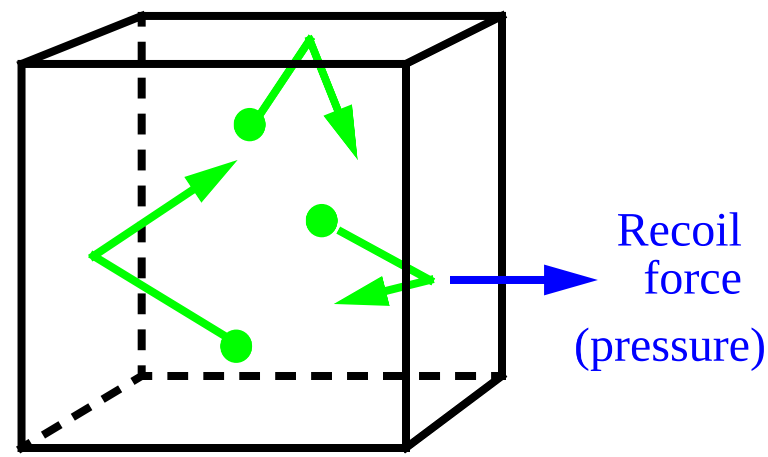
Lecture 7 Air Pressure

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

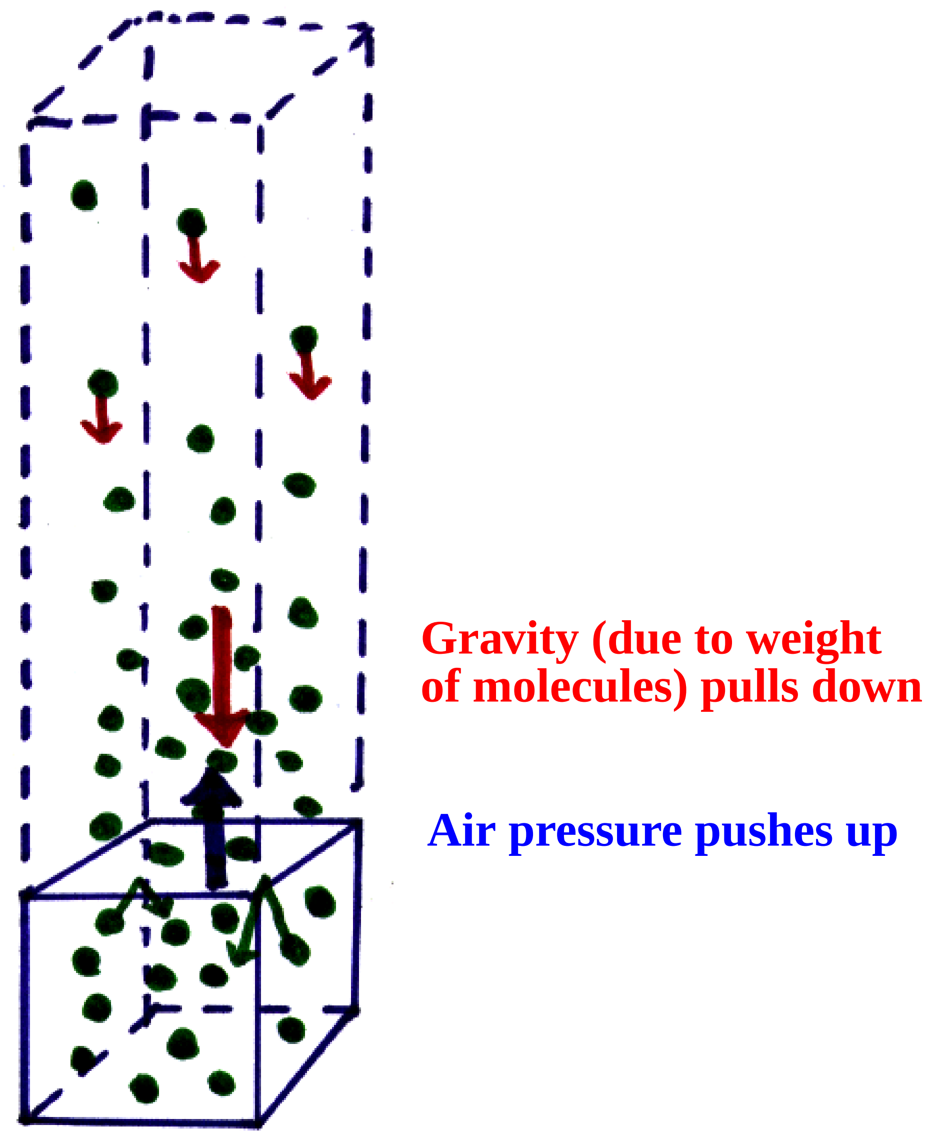
- In an air filled container, pressure is due at the molecular level to molecules pushing the sides outward by rebounding off them.



- This also applies to ‘parcel’ of air surrounded by more air; now molecules create pressure by rebounding off air molecules surrounding parcel.
- At any point, pressure is same in all directions, but...pressure varies from one point to another.
- Higher <u>density</u> (more molecules pushing) or <u>temperature</u> (faster molecules) produce more pressure.

Pressure supports air column weight

- Higher up, the weight of overlying air molecules is smaller, so pressure is also smaller.
- High pressure squeezes air most at bottom, so air is densest there.



Pressure decreases faster with height in cold air

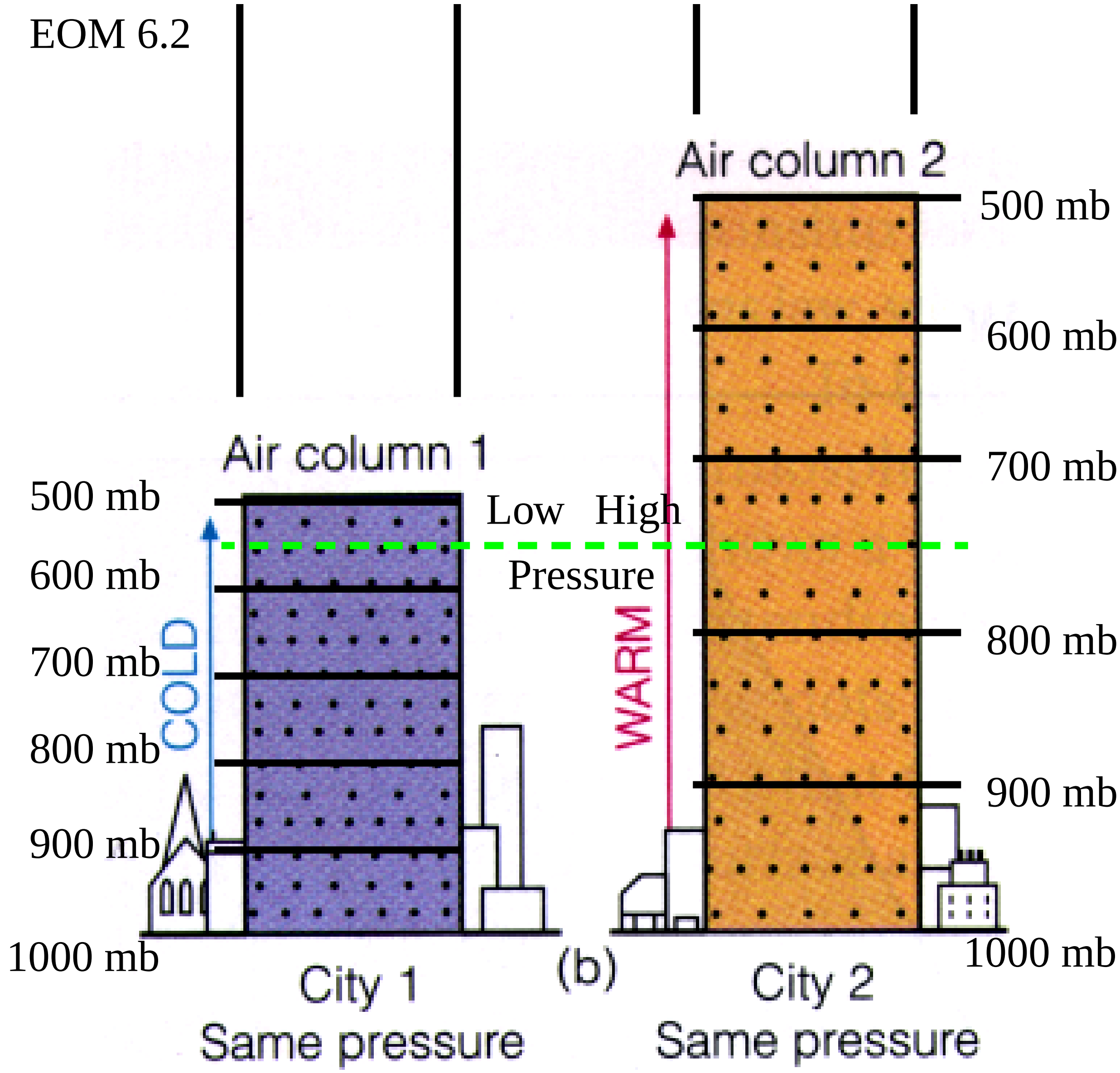
- It takes more cold, slow, molecules than hot, fast ones to exert a given pressure

⇒ Cold air is denser.

- Consider cold and warm air columns with equal weights, and equal amounts of overlying air.

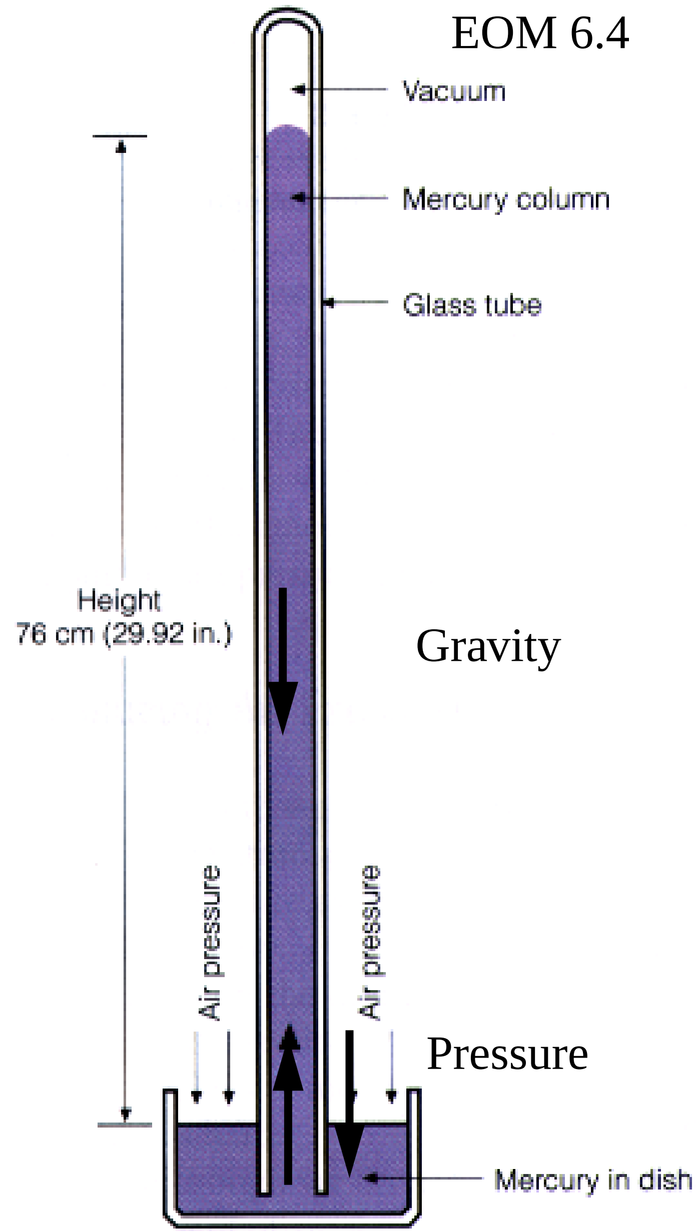
  Cold column is shorter

⇒ Pressure decreases faster with height in cold air.



Mercury barometers

- Weight of mercury in tube balanced by pressure
- A water barometer at sea level would have to be read from a ladder 30 ft high, since water is only 10% as dense as mercury.



Aneroid Barometers

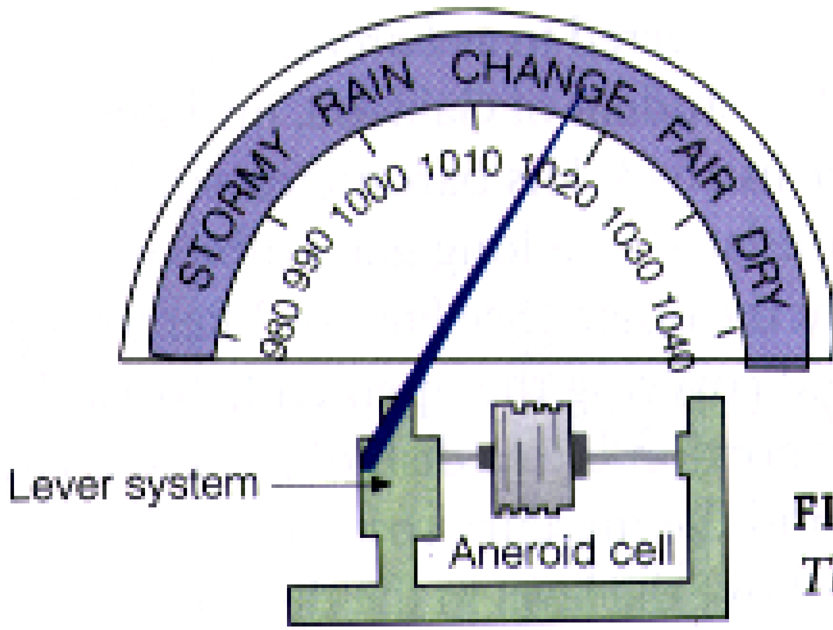


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FIGURE 6.5
The aneroid barometer.

- Aneroid is partly evacuated and sealed. Pressure increase compresses aneroid.
- Similar barometers in miniature are used in altimeters and altimeter watches.

Altimeters

...are aneroid barometers that use a standard formula (1 mb pressure decrease ≈ 30 ft height increase) to convert pressure change to height change.

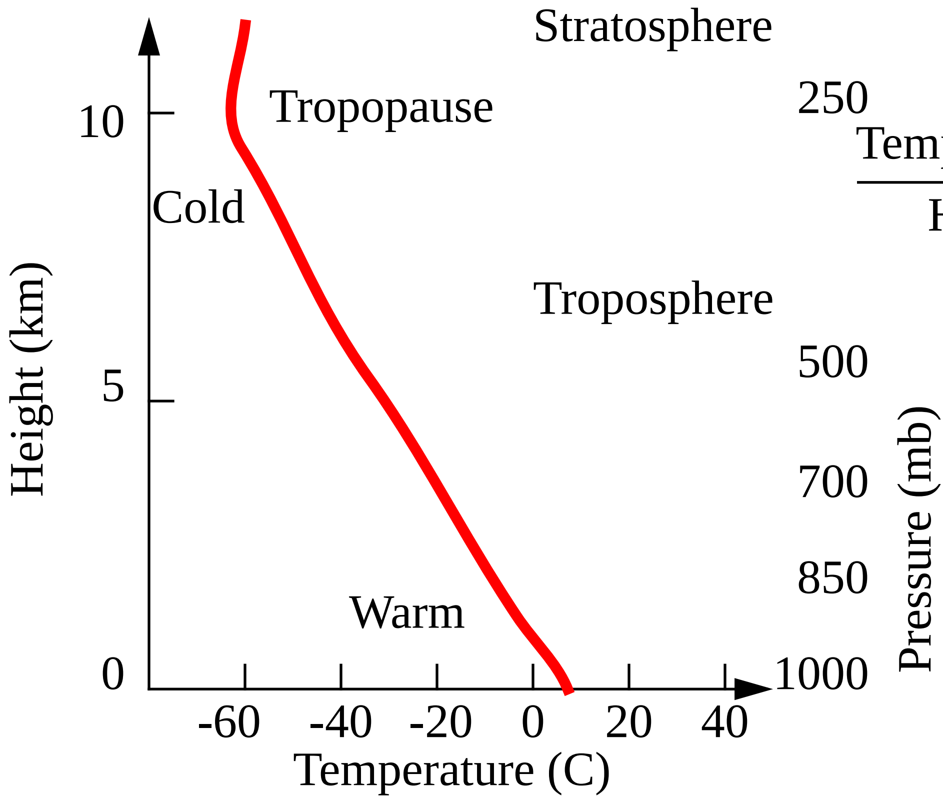
- Height errors occur if:
  1. Initial elevation not correct

     0-1000 ft errors
  2. Pressure changes with time or location.

     0-10 mb (0-300 ft) errors in 12 hours
     0-5 mb (0-150 ft) errors in 200 km distance
  3. Temperature vs. pressure different from formula

     15 C warmer causes pressure to decrease 5% slower with height, so altimeter underestimates height change by 50 ft per 1000 ft of rise.

Lapse Rate, Compressibility and Stratification



Lapse Rate = $\dfrac{\text{Temperature decrease}}{\text{Height Increase}}$

= 65 C / 10 km

= $\boxed{6.5\ \text{C/km}}$

- The troposphere is 50 C hotter at the bottom than at the top.
- We know that in convection, hot air rises and cold air sinks.

Question:

- Why don't we have convection everywhere, moving the warmer air from the surface to the upper troposphere?

Temperature changes as air rises and sinks

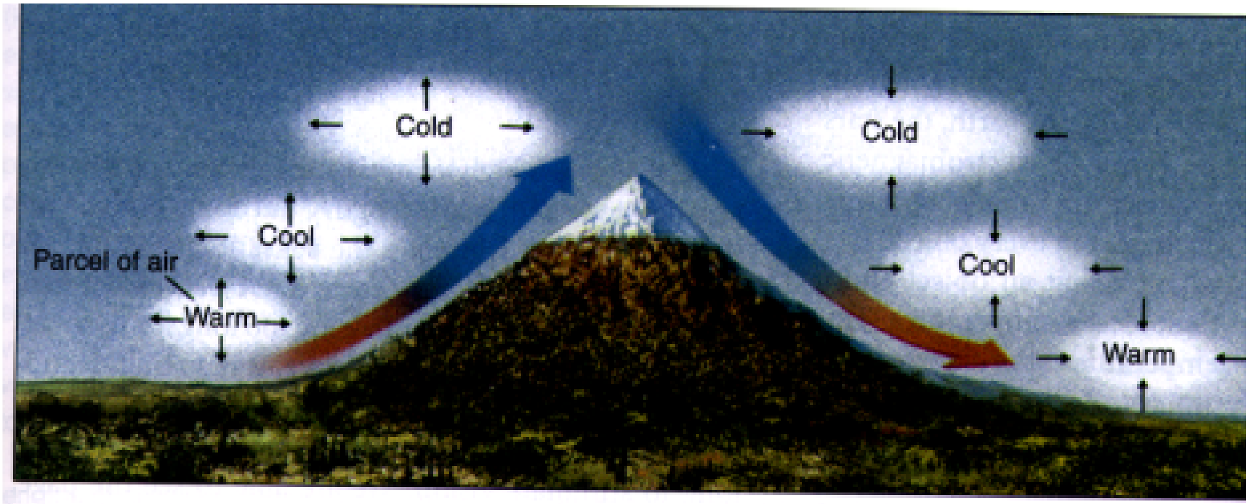


FIGURE 1
Rising air expands and cools; sinking air is compressed and warms.

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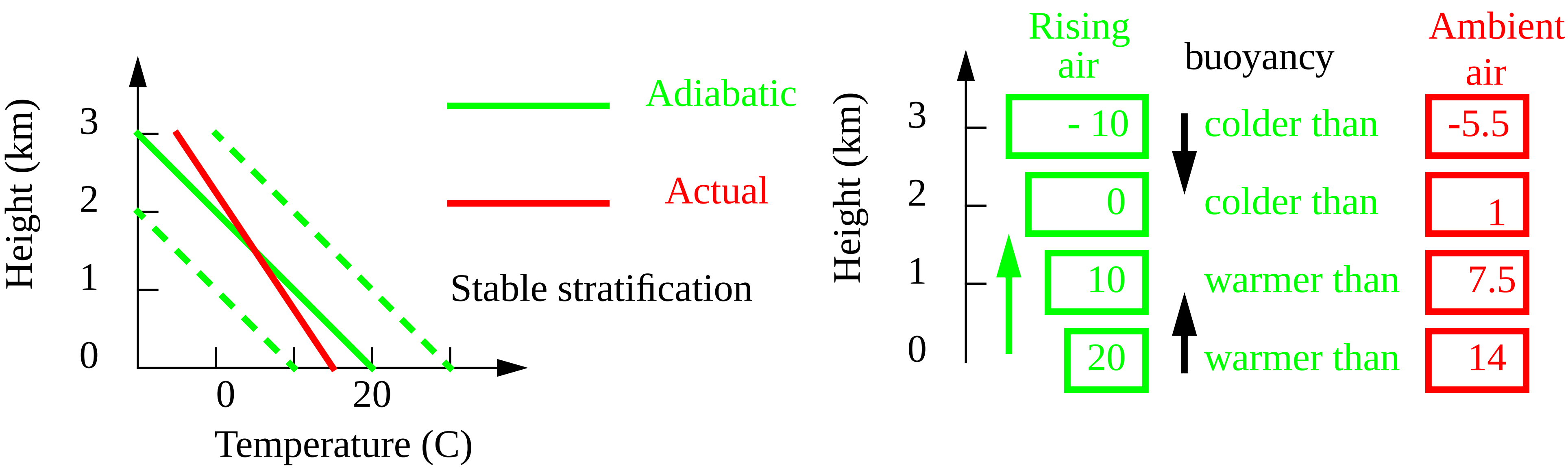
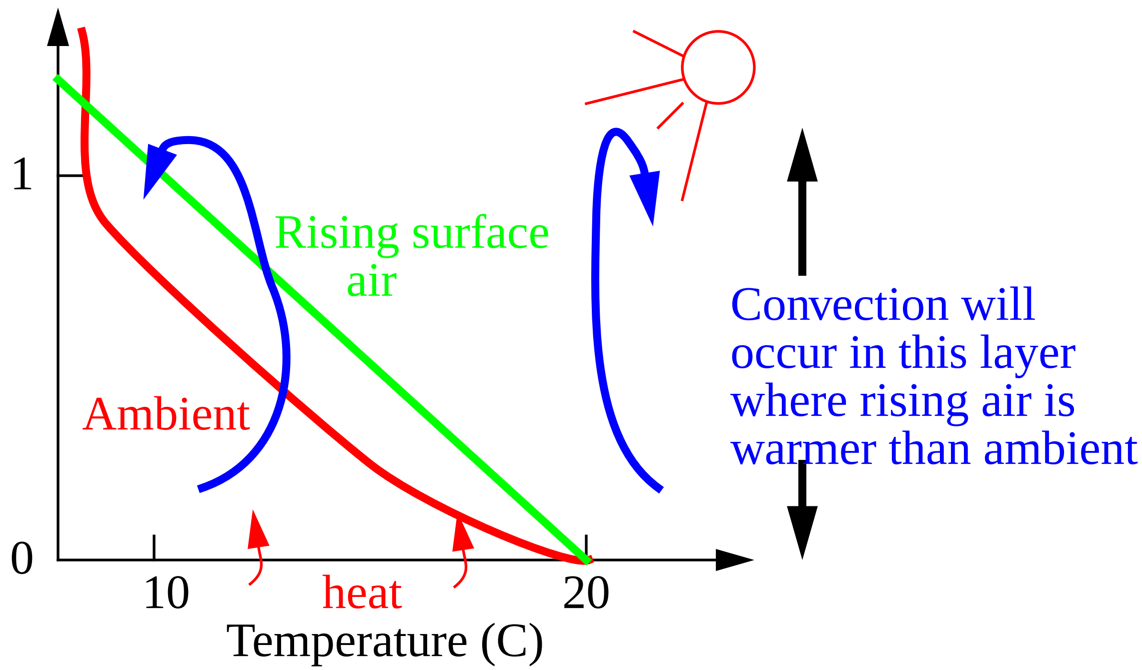
- As air rises, pressure of surrounding air drops.
- The air ‘parcel’ expands, pushing outward on surrounding air until its pressure drops to ambient.
- Pushing outward against a force (‘work’) consumes energy, which is taken from the random motions of the molecules, reducing temperature
- Thus dry air cools ‘adiabatically’ (without addition of heat) at about 10°C/km -- the *dry-adiabatic lapse rate*.
- Thus, as one hikes up the mountainside above, the temperature will be 10°C lower for each 1 km ascended.

Stratification



- The actual lapse rate of the troposphere is typically 6.5 C/km, less than the dry-adiabatic lapse rate of 10 C/km. This is called *stable stratification.*
- At any height, warmer air is less dense, buoyant.
- Temperature of unheated rising air decreases faster than ambient.
- Rising air loses buoyancy in stable stratification.
- Convection will occur whenever the lapse rate exceeds 10 C/km (*unstable stratification*). It exchanges the hot and cold air until the lapse rate is

reduced to 10 C/km.



- In clouds, latent heating of rising air due to condensation of water vapor into clouds may permit 'moist' convection to occur even in 'stable stratification' (lapse rate less than 10 C/km). Discuss this later.