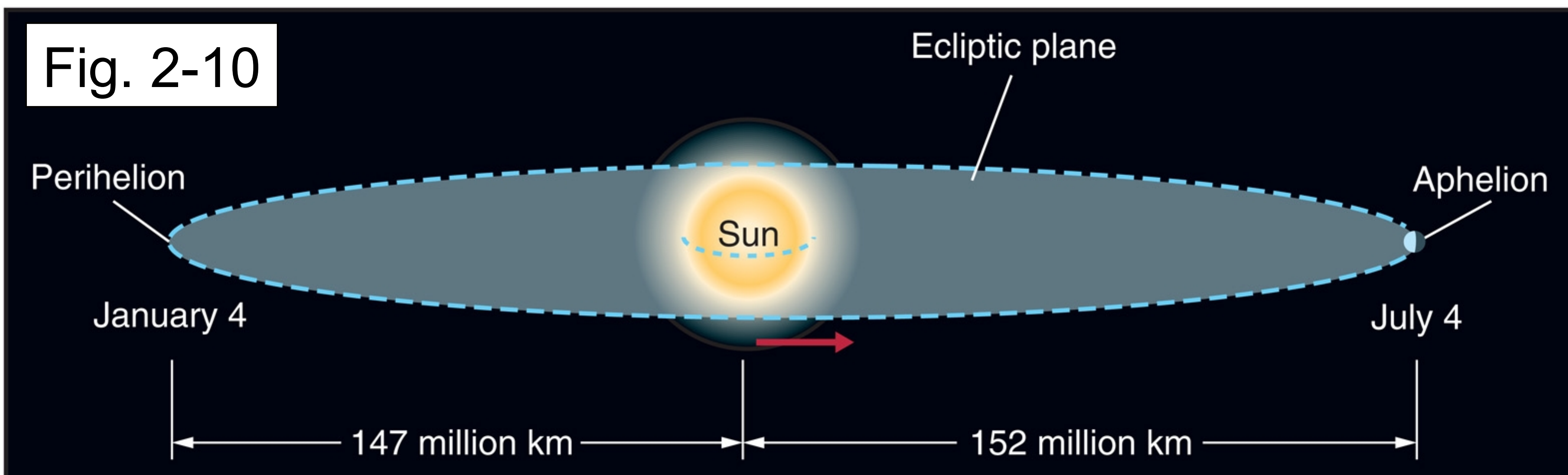


Fig. 2-9

The seasons are regulated by the amount of solar radiation received per unit of ground area per day at earth's surface. This is affected by sun-earth geometry which controls:

- noon solar elevation & daylength
- beam spreading (controlled by solar elevation)
- beam depletion (solar pathlength through atmosphere)



If earth's spin axis lay in the ecliptic plane… (it doesn't)

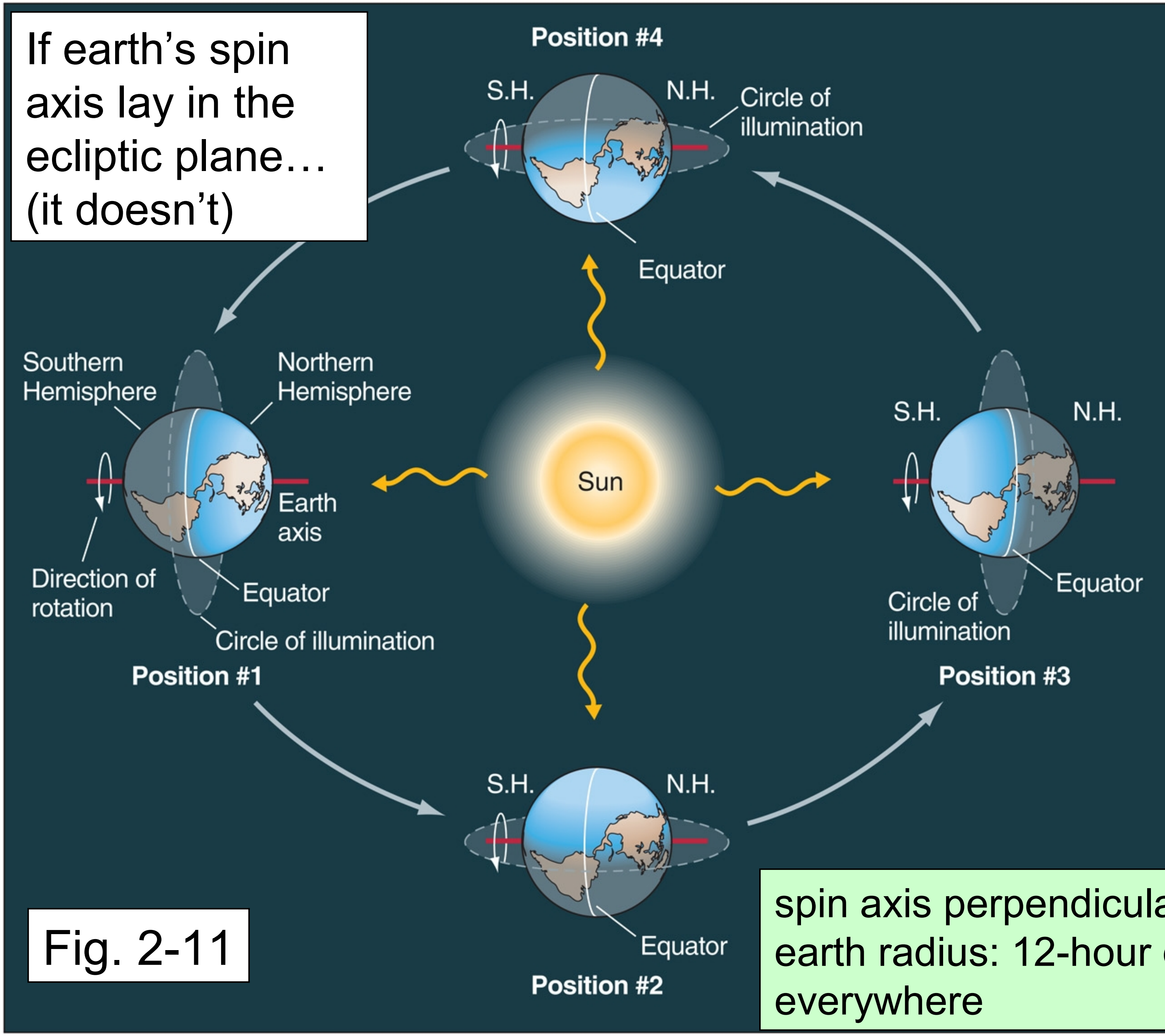


Fig. 2-11

spin axis parallel to sun-earth radius: 24-hour day in S.H.

spin axis perpendicular to sun-earth radius: 12-hour day everywhere

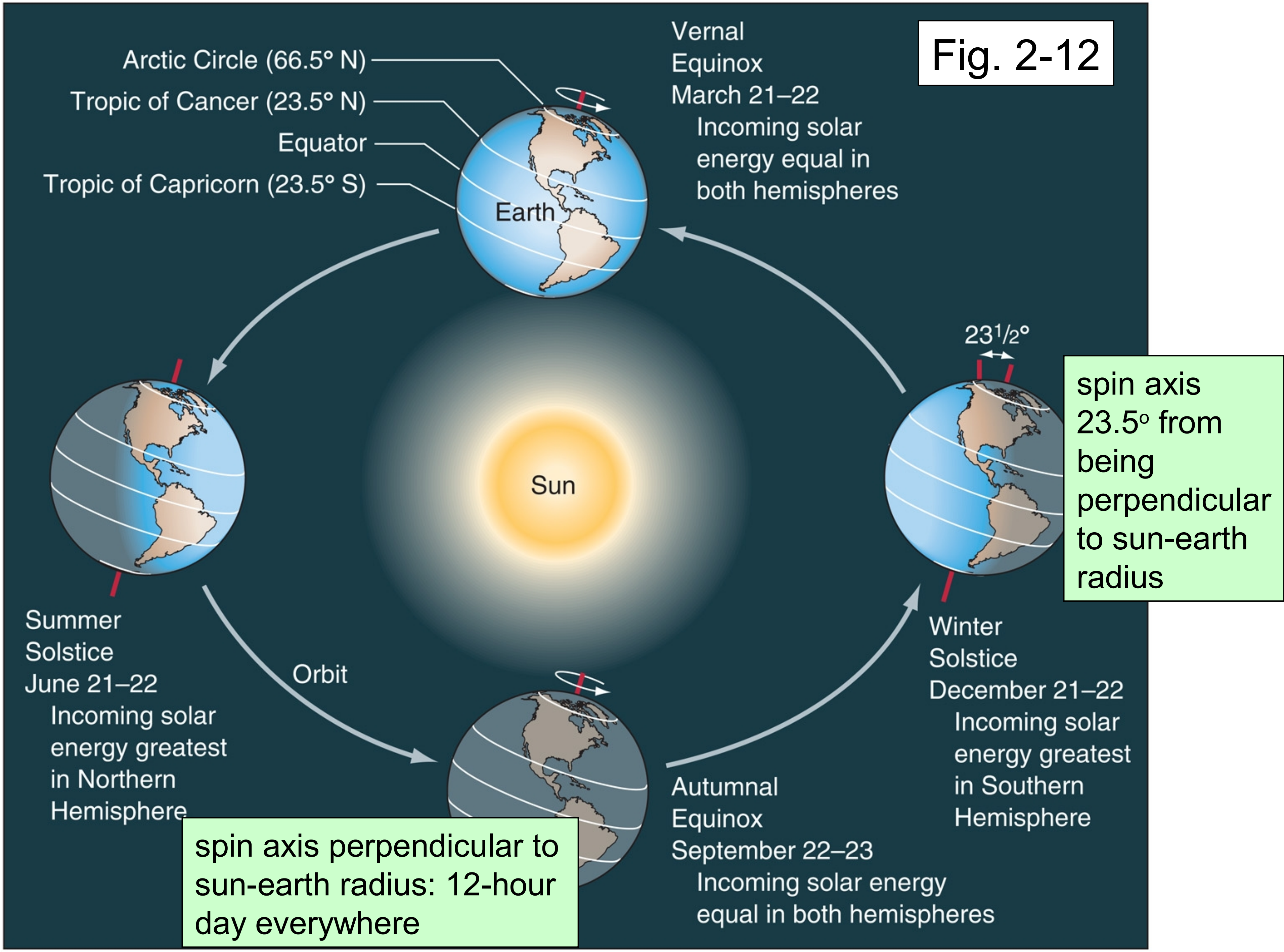
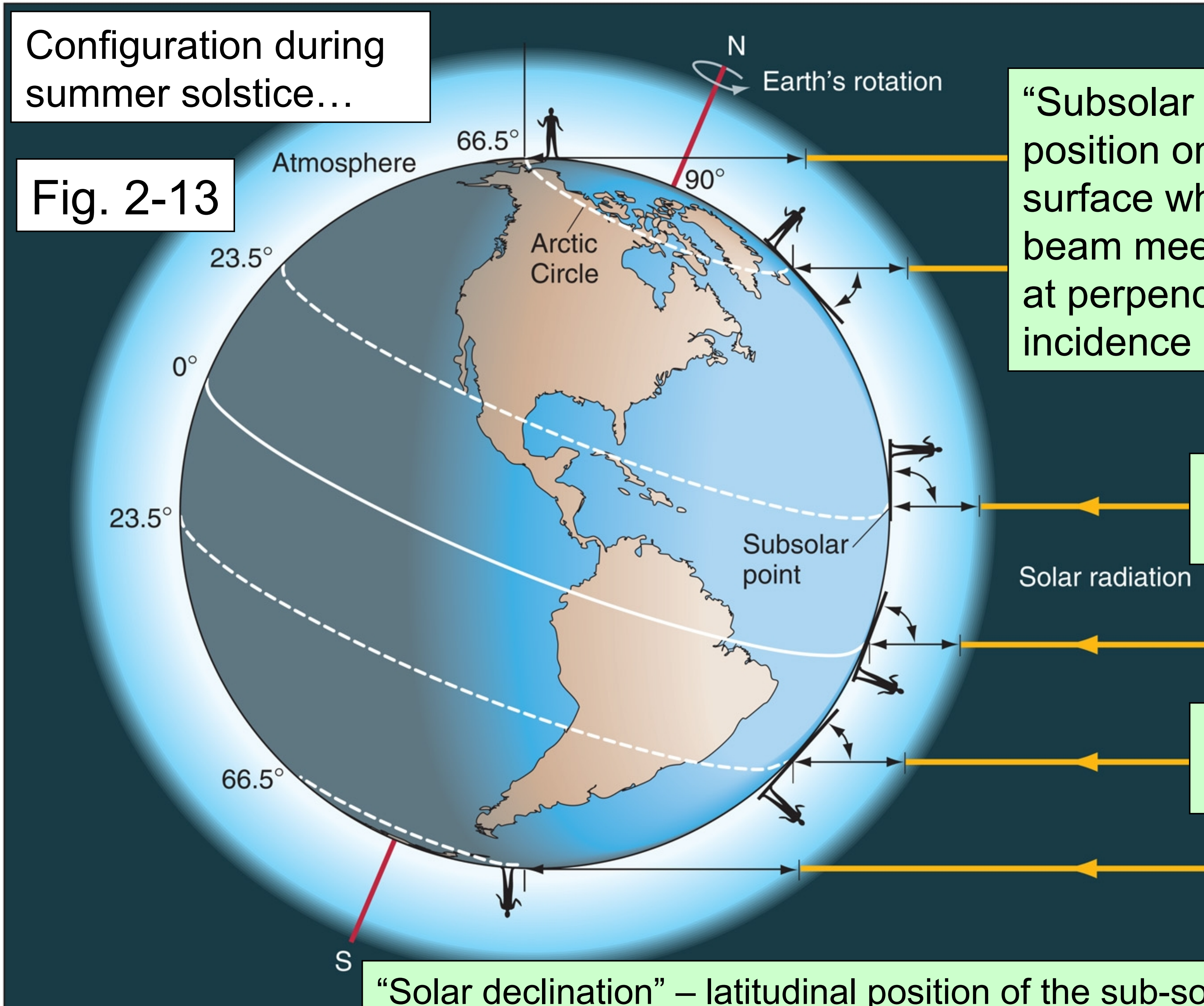


Fig. 2-12
Arctic Circle (66.5° N)
Tropic of Cancer (23.5° N)
Equator
Tropic of Capricorn (23.5° S)
Earth
Vernal Equinox March 21–22
Incoming solar energy equal in both hemispheres
Sun
23½°
spin axis 23.5° from being perpendicular to sun-earth radius
Summer Solstice June 21–22
Incoming solar energy greatest in Northern Hemisphere
Orbit
Winter Solstice December 21–22
Incoming solar energy greatest in Southern Hemisphere
Autumnal Equinox September 22–23
Incoming solar energy equal in both hemispheres
spin axis perpendicular to sun-earth radius: 12-hour day everywhere

Configuration during summer solstice…

Fig. 2-13



"Subsolar point" – position on earth's surface where solar beam meets surface at perpendicular incidence

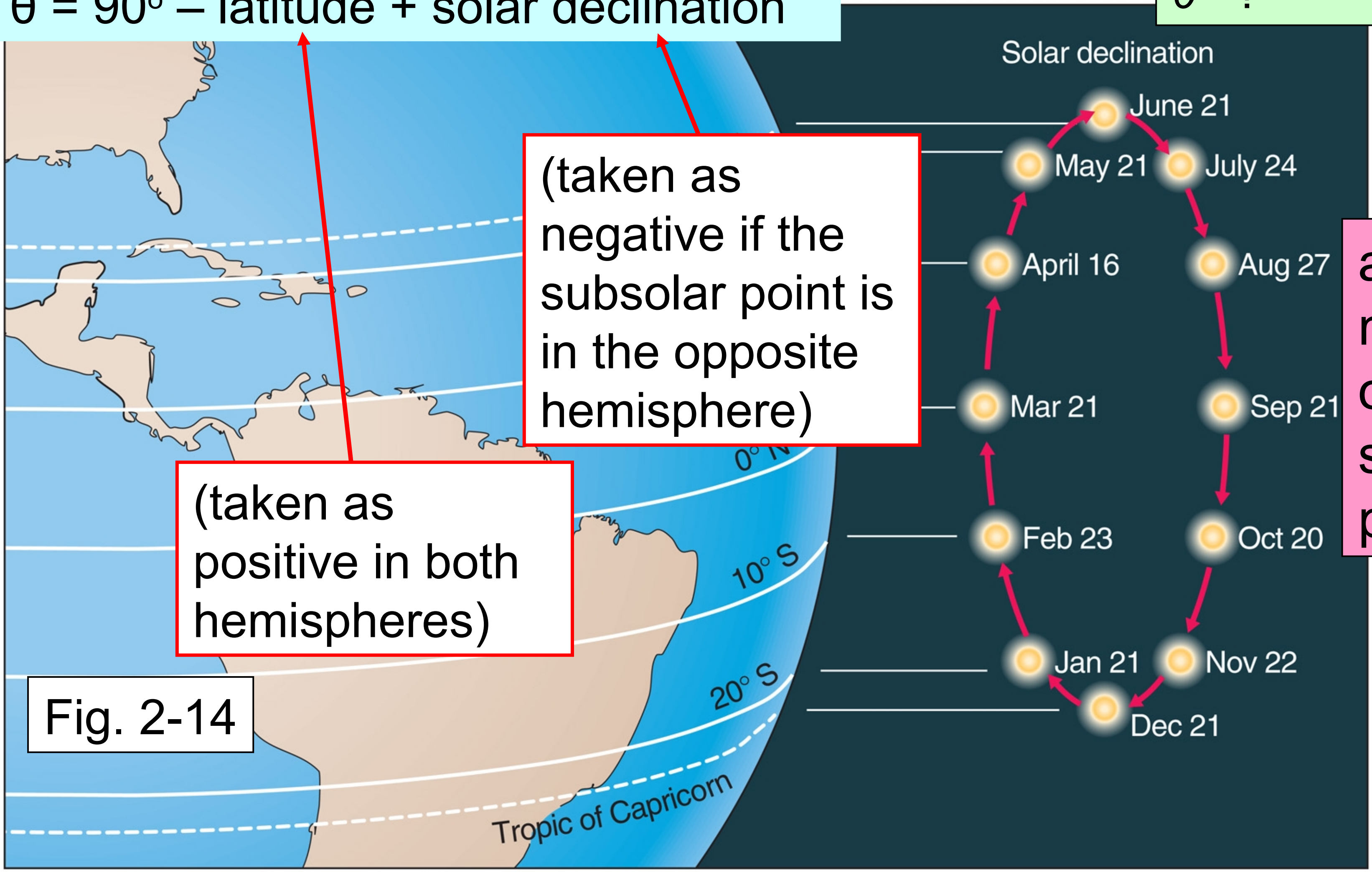
Tropic of Cancer

Tropic of Capricorn

"Solar declination" – latitudinal position of the sub-solar point. It depends only on time of year

Noontime solar elevation angle (p50):

θ = 90° – latitude + solar declination



(taken as negative if the subsolar point is in the opposite hemisphere)

(taken as positive in both hemispheres)

Fig. 2-14

annual migration of the sub-solar point

Edmonton, Jun 21:

θ =?

Sydney, Australia (34°S),
Jun 21: θ =90 – 34 + (-23.5) = 32.5°
Dec 21: θ =90 – 34 + (23.5) = 79.5°

Edmonton, Dec 21:

θ =?