ATOC 1060-002
OUR CHANGING ENVIRONMNET

Class 8 (Chapter 3)

Objectives of today's class:

1) Demonstration of greenhouse effect;
2) Atmospheric composition and structure;
3) Physical causes of the greenhouse effect;

http://atoc.colorado.edu/~whan/ATOC1060

Flux (F): the amount of energy that passes through a given perpendicular area per unit time.

W/m^2

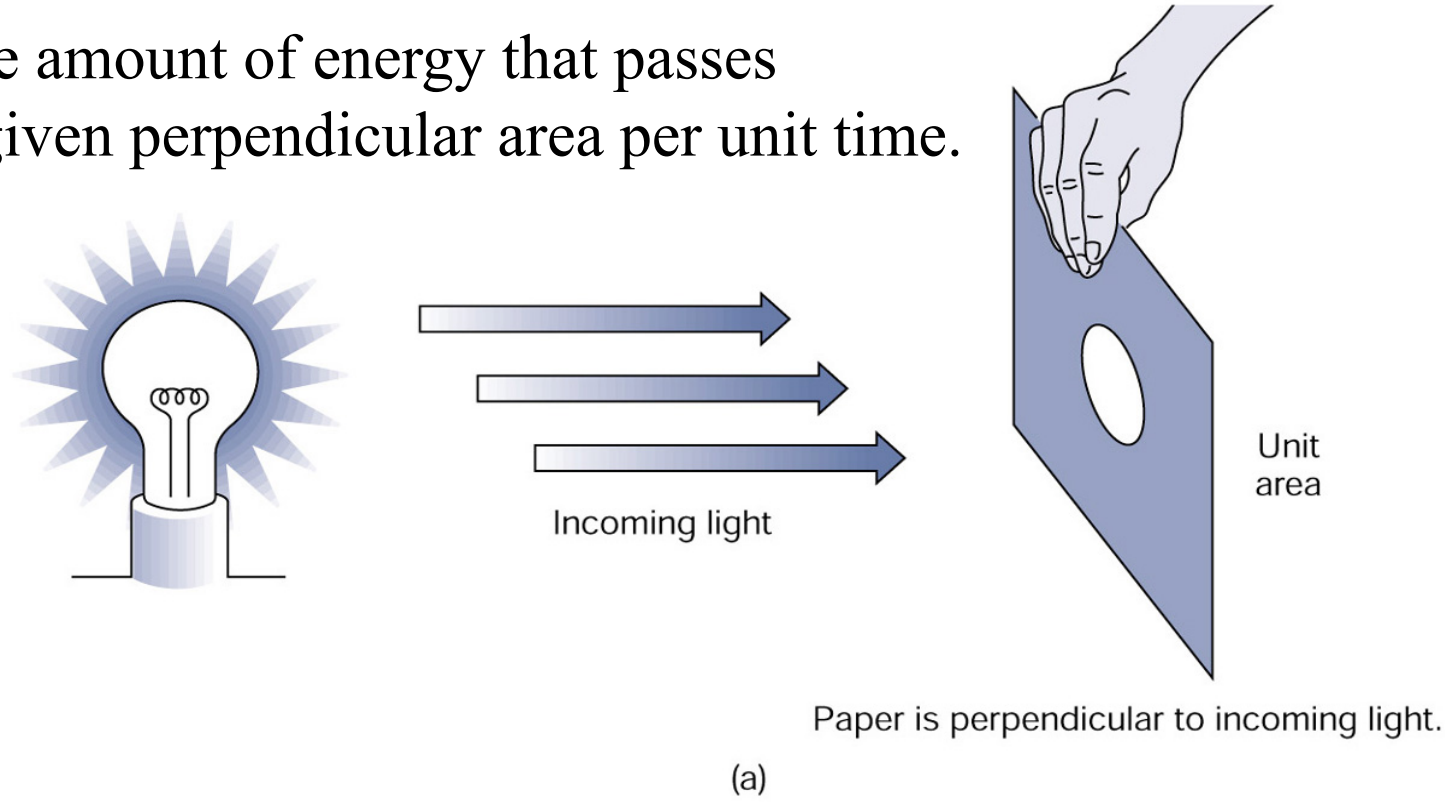
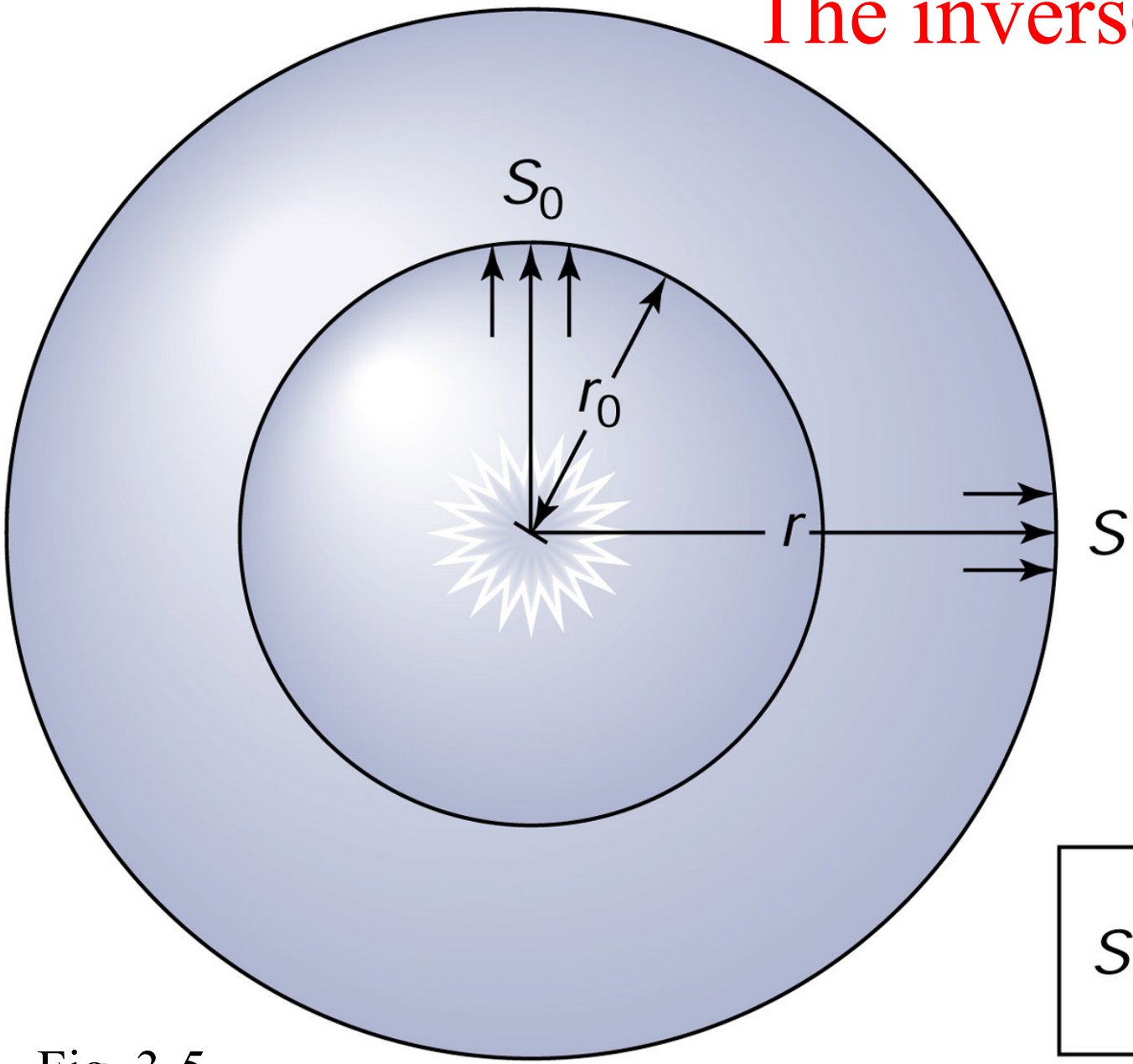


Fig. 3-4

The inverse square law



$$\frac{S}{S_0} = \frac{r_0^2}{r^2}$$

$$S = S_0\left(\frac{r_0}{r}\right)^2$$

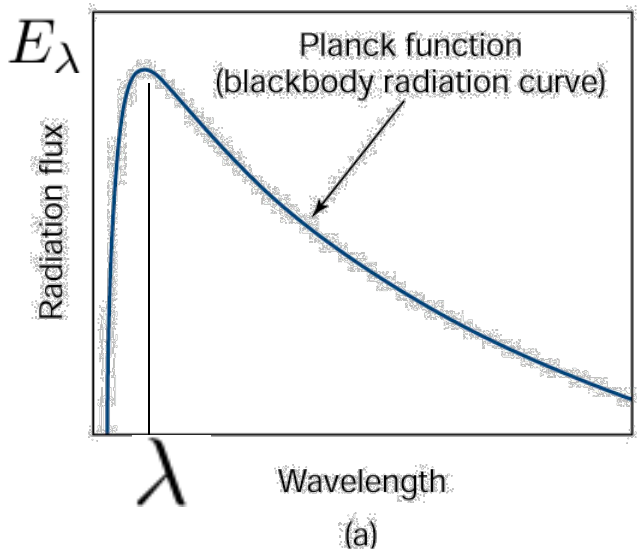
Fig. 3-5

Previous class: Blackbody radiation laws

Wien's Law

$$\lambda_{max} \approx \frac{2898}{T}$$

Micrometers (μm) Kelvin (K)



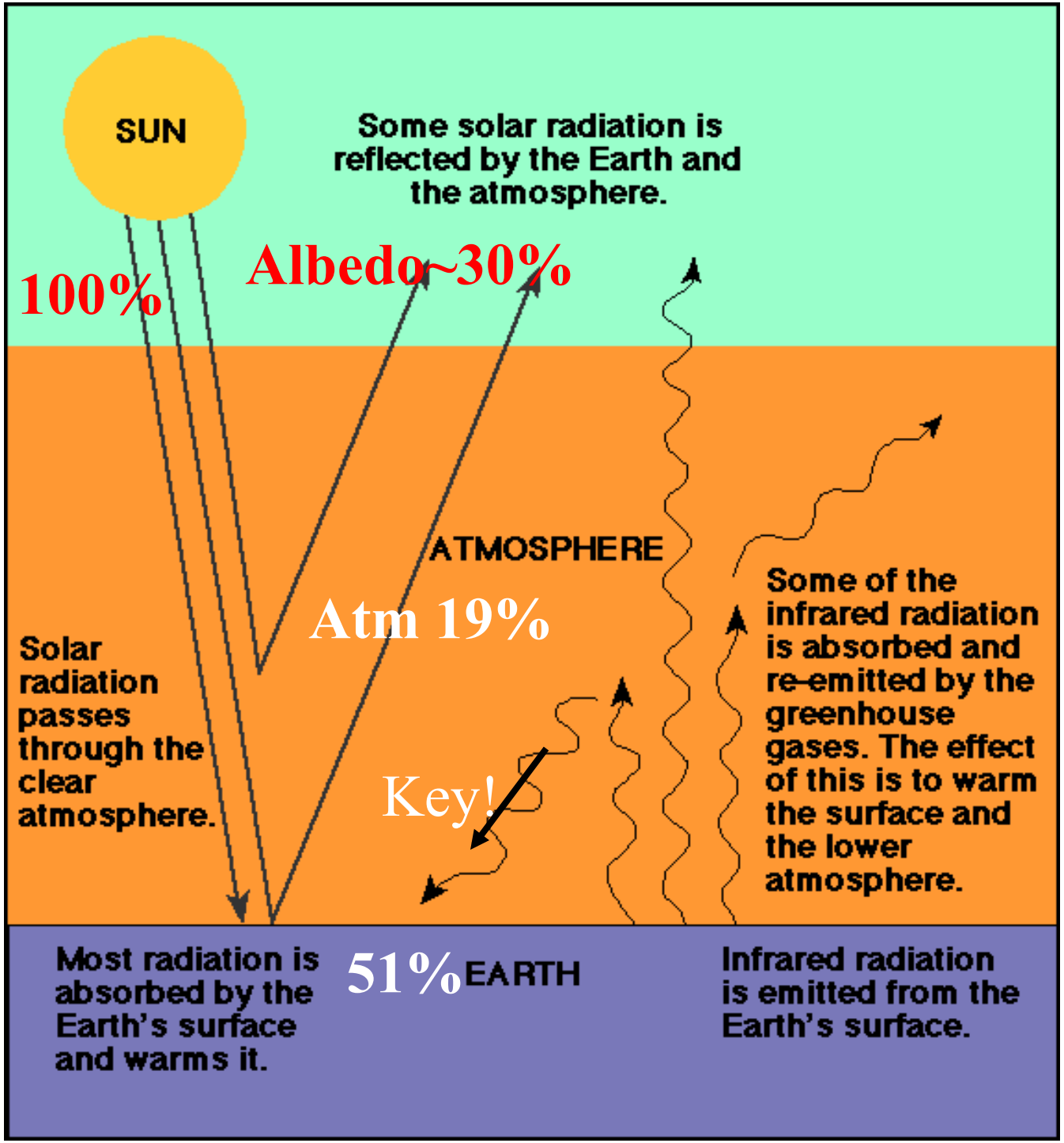
Stefan-Boltzmann Law

$$F = \sigma T^4$$

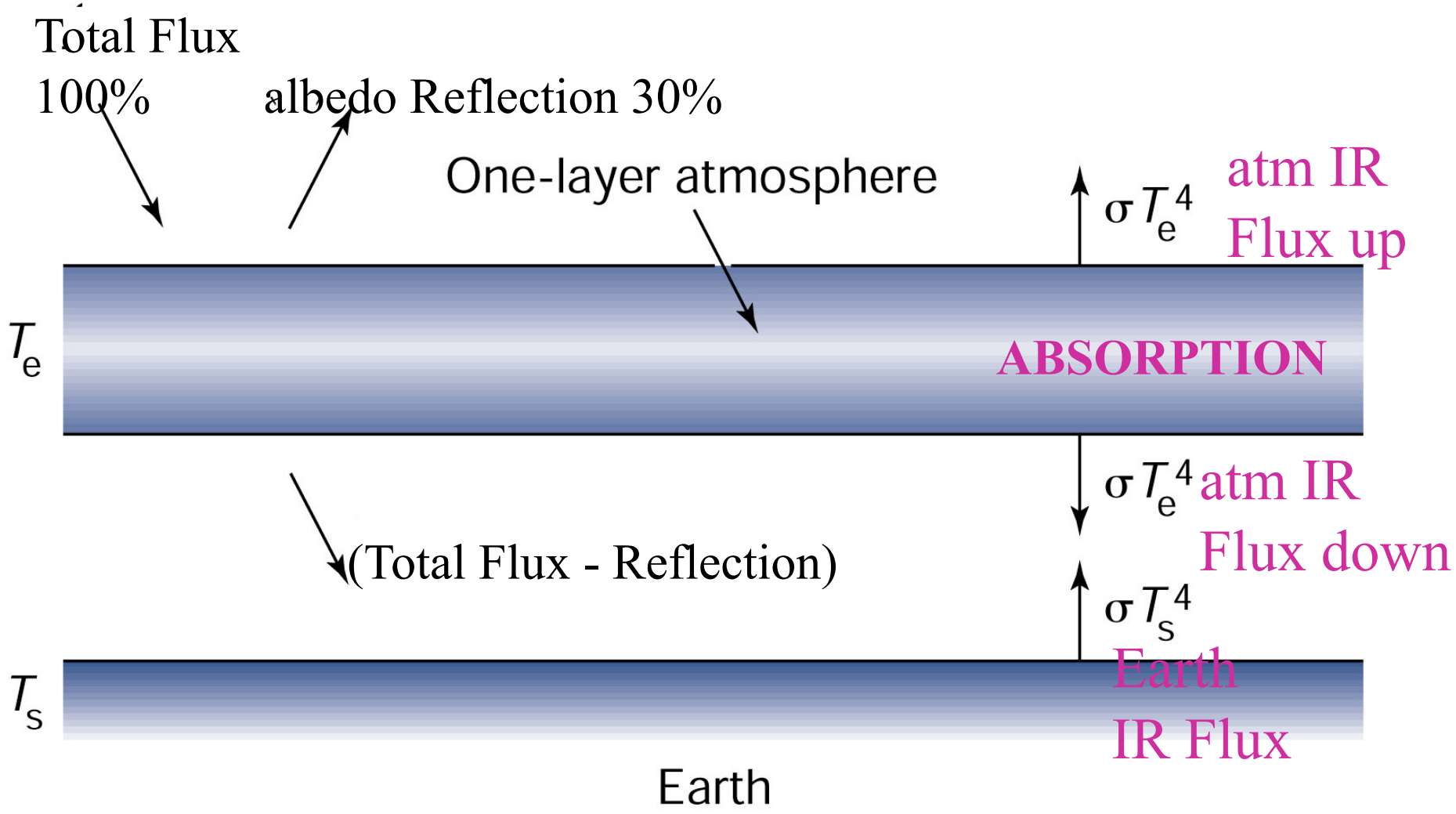
$$\sigma = 5.67 \times 10^{-8} W/m^2/K^4$$

Give a real exmaple

Clicker’s question 1


SUN
Some solar radiation is reflected by the Earth and the atmosphere.
Albedo~30%
100%
ATMOSPHERE
Atm 19%
Solar radiation passes through the clear atmosphere.
Key!
Some of the infrared radiation is absorbed and re-emitted by the greenhouse gases. The effect of this is to warm the surface and the lower atmosphere.
Most radiation is absorbed by the Earth's surface and warms it.
51%EARTH
Infrared radiation is emitted from the Earth's surface.

1. How does the greenhouse effect work?
Idealized example:



Box Figure 3-2

Magnitude of the greenhouse effect

=> $T_e = 255K$ (Earth temperature with no greenhouse Effect)

$-18°C$

Observed earth temperature with Greenhouse:

$$15°C = 288K$$

288K-255K=33K- greenhouse effect!

Clicker question 2

2. Atmospheric composition and structure

TABLE 3-2

Major Constituents of Earth's Atmosphere Today

Name and Chemical Symbol	*Concentration (% by volume)*
Nitrogen, N_2	78
Oxygen, O_2	21
Argon, Ar	0.9
Water vapor, H_2O	0.00001 (South Pole)–4 (tropics)
Carbon dioxide, CO_2	0.037*

*In 2002

$$1\% = \frac{1}{100} = \frac{10000}{1000000} = \frac{10000}{1 million}$$

TABLE 3-3

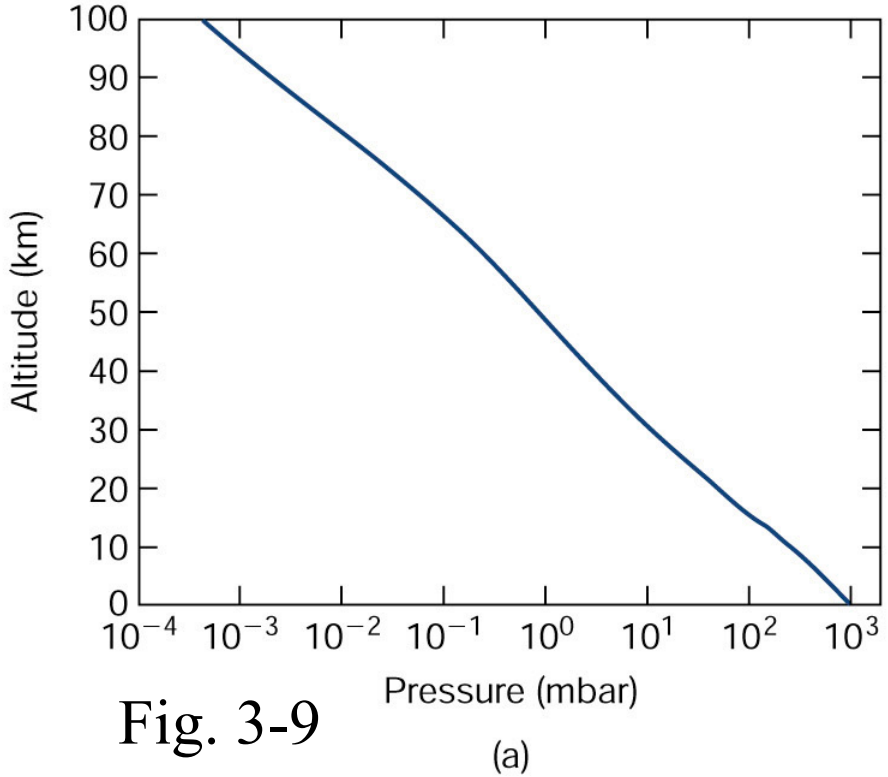
Important Atmospheric Greenhouse Gases

Name and Chemical Symbol	*Concentration (ppm by volume)*
Water vapor, H_2O Variable	0.1 (South Pole)–40,000 (tropics)
Carbon dioxide, CO_2	370
Methane, CH_4	1.7
Nitrous oxide, N_2O	0.3
Ozone, O_3 (depletion)	0.01 (at the surface)
Freon-11, CCl_3F	0.00026
Freon-12, CCl_2F_2	0.00054

Clicker question 3

Atmospheric structure

Pressure (mbar)



Temperature

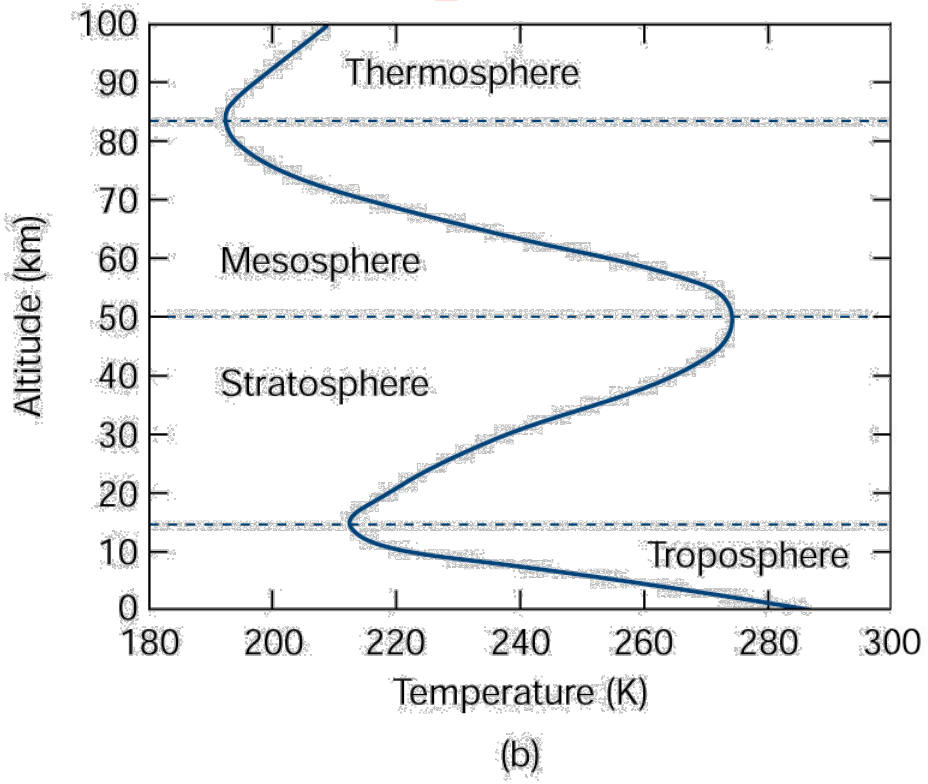


Fig. 3-9

Pressure: the force per unit area exerted by a gas or liquid on some surface with which it is in contact.

The pressure exerted by the atmosphere at sea level is one atmosphere (1 atm). 1Pascal (Pa) =1 N /m^2 ; 1bar=10^3mbar=10^5Pa.

The troposphere

Weather phenomena: clouds, rain, snow, storms.

Well mixed by convection

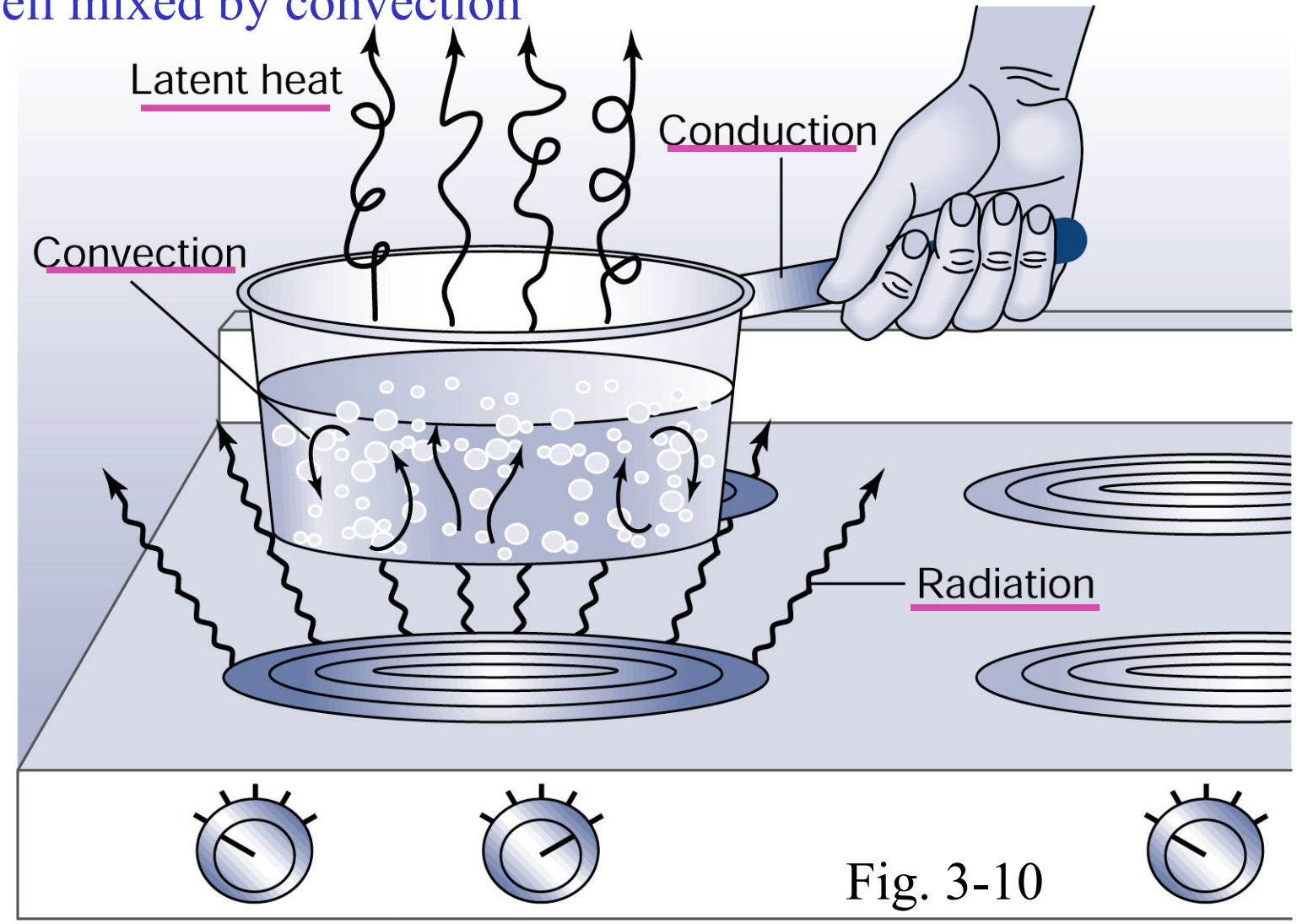


Fig. 3-10

Heat transfer

Radiation.

Convection: a process in which heat energy is transported by the motions of a fluid (a liquid or a gas).

Conduction: the transfer of heat energy by direct contact between molecules.

Latent heat: the heat energy released or absorbed during the transition from one phase-gaseous, liquid, or solid-to another.

Temperature decreases with height because the heat Source is at the Earth's surface.

The stratosphere

Lower pressure, dry, weather phenomena basically absent;

Exception: winter polar stratospheric clouds, plays a key role in the development of the Antarctic ozone hole.

contain most of Earth's ozone;

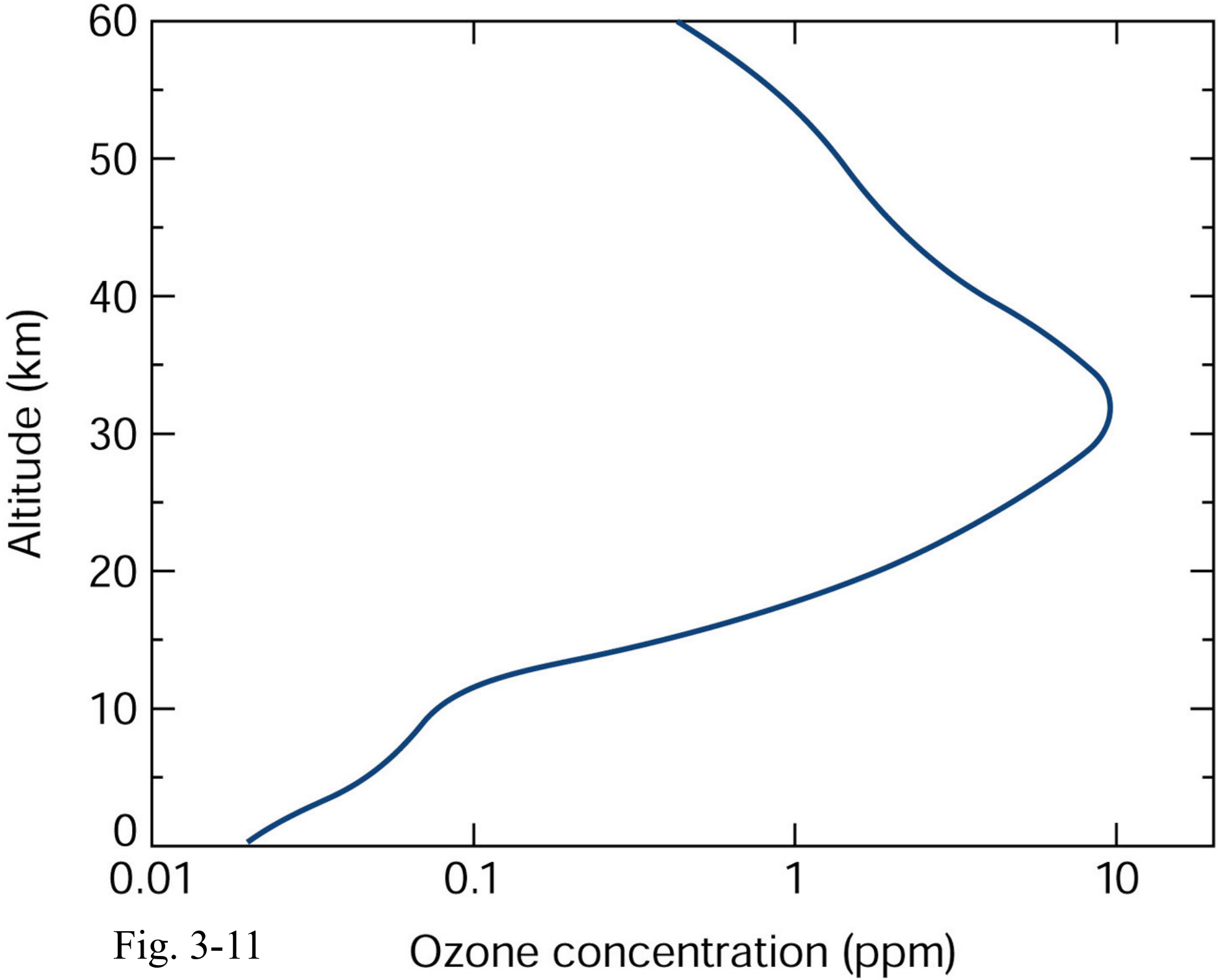

60
50
40
30
20
10
0
Altitude (km)
0.01
0.1
1
10
Ozone concentration (ppm)

Fig. 3-11

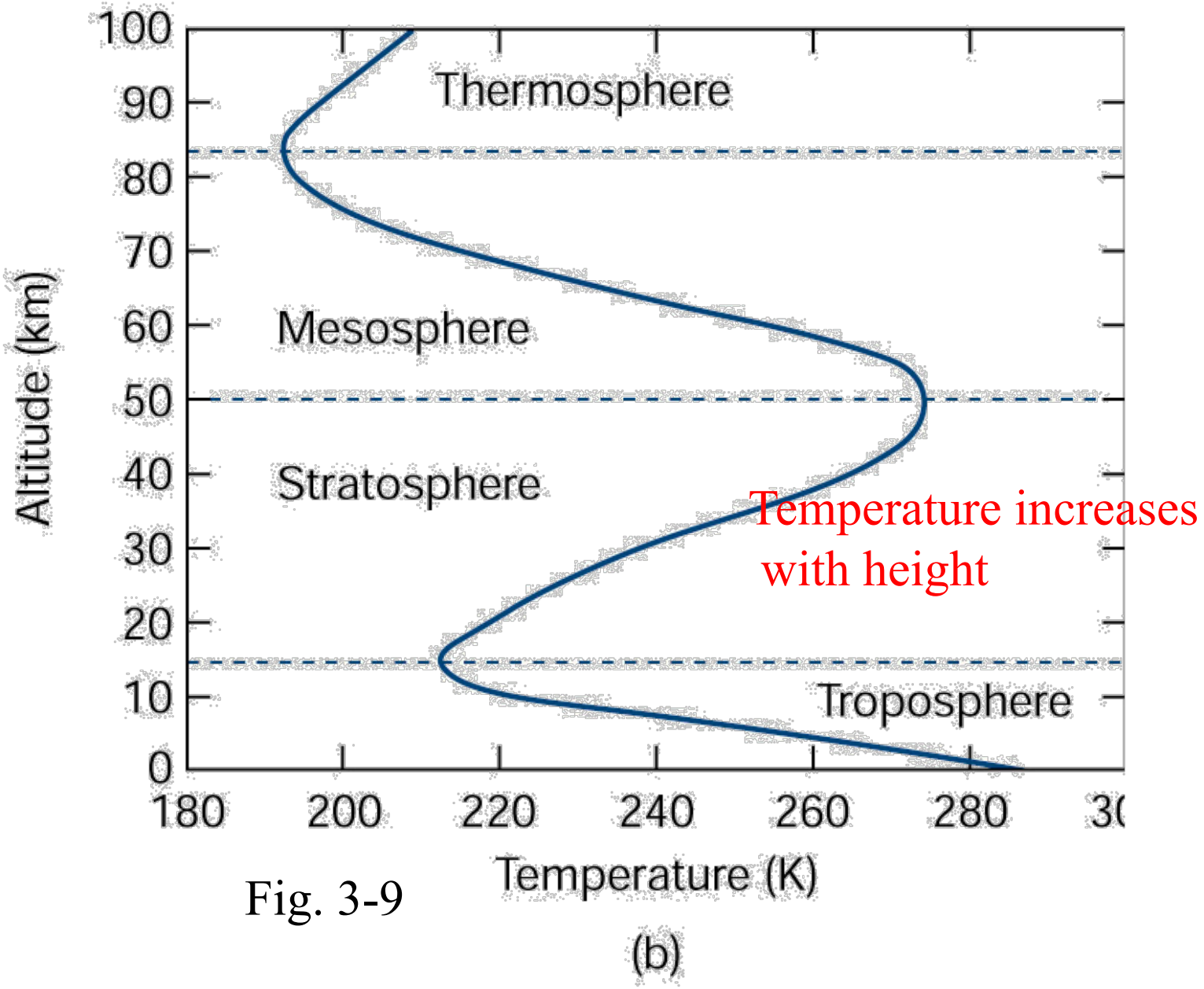


Fig. 3-9

Temperature profile: explanation.

Clicker question 4

3. Physical causes of the greenhouse effect

The defining property of a greenhouse gas is its ability to absorb or emit infrared radiation.

a)Quantum mechanics: molecules can rotate only at certain discrete frequencies (just like fans can rotate at certain speeds). Determined by molecule's structure.

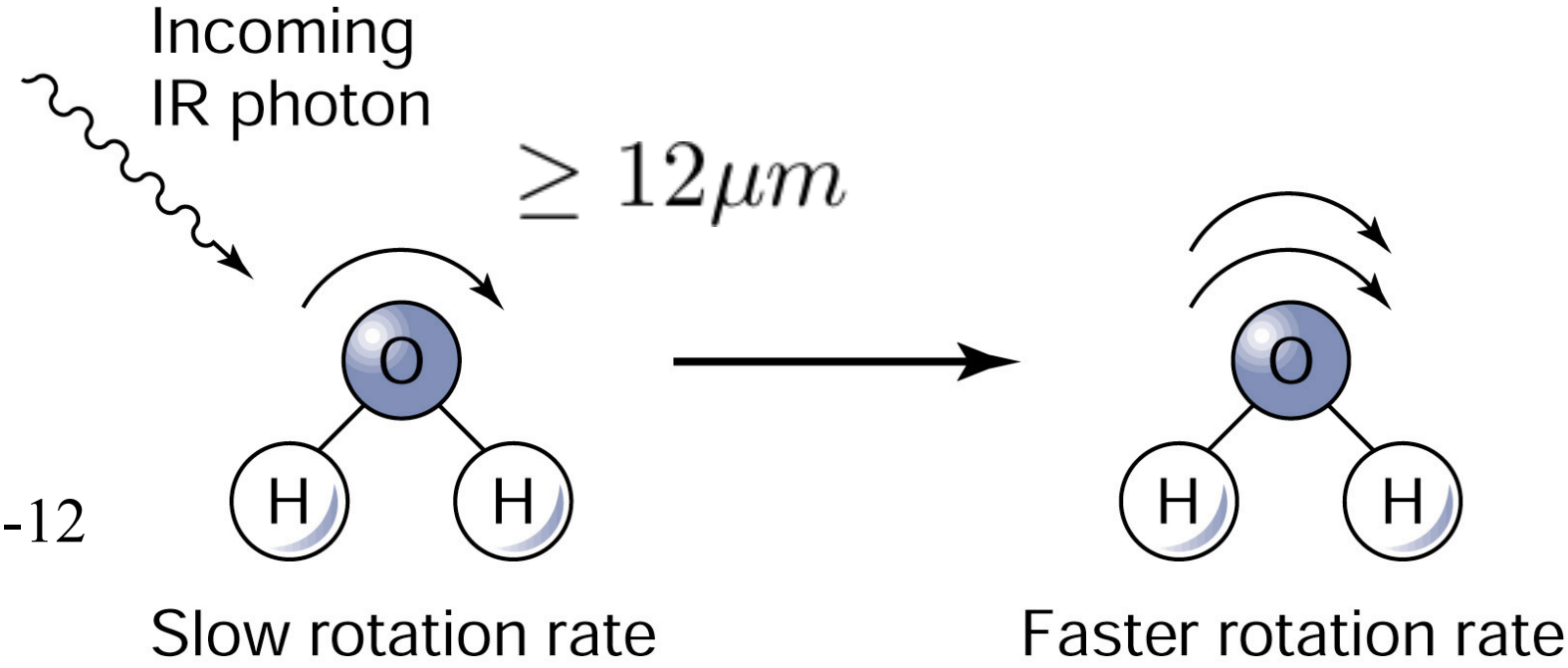


Fig. 3-12

b) Molecules can absorb or emit IR radiation by changing the amplitude with which they vibrate.

CO_2 molecule can vibrate in 3 ways. This vibration has a frequency that allows the molecule to absorb IR with wavelength $\approx 15\mu m$

This wavelength is near the peak of the Earth's IR radiation, important to Earth's climate!
IMPORTANT greenhouse gas!

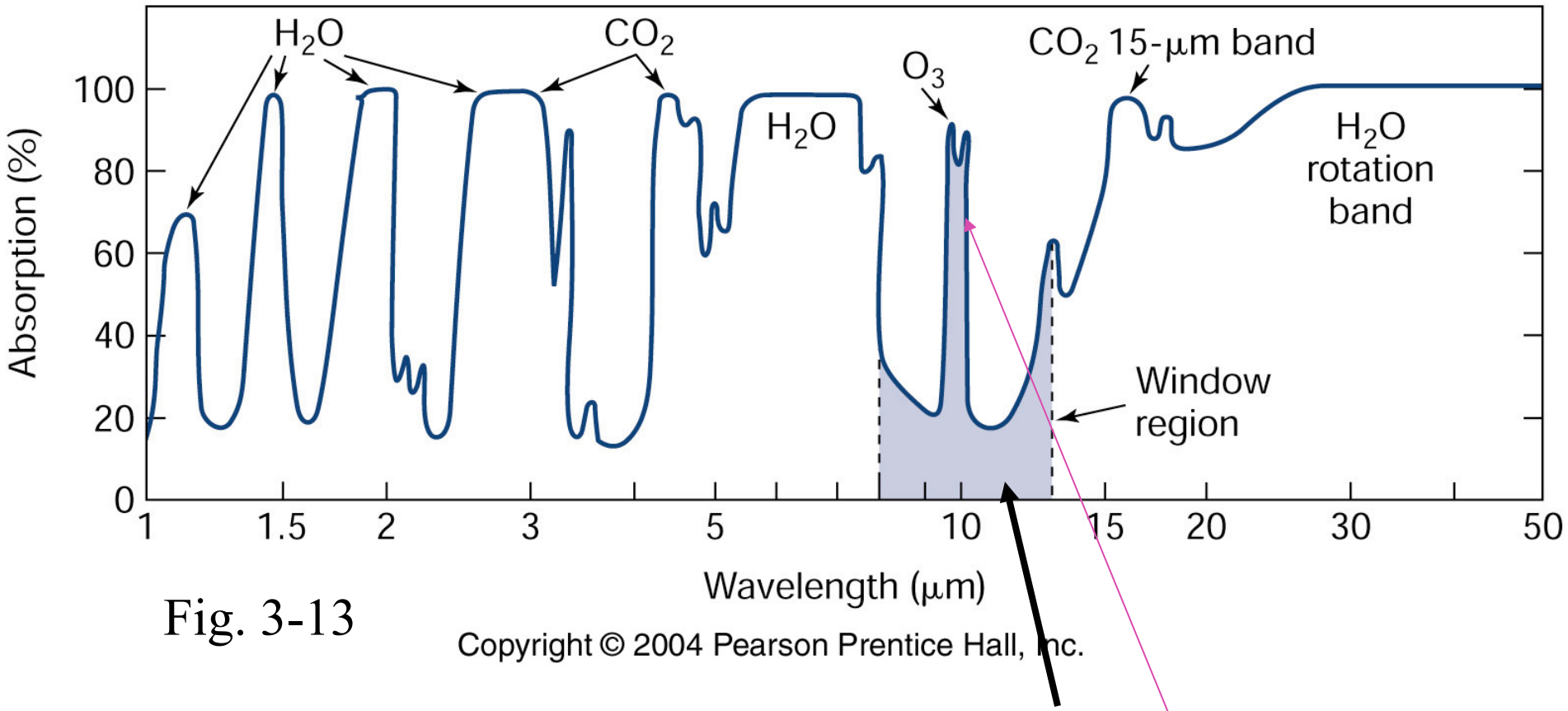
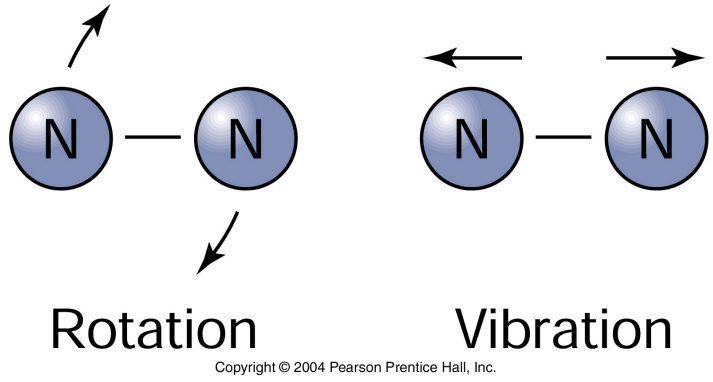


Fig. 3-13

Other greenhouse gases: Freons, O_3

Diatomic (two-atom) molecules: symmetric, no positive/negative charge.

Does not interfere with IR!



Earth's surface temperature depends on:

i) Solar flux at the top of the Earth's atmosphere, which is largely determined by the distance from the $1370 W/m^2$

ii) Earth's reflectivity (albedo; ~30%);

iii) warming provided by atmosphere (greenhouse effect).

Greenhouse effect: view the Earth as a blackbody (although not exactly true).