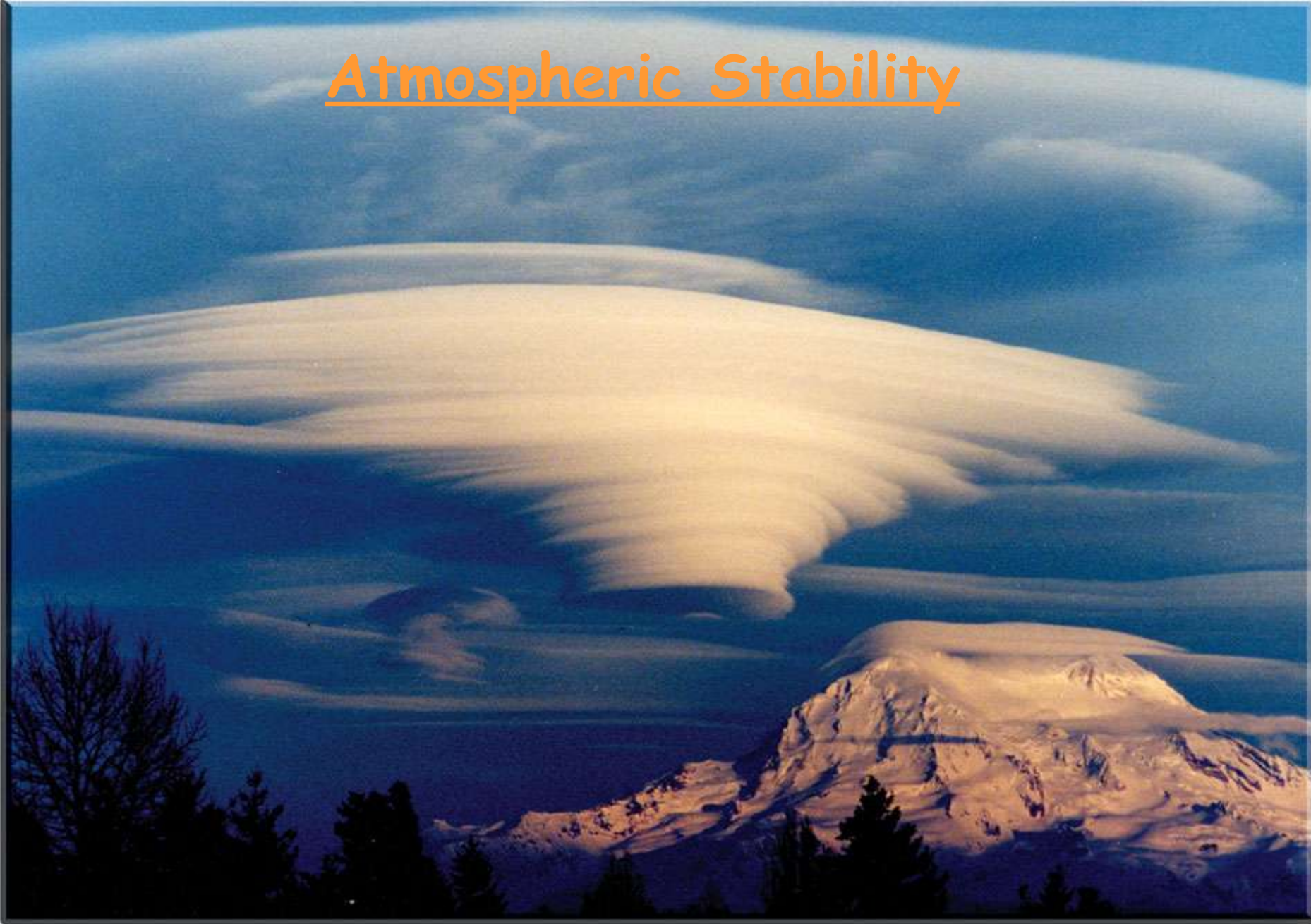


Atmospheric Stability



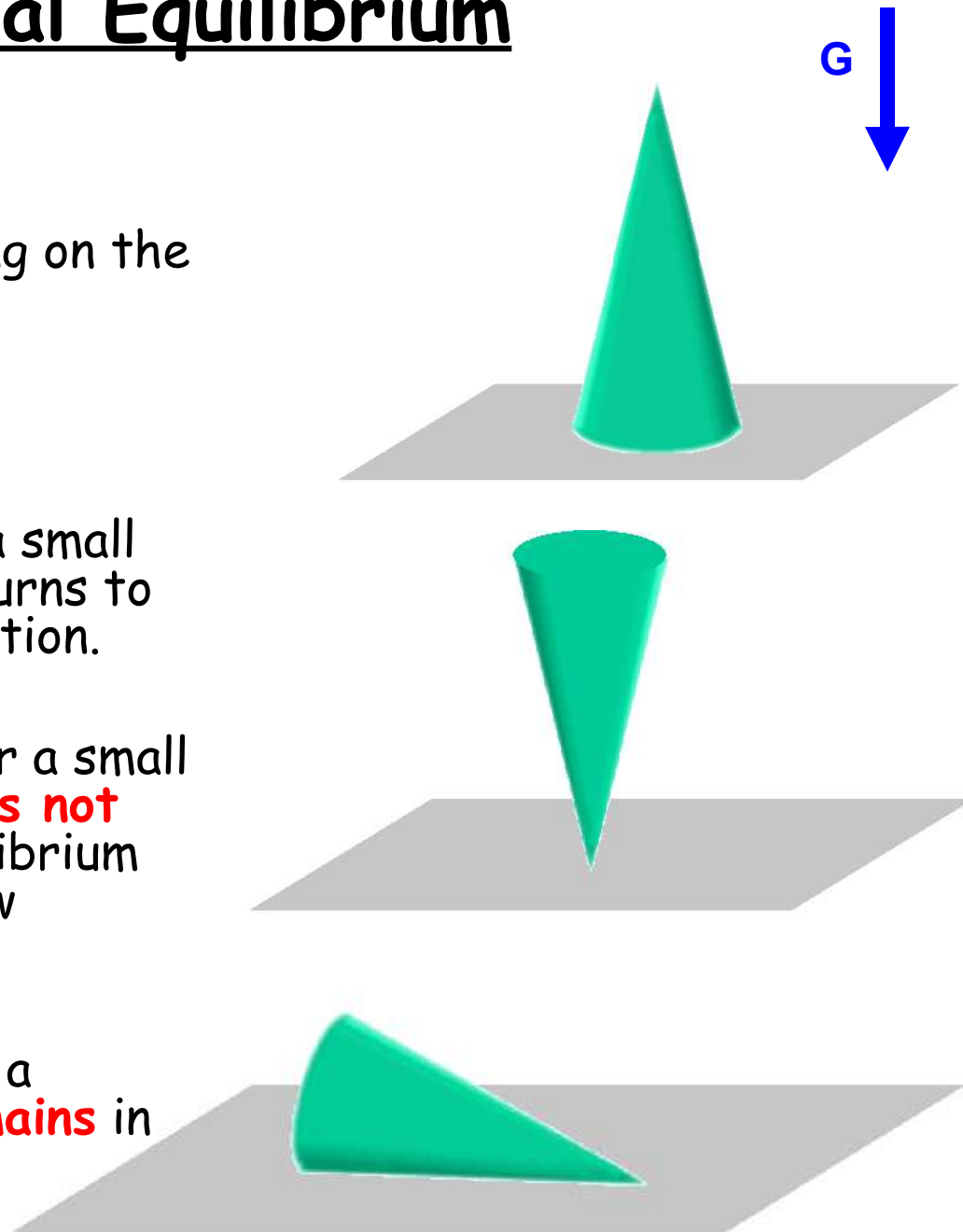
Mechanical Equilibrium

- **Equilibrium. Definition:**

- ◆ The body is at rest
- ◆ The sum of all forces acting on the body is zero.

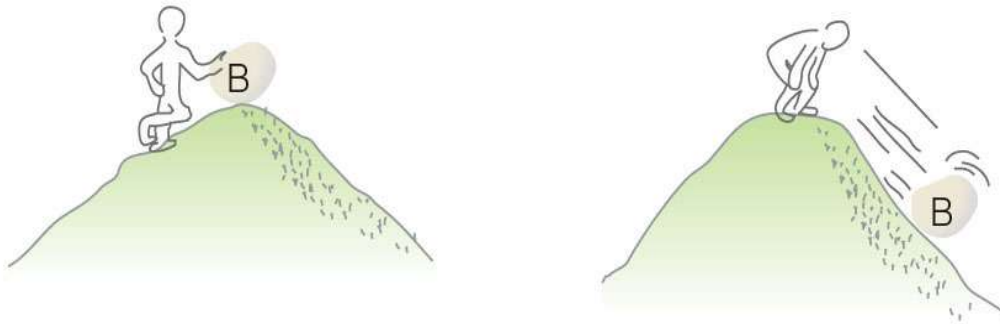
- **Types of equilibrium:**

- ◆ **Stable equilibrium:** after a small displacement the body returns to its **original** equilibrium position.
- ◆ **Unstable equilibrium:** after a small displacement the body **does not return** to the original equilibrium position and moves to a new equilibrium position.
- ◆ **Neutral equilibrium:** after a displacement the body **remains** in the displaced position.



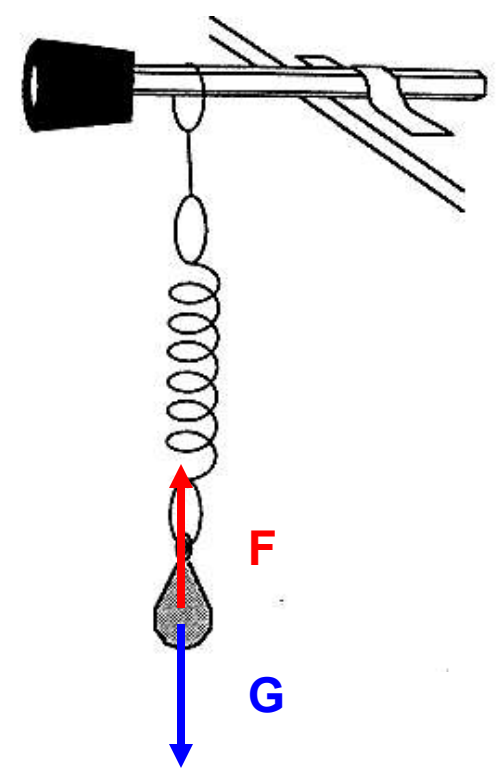


Stable equilibrium

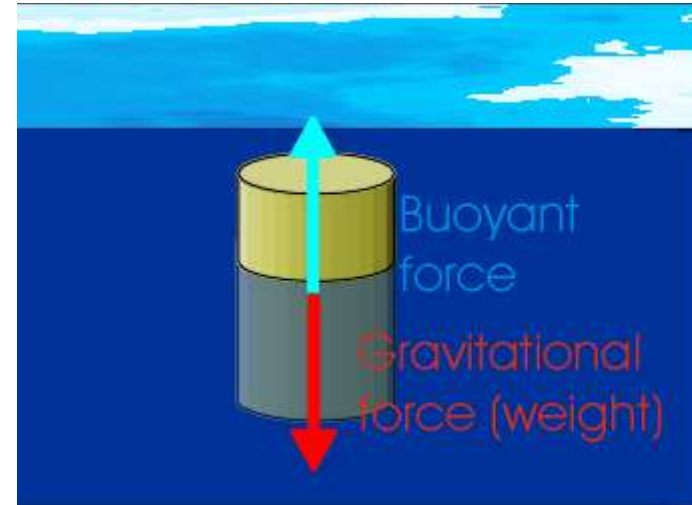


Unstable equilibrium

© 2007 Thomson Higher Education



Examples of mechanical equilibrium



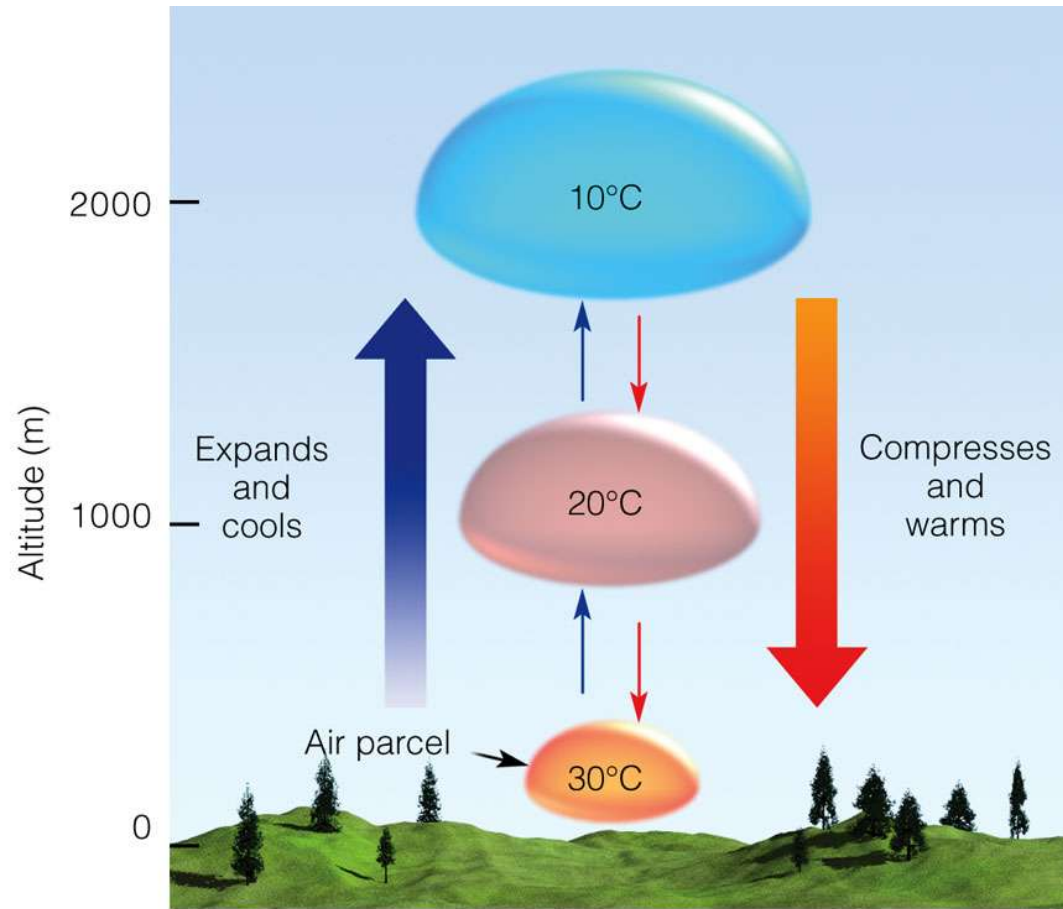
The principle of hot air balloon flight

Hot air rises in cooler air



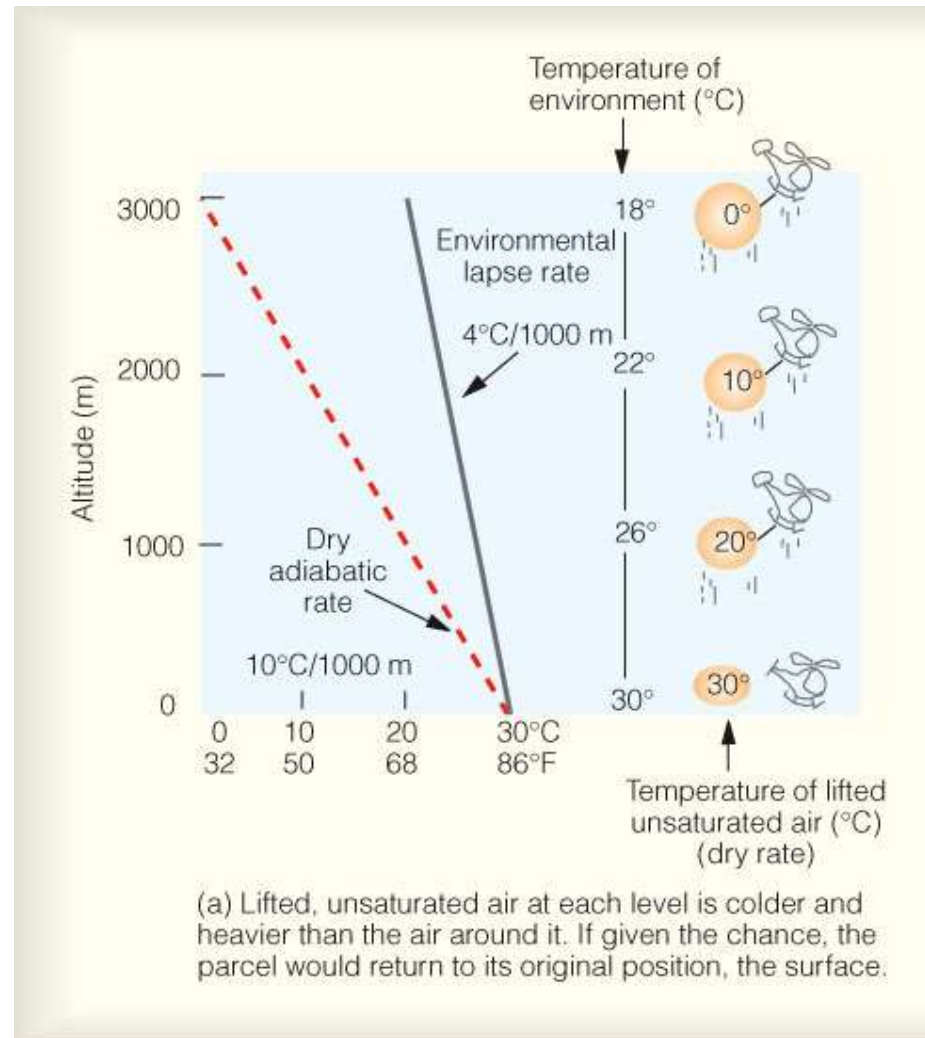
Adiabatic cooling/heating

- **Ascending motion:** the parcel of air expands, does work on the rest of the atmosphere and **cools down**.
- **Descending motion:** the air parcel compresses, work is done on the air parcel and it **warms up**.
- **Adiabatic process:** **no heat** is exchanged between the air parcel and the rest of the atmosphere



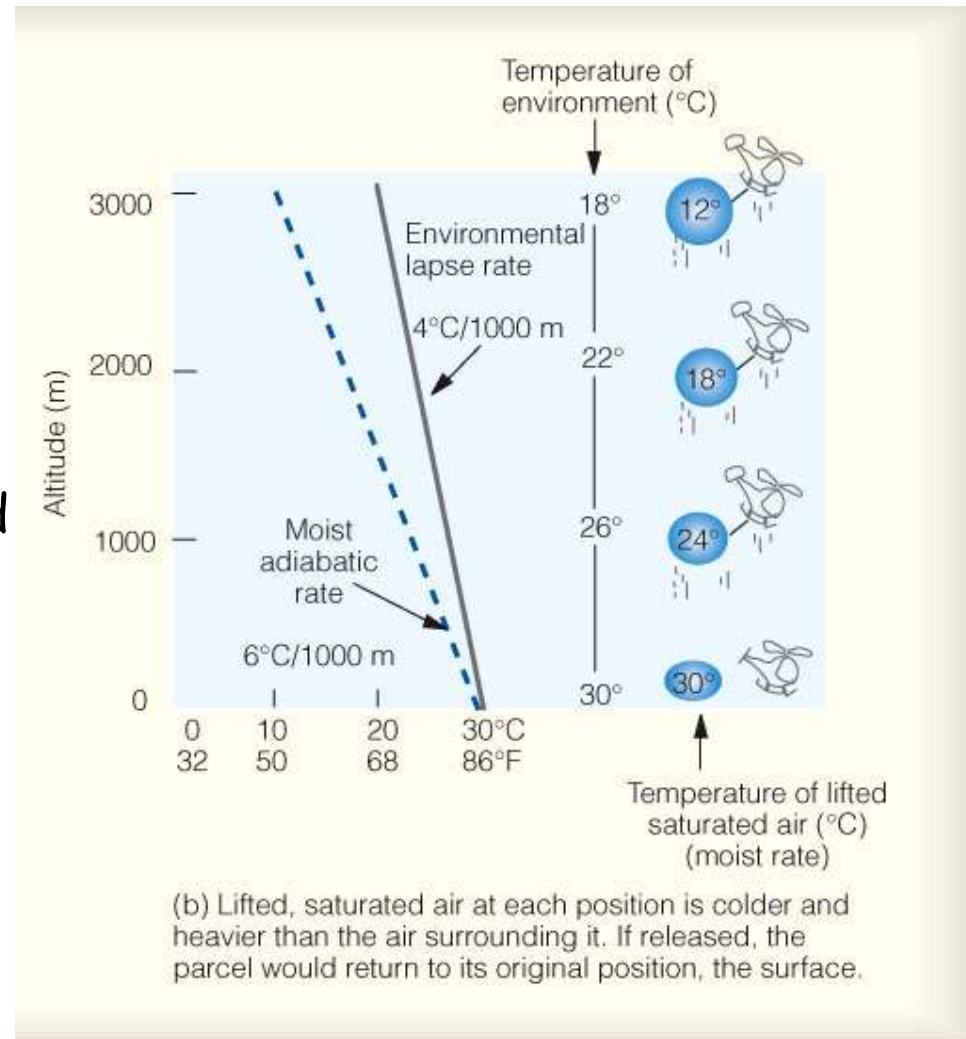
Adiabatic lapse rates

- **Adiabatic lapse rate:** the rate of change of the temperature of a rising (sinking) air parcel with altitude as a result of adiabatic expansion (compression).
- **Dry adiabatic lapse rate:** the air parcel is unsaturated ($RH < 100\%$), (otherwise condensation, latent heat, see below)
 - ◆ For the Earth: 10 deg C/km.
 - ◆ For Jupiter: 2 deg C/km.
- **Environmental lapse rate:** the actual rate of change of the temperature with height.



Moist adiabatic lapse rate

- A rising air parcel is cooling → its RH increases → air becomes saturated → condensation → latent heat released → partially offsets the cooling effect
- **Moist adiabatic lapse rate:** the adiabatic lapse rate for saturated air. It is the result of two competing effects:
 - ◆ Cooling due to expansion
 - ◆ Heating due to condensation
 - ◆ Cooling wins, but the resulting lapse rate is less than for dry air
 - ◆ For the Earth: ~ 6 deg C/km.
 - ◆ It depends on temperature and moisture content.



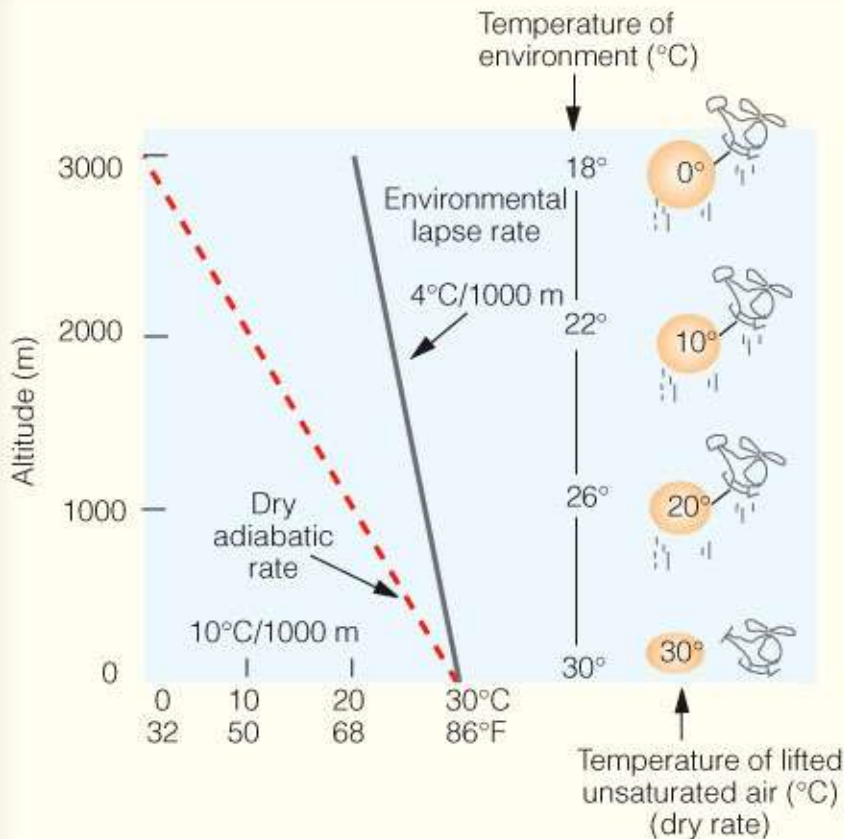
• **TABLE 6.1**

The Moist Adiabatic Rate for Different Temperatures and Pressures in °C/1000 m and °F/1000 ft

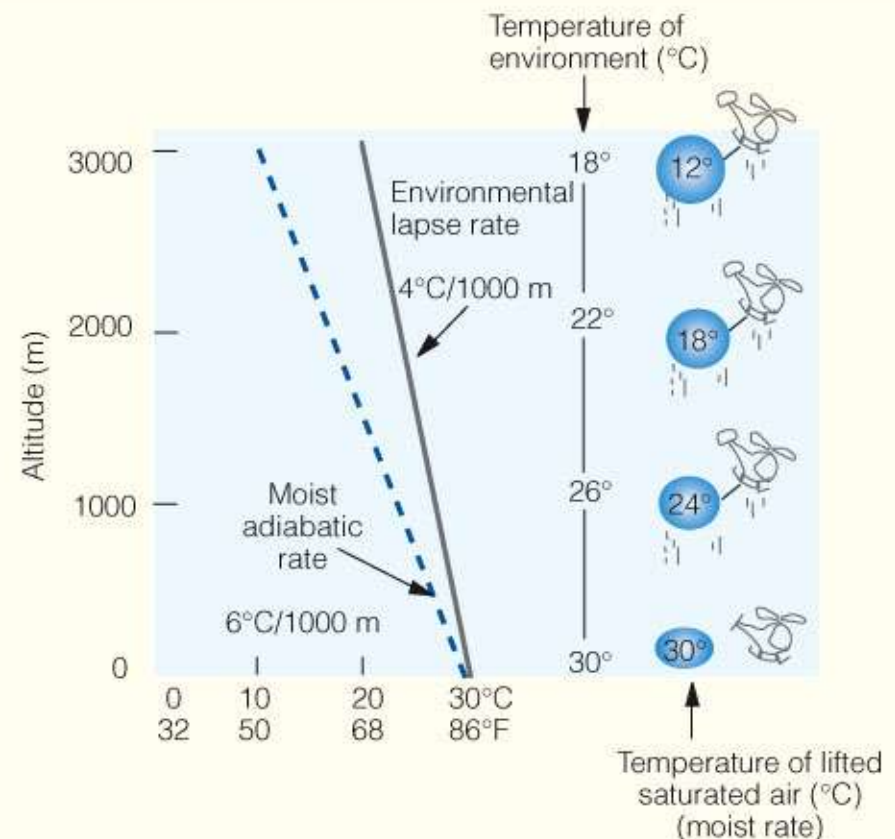
	TEMPERATURE (°C)					TEMPERATURE (°F)				
PRESSURE (MB)	-40	-20	0	20	40	-40	-5	30	65	100
1000	9.5	8.6	6.4	4.3	3.0	5.2	4.7	3.5	2.4	1.6
800	9.4	8.3	6.0	3.9		5.2	4.6	3.3	2.2	
600	9.3	7.9	5.4			5.1	4.4	3.0		
400	9.1	7.3				5.0	4.0			
200	8.6					4.7				

Dry versus moist adiabatic rate

- The moist adiabatic rate is **always less** than the dry rate



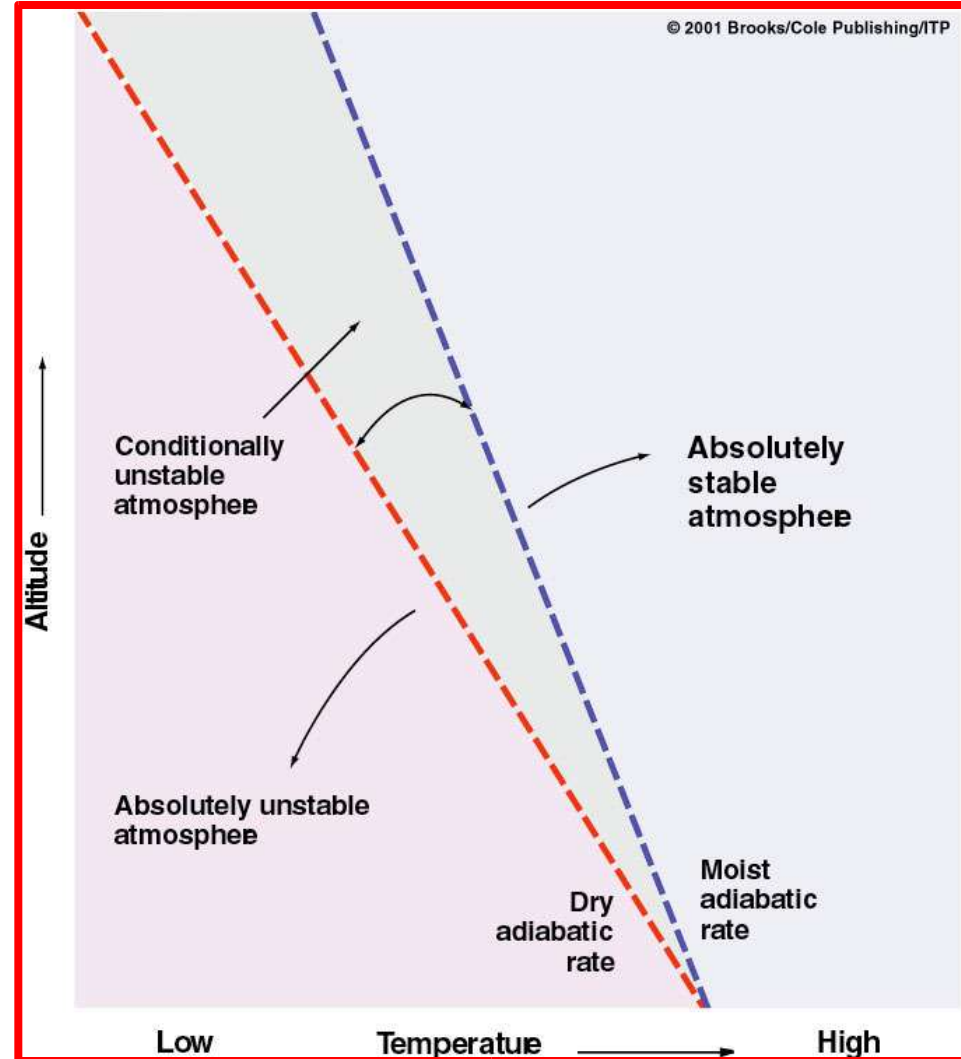
(a) Lifted, unsaturated air at each level is colder and heavier than the air around it. If given the chance, the parcel would return to its original position, the surface.



(b) Lifted, saturated air at each position is colder and heavier than the air surrounding it. If released, the parcel would return to its original position, the surface.

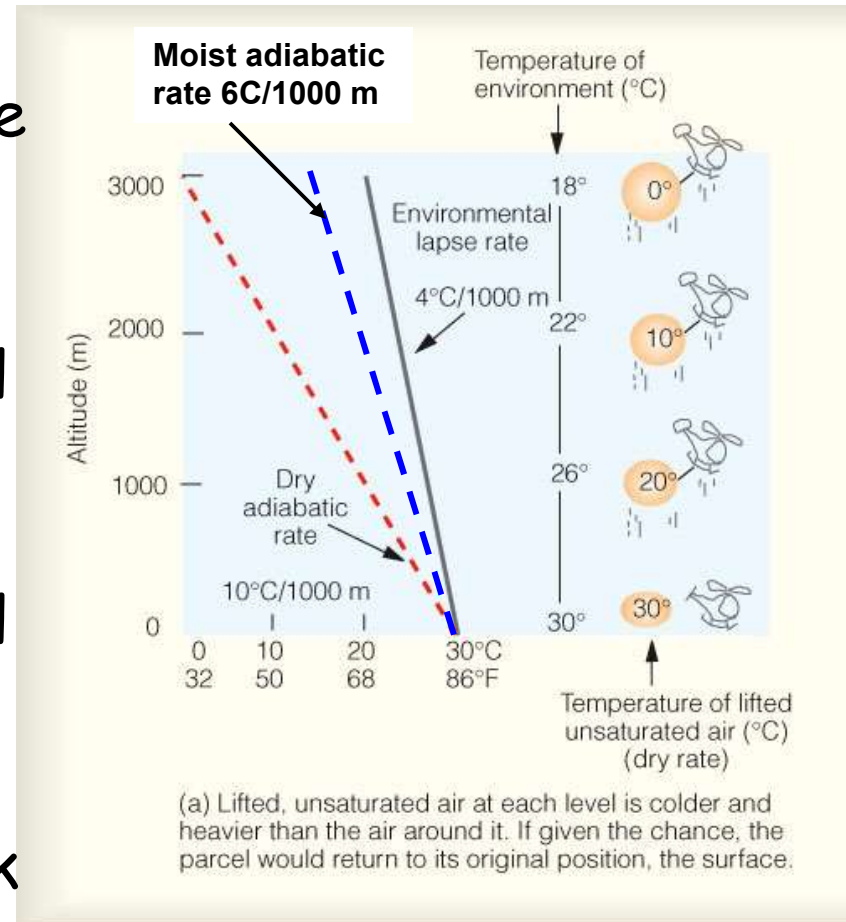
Where are we going from here?

- Consider the three (5?) distinct possibilities for the environmental lapse rate (not shown)
- In order to determine the stability of the atmosphere, think what happens to a rising air parcel.
- If the parcel is **colder** (**warmer**) than the environment it wants to go **down** (**up**)



Absolutely stable atmosphere

- The environmental lapse rate is less than both the moist and the dry adiabatic lapse rates.
- Why is the atmosphere stable?
 - ◆ The rising (sinking) air parcel is colder (warmer) than its surroundings.
 - ◆ The rising (sinking) air parcel is heavier (lighter) than its surroundings.
 - ◆ The parcel of air moves back to its original position.

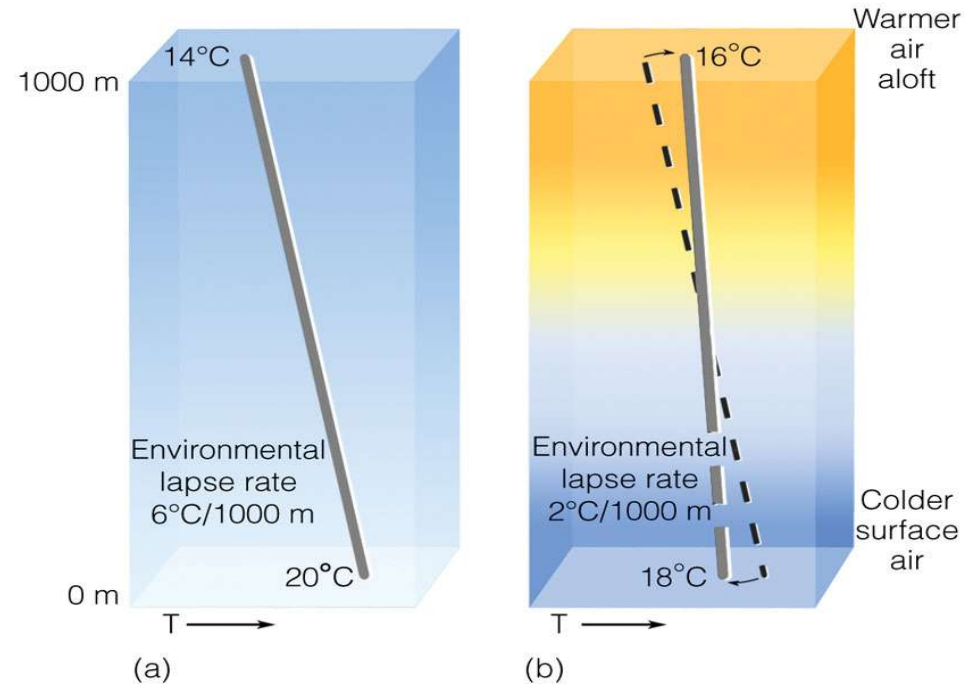


Absolutely stable atmosphere

- **Favorable conditions:**

- ◆ Temperature inversions: warm air above cold air.
- ◆ Small environmental lapse rate
 - Heating the air aloft.
 - Cooling the air below: radiational cooling; cold advection; air moving over a cold surface

- **Observed phenomena:** fog, haze.
- When forced to rise, stable air spreads out horizontally: clouds form in thin layers with flat tops and bases



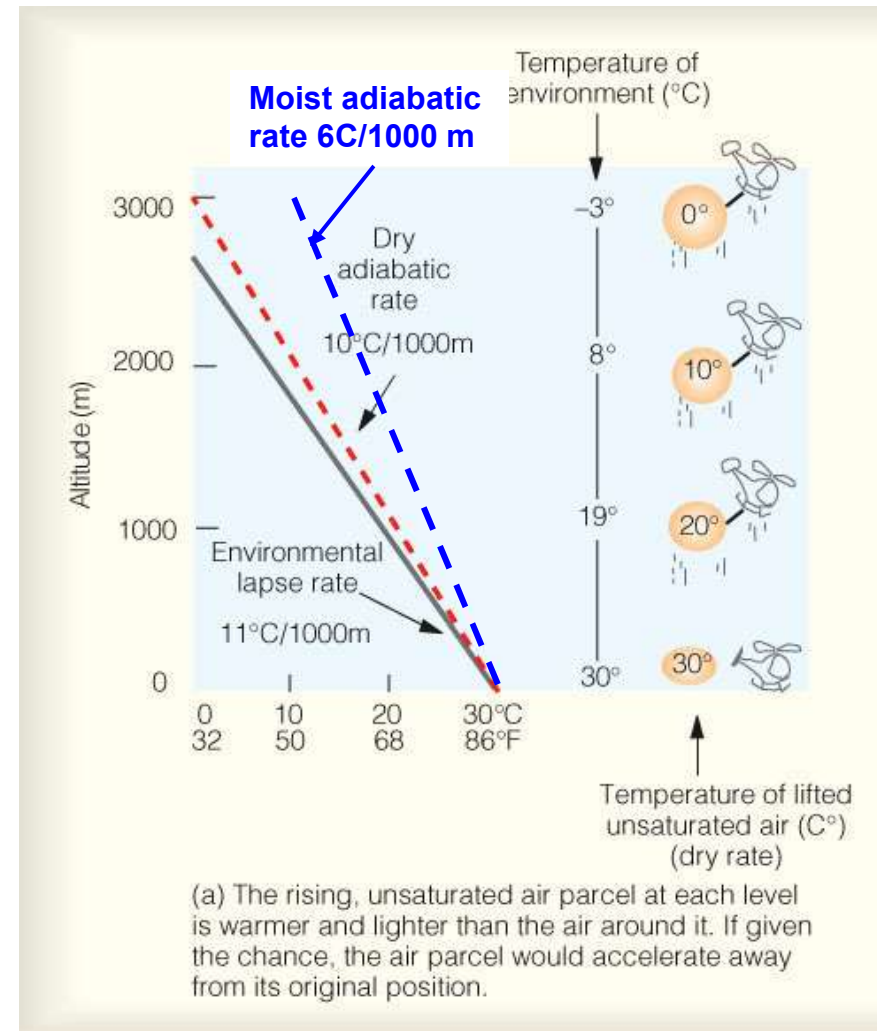
© 2007 Thomson Higher Education



© 2007 Thomson Higher Education

Absolutely unstable atmosphere

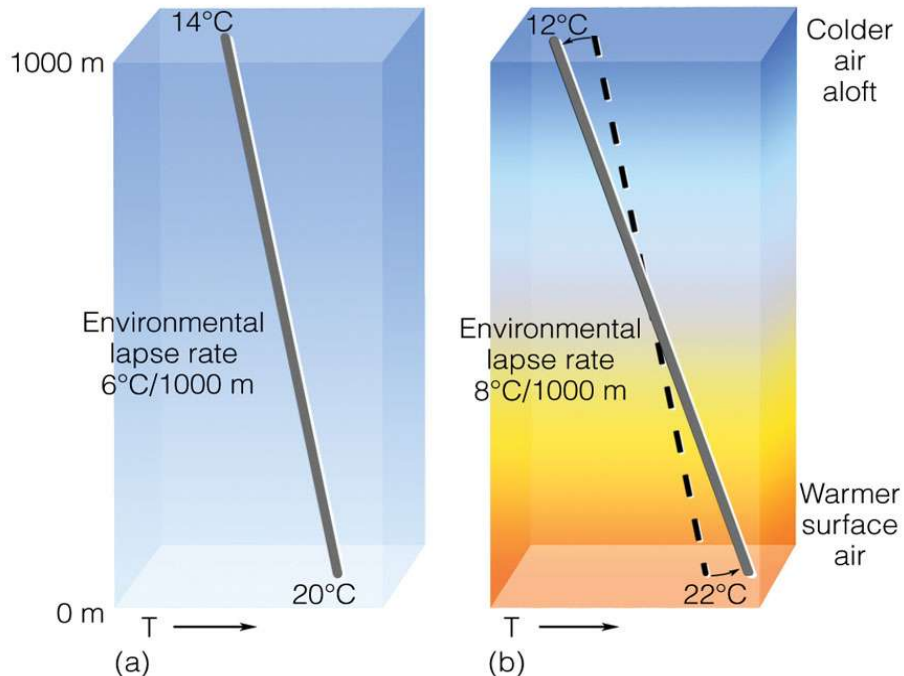
- The environmental lapse rate is larger than both the dry and the moist adiabatic lapse rates.
- Why is the air unstable?
 - ◆ The **rising** (**sinking**) air parcel is **warmer** (**colder**) than its surroundings.
 - ◆ The **rising** (**sinking**) air parcel is **lighter** (**heavier**) than its surroundings.
 - ◆ The parcel of air keeps moving...



Absolutely unstable atmosphere

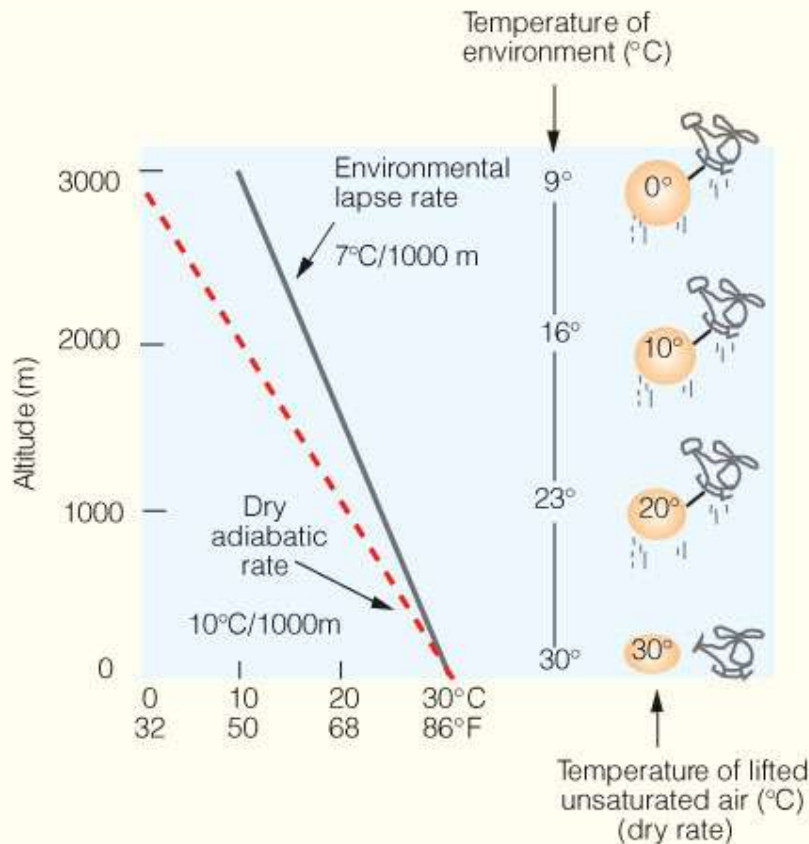
- **Favorable conditions:**

- ◆ Large environmental lapse rate
 - Cooling the air aloft: cold winds, cloud IR radiation
 - Heating the air below: solar heating; warm air advection; wind over a warm surface, forest fires

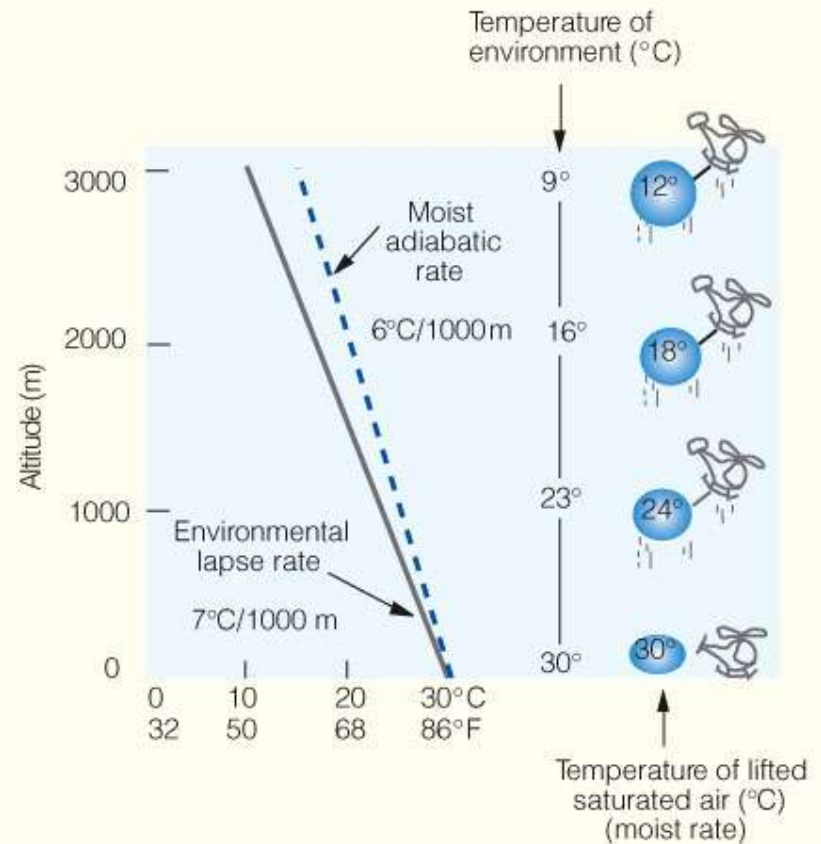


Conditionally unstable atmosphere

- The environmental lapse rate is smaller than the dry but larger than the moist adiabatic lapse rate.



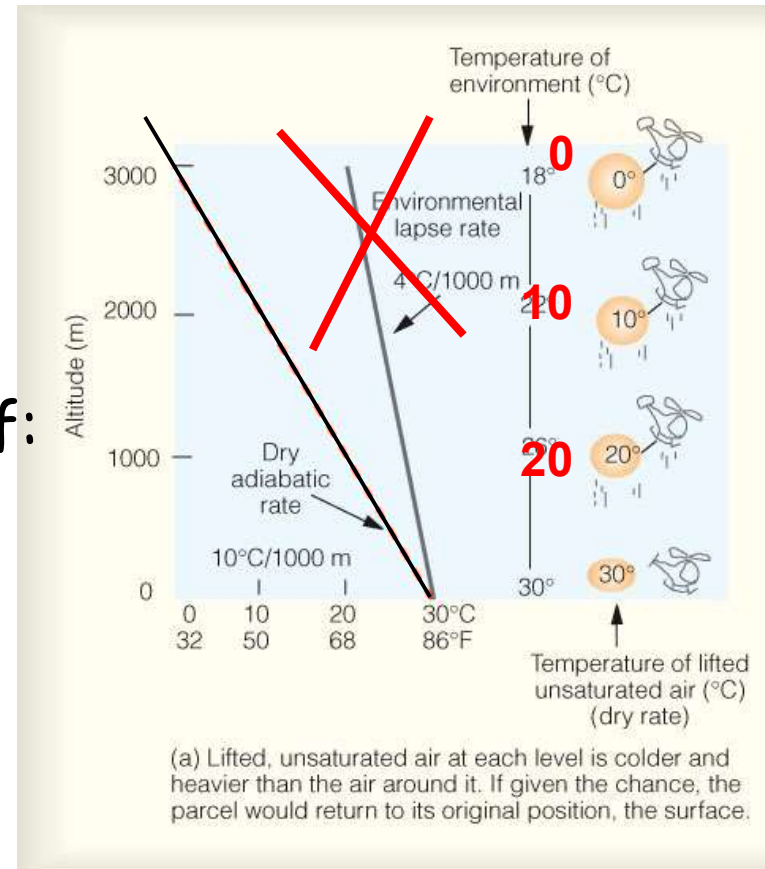
(a) The unsaturated parcel of air at each elevation is colder than its surroundings. The atmosphere is stable with respect to unsaturated, rising air.



(b) The lifted, saturated air parcel is warmer at each elevation than its surroundings. The atmosphere is unstable with respect to saturated, rising air.

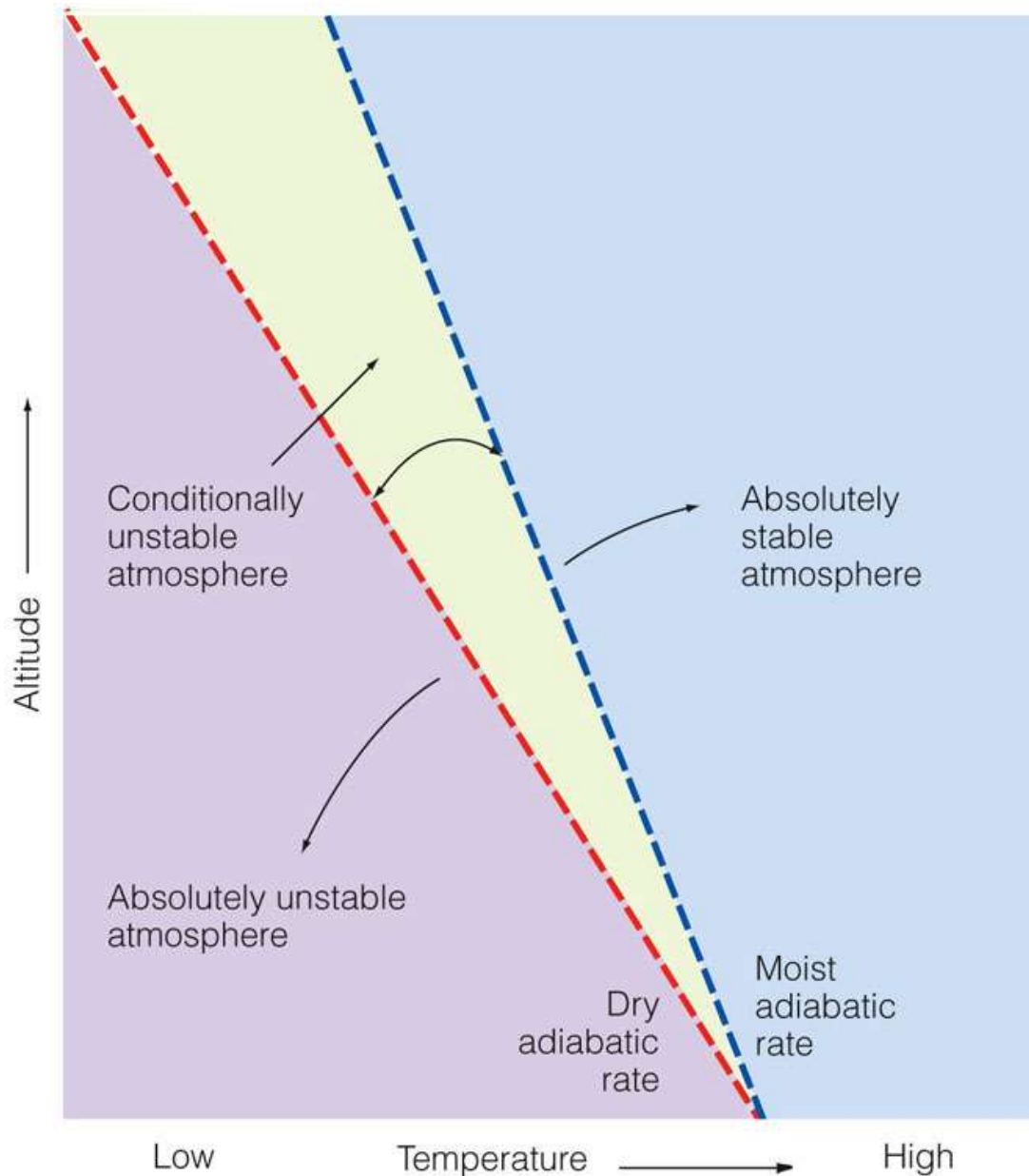
Neutral Stability

- **Dry air** is neutrally stable if:
 - ◆ the environmental lapse rate is equal to the dry adiabatic lapse rate.
- **Saturated air** is neutrally stable if:
 - ◆ The environmental lapse rate is equal to the moist lapse rate.
- Rising air cools off exactly at the same rate as the surrounding air.
The air parcel will neither tend to rise nor tend to sink if left on its own



© 2007 Thomson Higher Education

Summary chart - air stability



Air Stability During the Day

- The stability of the atmosphere varies with time
- In the **early morning**:
 - ◆ Radiative cooling of the ground (T inversion)
 - ◆ The atmosphere is stable.
 - ◆ Fog, haze or stratus clouds are typically observed.
- In the **afternoon**:
 - ◆ The ground reaches maximum temperature.
 - ◆ The air above becomes unstable.
 - ◆ The air is convective and moist air rises.
 - ◆ Late afternoon cumulus clouds are formed and thunderstorms develop.

