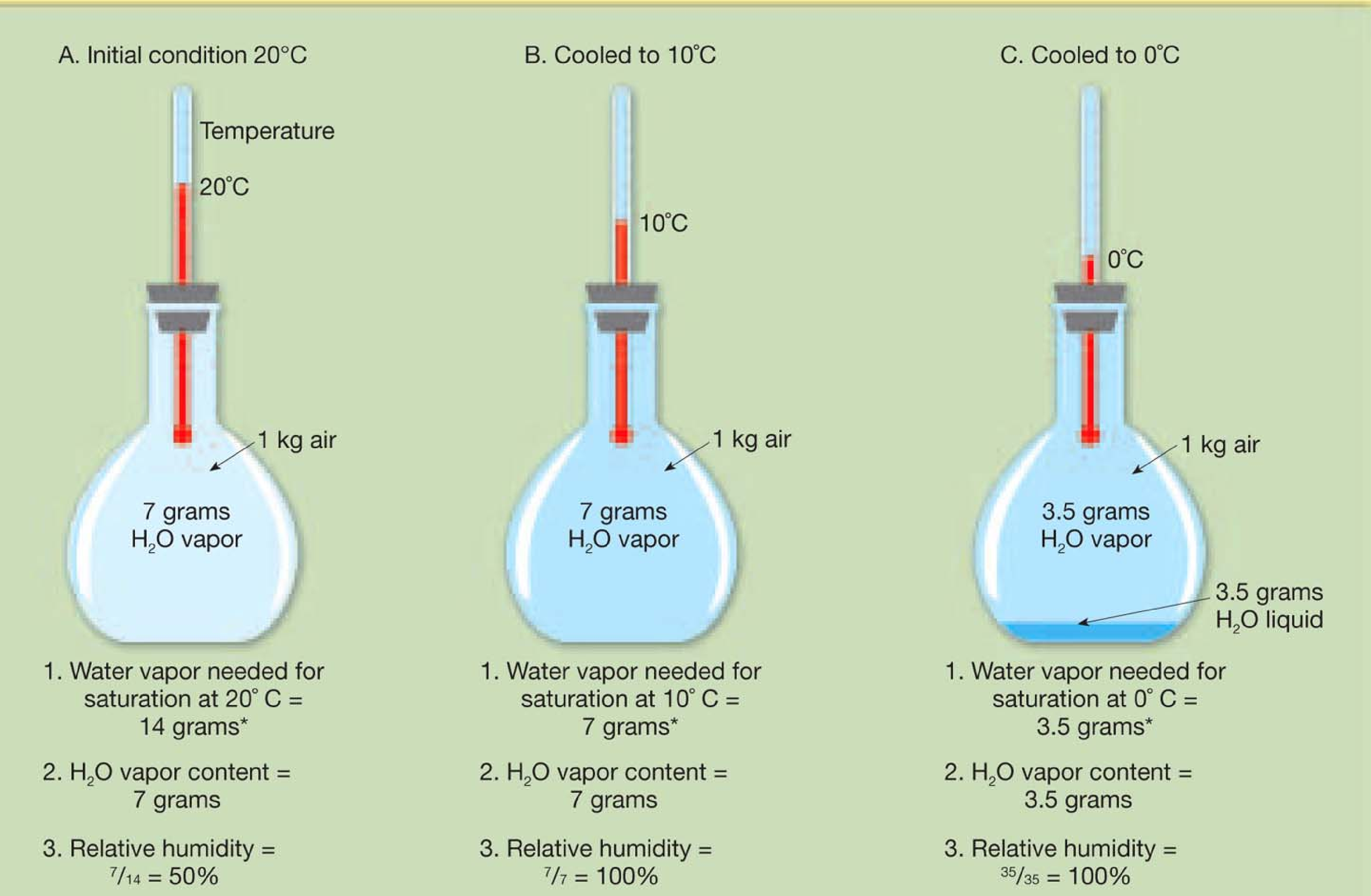
Humidity and Atmospheric Moisture

Latent Heat of Water
Atmospheric Temperature Change

click here for 9/page to print

Humidity

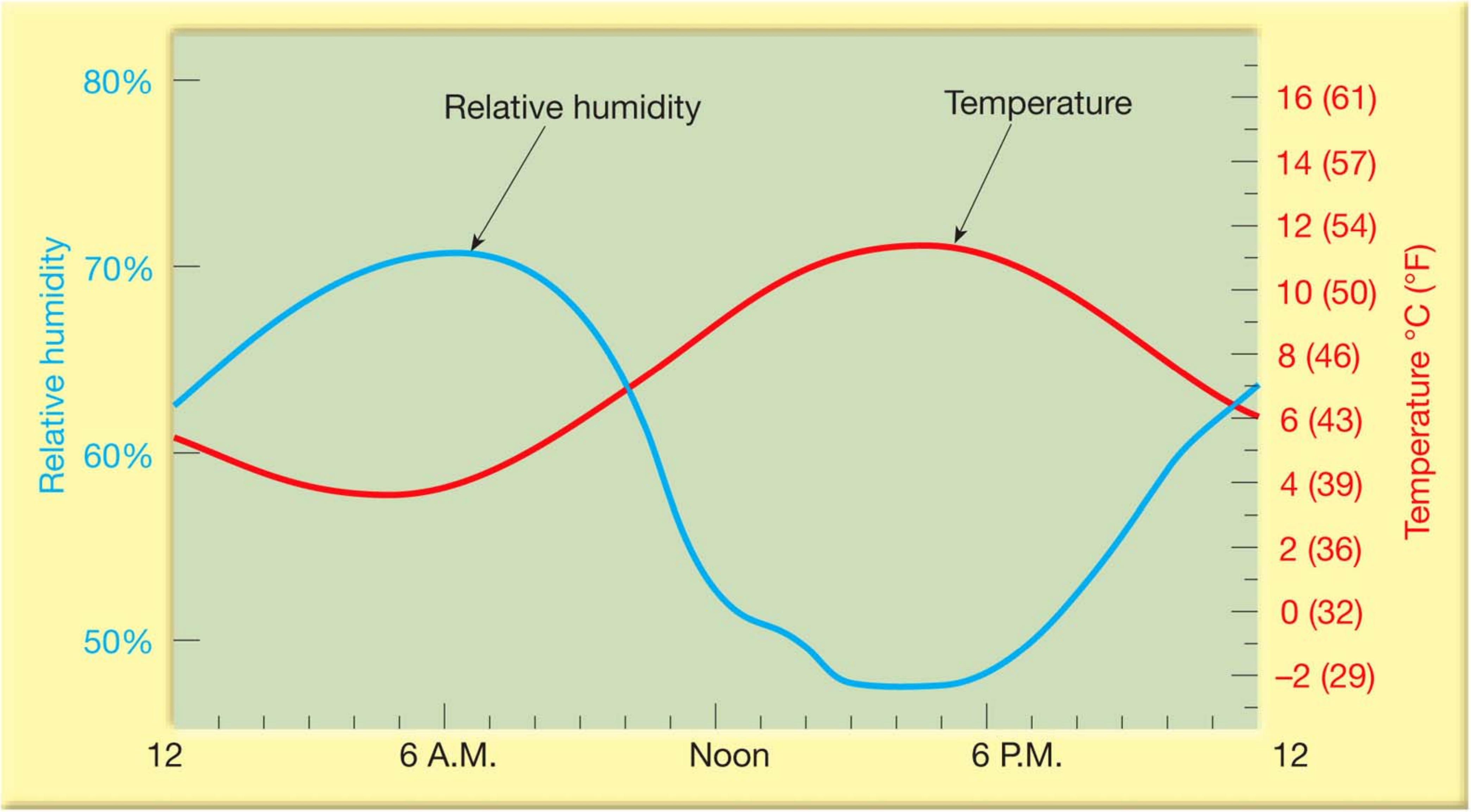
- Description of how much water air contains
- Relative Humidity compares how much moisture is in the air, to how much moisture the air could hold
- The amount of water that air can hold is a function of temperature


A. Initial condition 20°C
Temperature
20˚C
1 kg air
7 grams
H2O vapor
1. Water vapor needed for saturation at 20˚ C = 14 grams*
2. H2O vapor content = 7 grams
3. Relative humidity = 7/14 = 50%
B. Cooled to 10˚C
10˚C
1 kg air
7 grams
H2O vapor
1. Water vapor needed for saturation at 10˚ C = 7 grams*
2. H2O vapor content = 7 grams
3. Relative humidity = 7/7 = 100%
C. Cooled to 0˚C
0˚C
1 kg air
3.5 grams
H2O vapor
3.5 grams
H2O liquid
1. Water vapor needed for saturation at 0˚ C = 3.5 grams*
2. H2O vapor content = 3.5 grams
3. Relative humidity = 35/35 = 100%

ble 17.1

Dew Point Temperature

- The air cools to the temperature that it has 100% relative humidity
- Air is SATURATED at 100% RH
- This temperature is the DEW POINT TEMPERATURE

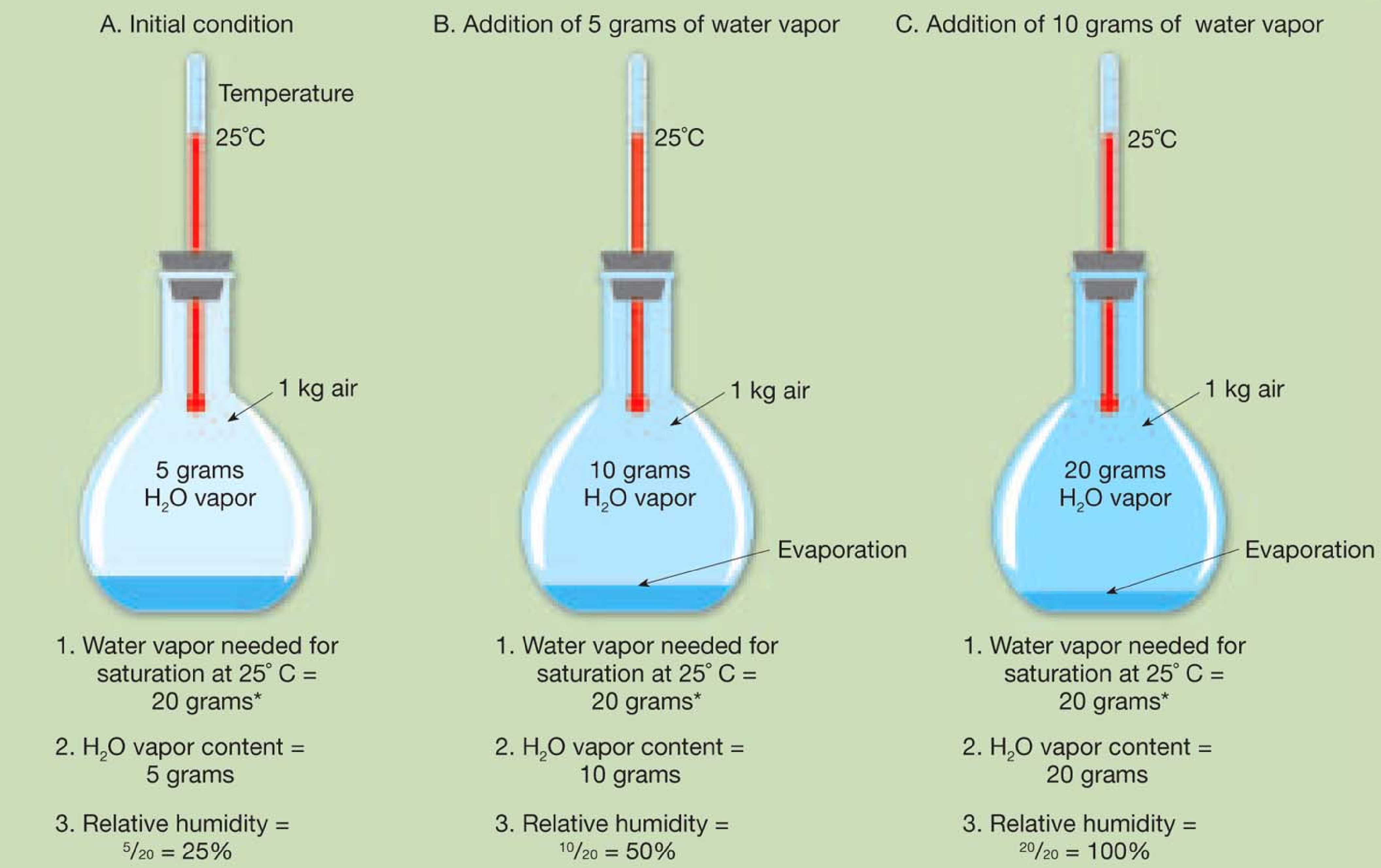


80%
70%
60%
50%
Relative humidity
Relative humidity
Temperature
16 (61)
14 (57)
12 (54)
10 (50)
8 (46)
6 (43)
4 (39)
2 (36)
0 (32)
–2 (29)
Temperature °C (°F)
12
6 A.M.
Noon
6 P.M.
12

Changes of humidity

- Can warm or cool air, and not change water content
- Will result in different relative humidity

- Can increase or decrease water content of air without change in temperature



A. Initial condition
Temperature
25°C
1 kg air
5 grams
H_2O vapor
1. Water vapor needed for saturation at 25° C = 20 grams*
2. H_2O vapor content = 5 grams
3. Relative humidity = $^{5}/_{20}$ = 25%
B. Addition of 5 grams of water vapor
25°C
1 kg air
10 grams
H_2O vapor
Evaporation
1. Water vapor needed for saturation at 25° C = 20 grams*
2. H_2O vapor content = 10 grams
3. Relative humidity = $^{10}/_{20}$ = 50%
C. Addition of 10 grams of water vapor
25°C
1 kg air
20 grams
H_2O vapor
Evaporation
1. Water vapor needed for saturation at 25° C = 20 grams*
2. H_2O vapor content = 20 grams
3. Relative humidity = $^{20}/_{20}$ = 100%

able 17.1

Sling psychrometer

- Dry bulb is air temperature
- Wet bulb has lower temperature due to evaporation
- Temperature of wet bulb depends on how much moisture is in the atmosphere

Relative Humidity

- Can calculate the amount of water in the air from the relative humidity, if you know the air temperature and the amount of water the air could hold at that temperature

$$\frac{RH\%}{100} \cdot \left(\begin{array}{c} \text{amount of water} \\ \text{the air could hold} \end{array} \right) = \left(\begin{array}{c} \text{amount of water} \\ \text{the air has} \end{array} \right)$$

Changes in temperature with change in elevation

- Two different mechanisms
  - Earth's atmosphere is heated from below
  - Gases cool as they expand

Environmental Lapse Rate

- Earth's atmosphere is heated from below
- Regularly cooler at greater distances from Earth's surface
- Varies with moisture, temperature, cloud cover, and other local conditions

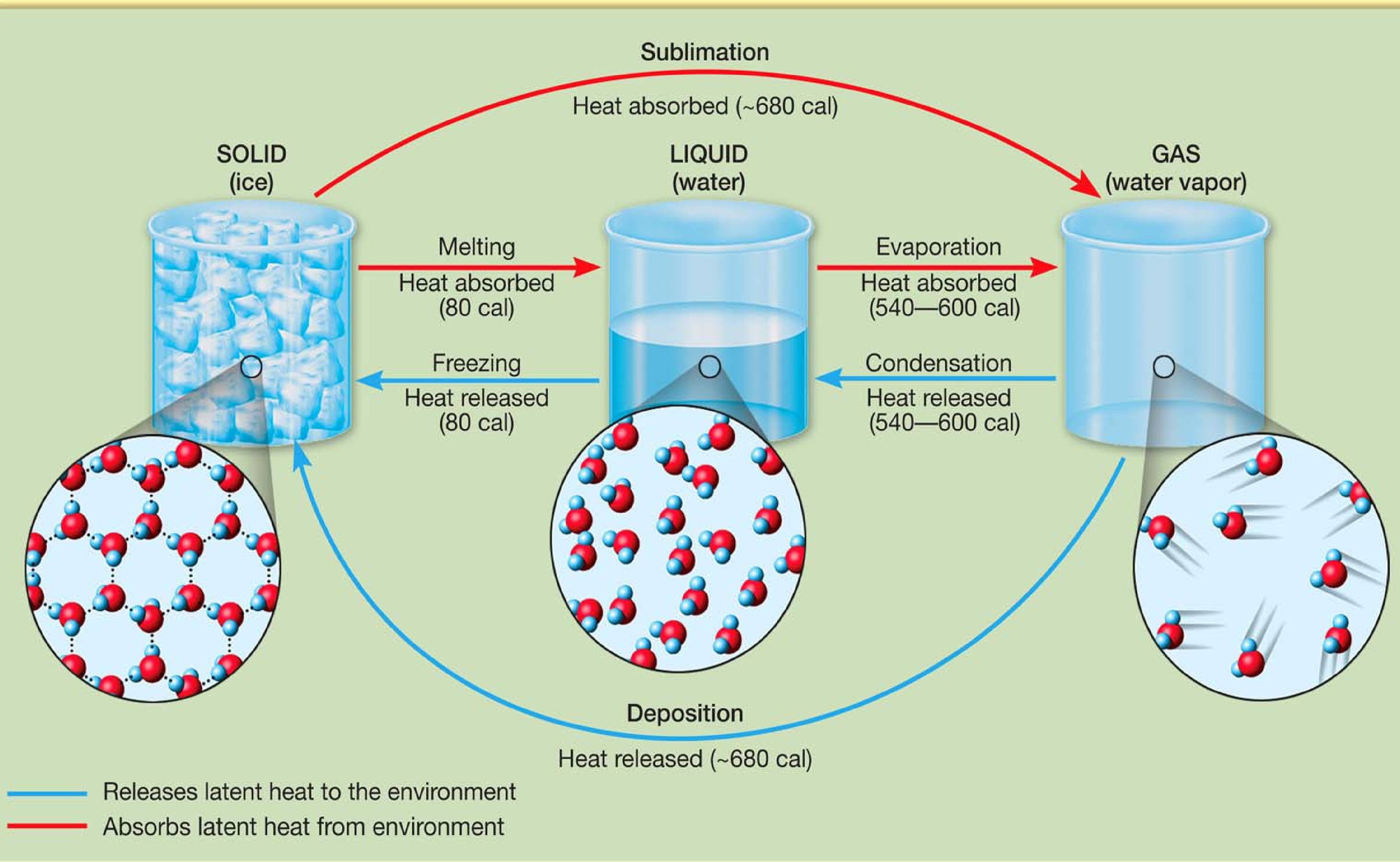
Gases cool as they expand

- Still have same heat energy
- Take up larger volume
- Increase in volume at lower pressure
- Atmospheric pressure declines with altitude
- Temperature change due to change in volume called “**Adiabatic lapse rate**”

Latent Heat of Water

- Heat energy that water releases or absorbs when it changes phase
- Gains it from environment as it melts or evaporates
  - So it cools the environment
- Loses it when it freezes or condenses
  - So it warms the environment

Latent heat of water

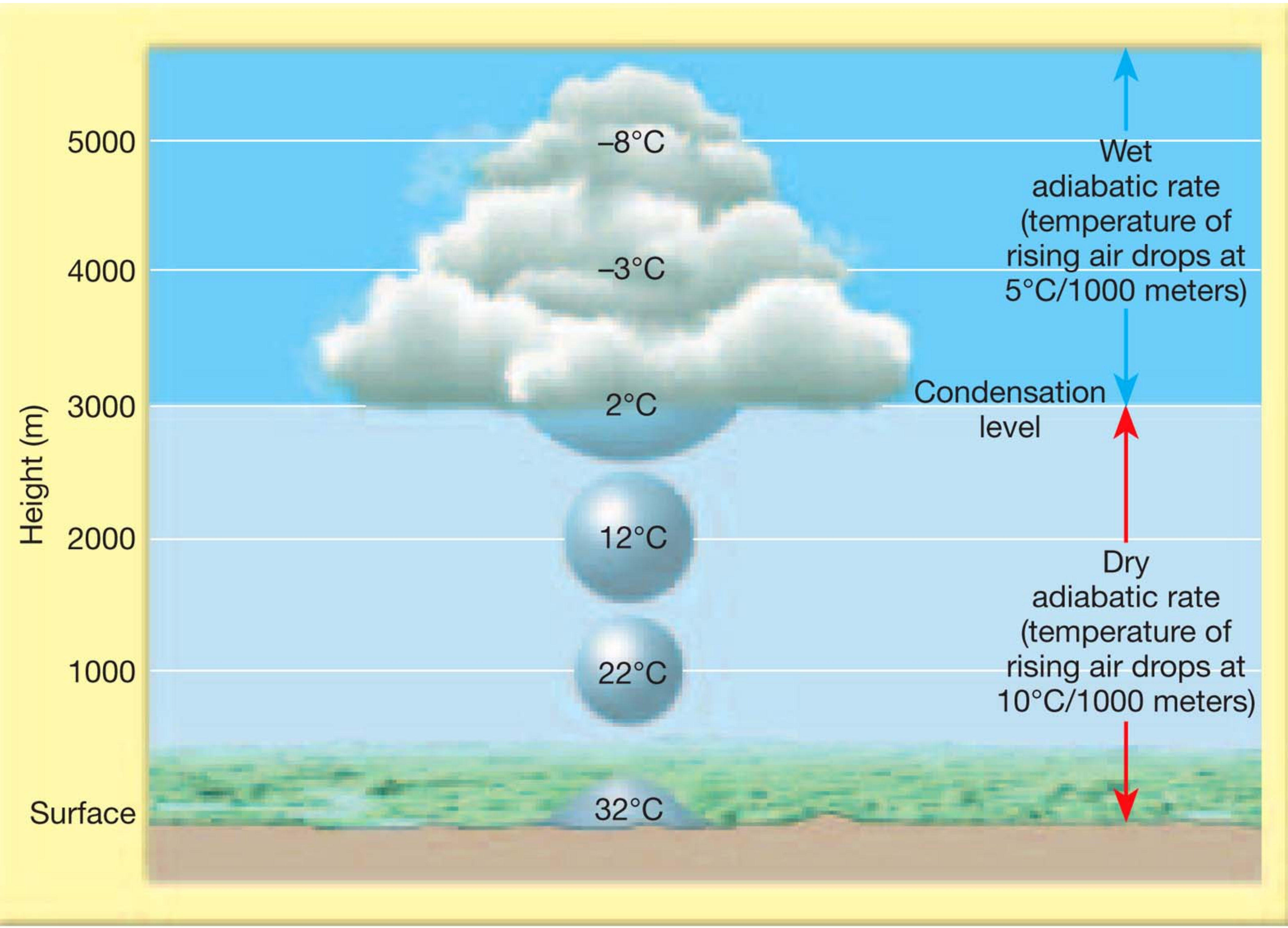


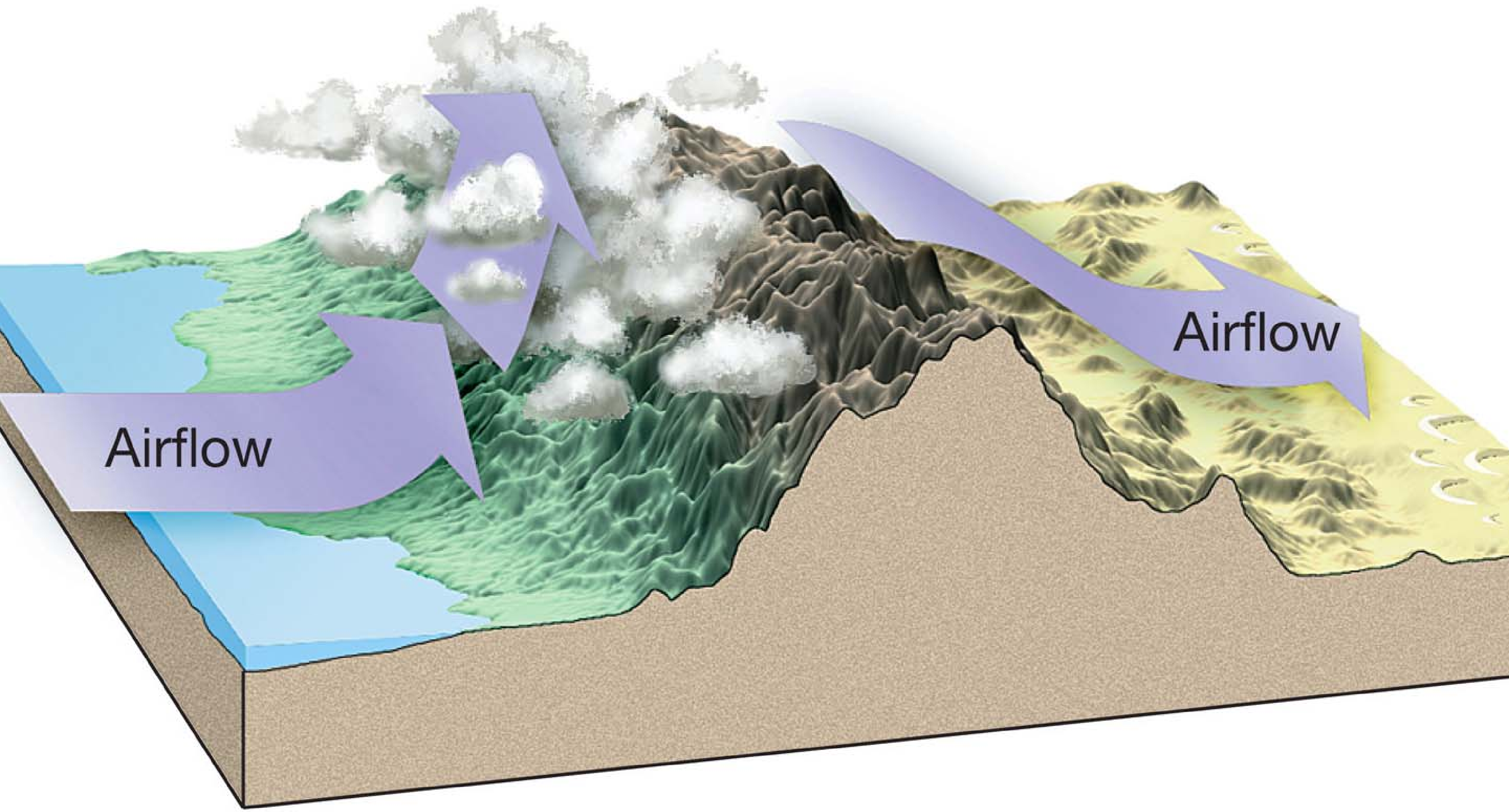
Adiabatic lapse rate

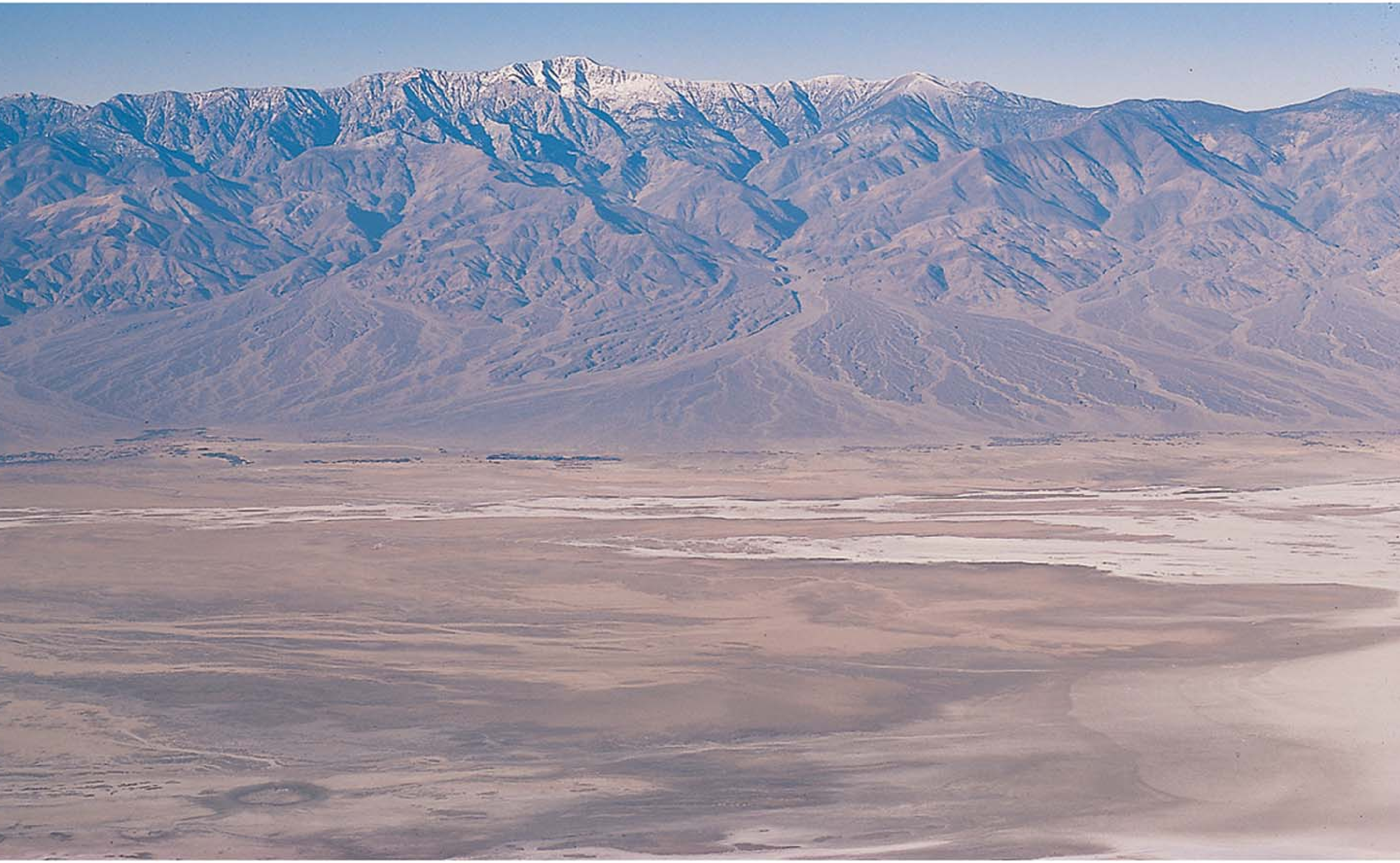
- Temperature declines with lowering pressure, as air moves to higher altitude
- Temperature increases with increasing pressure, as air moves to lower altitude

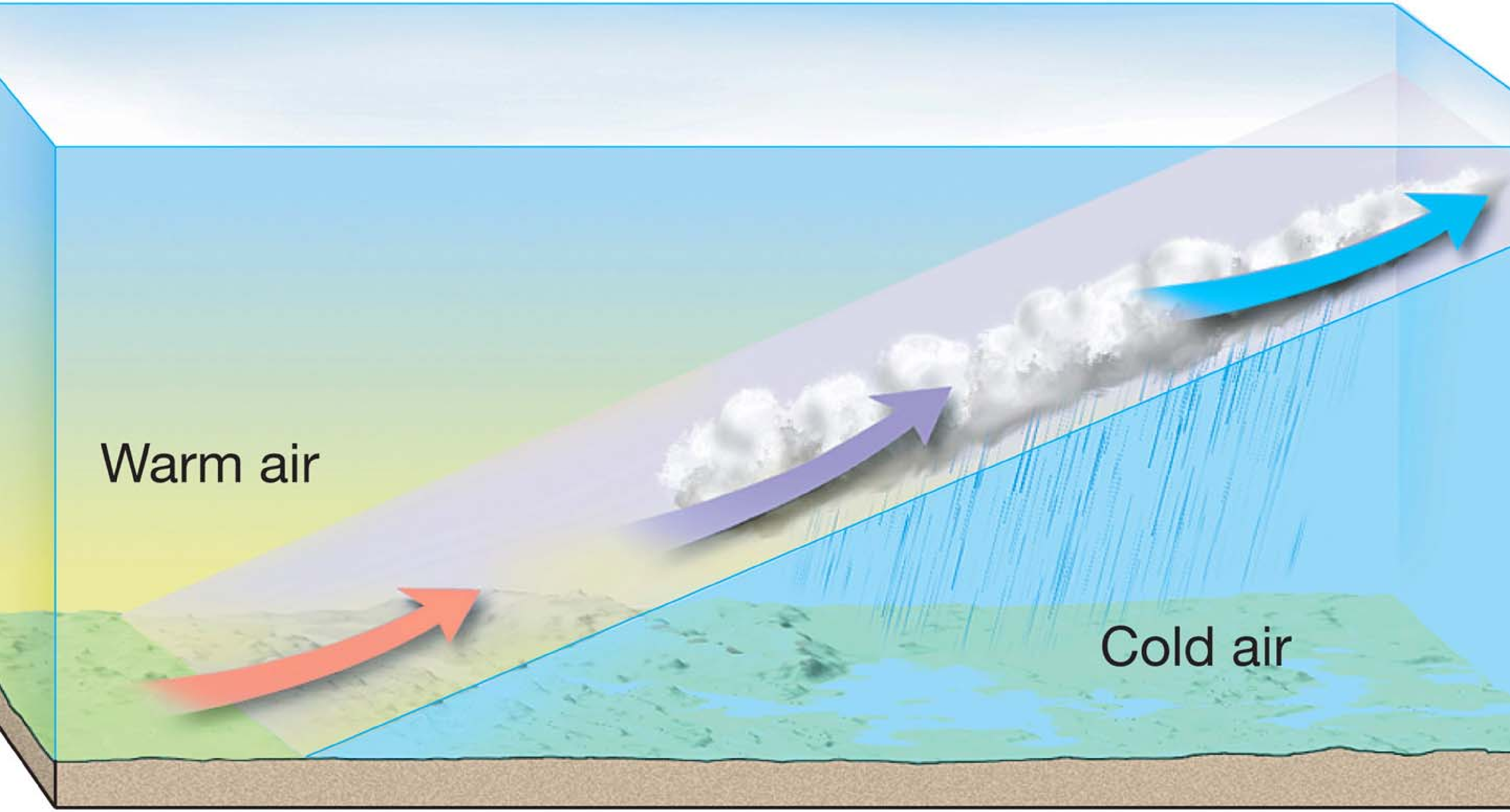
Adiabatic lapse rate

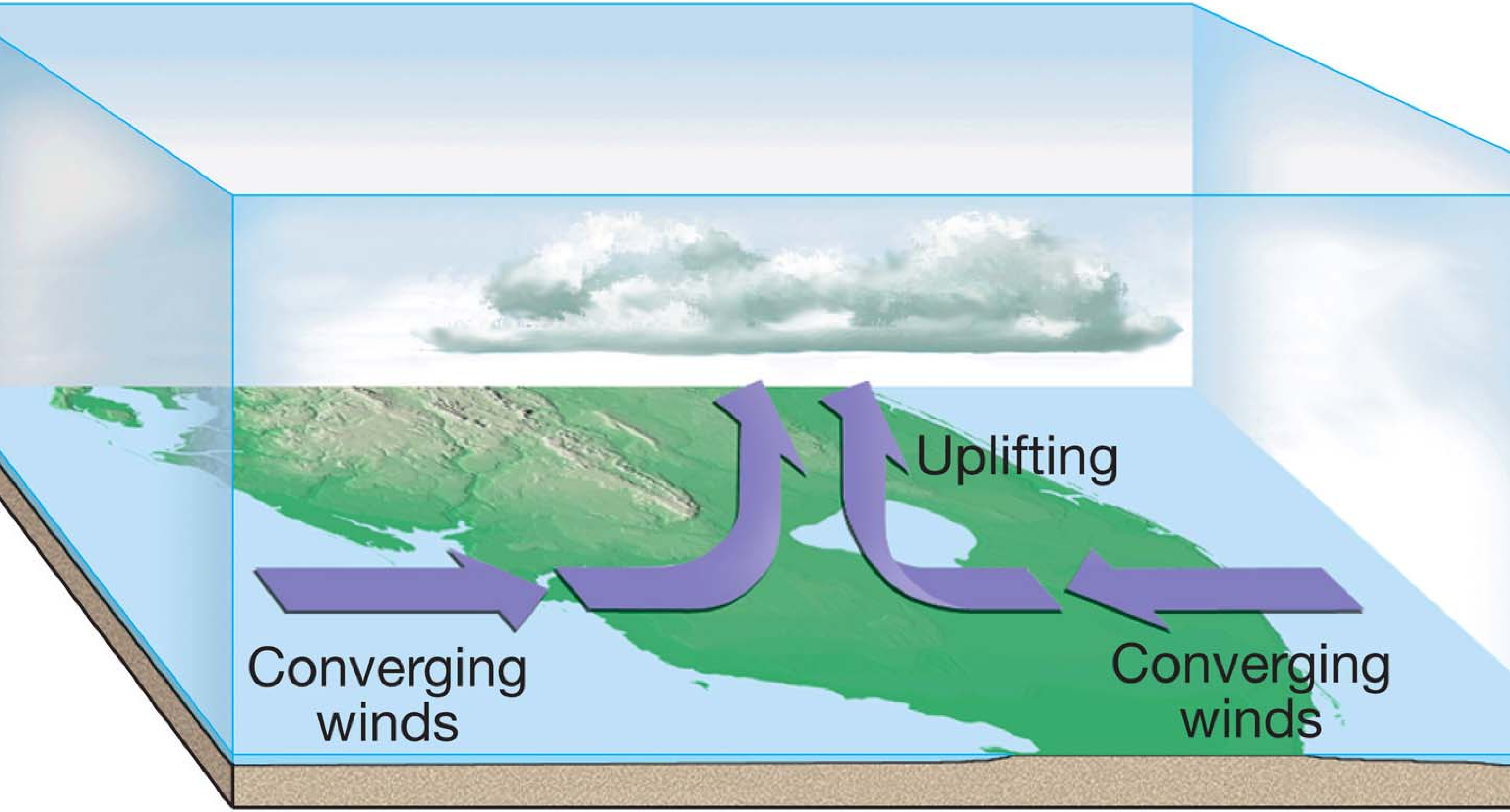
- Rate of temperature change depends on saturation
- Saturated air has condensation of water, which releases heat: warms environment
  - 10^{o} C / 1000 m if not saturated
  - 5^{o} C / 1000 m if condensation is occurring


5000
4000
3000
2000
1000
Surface
Height (m)
–8°C
–3°C
2°C
12°C
22°C
32°C
Wet adiabatic rate (temperature of rising air drops at 5°C/1000 meters)
Condensation level
Dry adiabatic rate (temperature of rising air drops at 10°C/1000 meters)

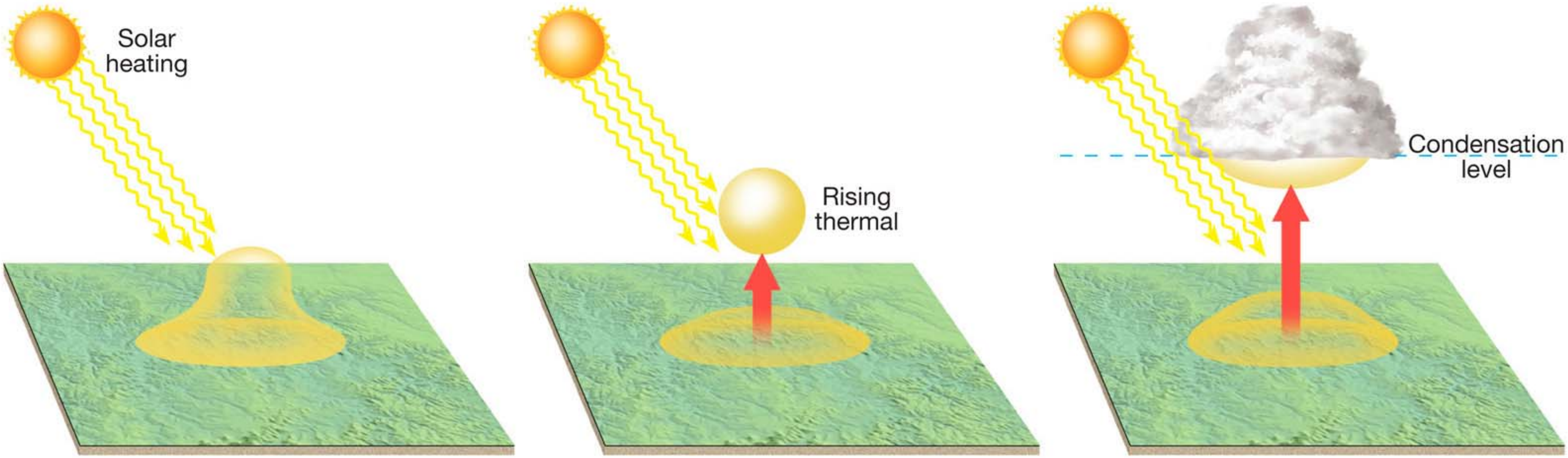

Airflow
Airflow

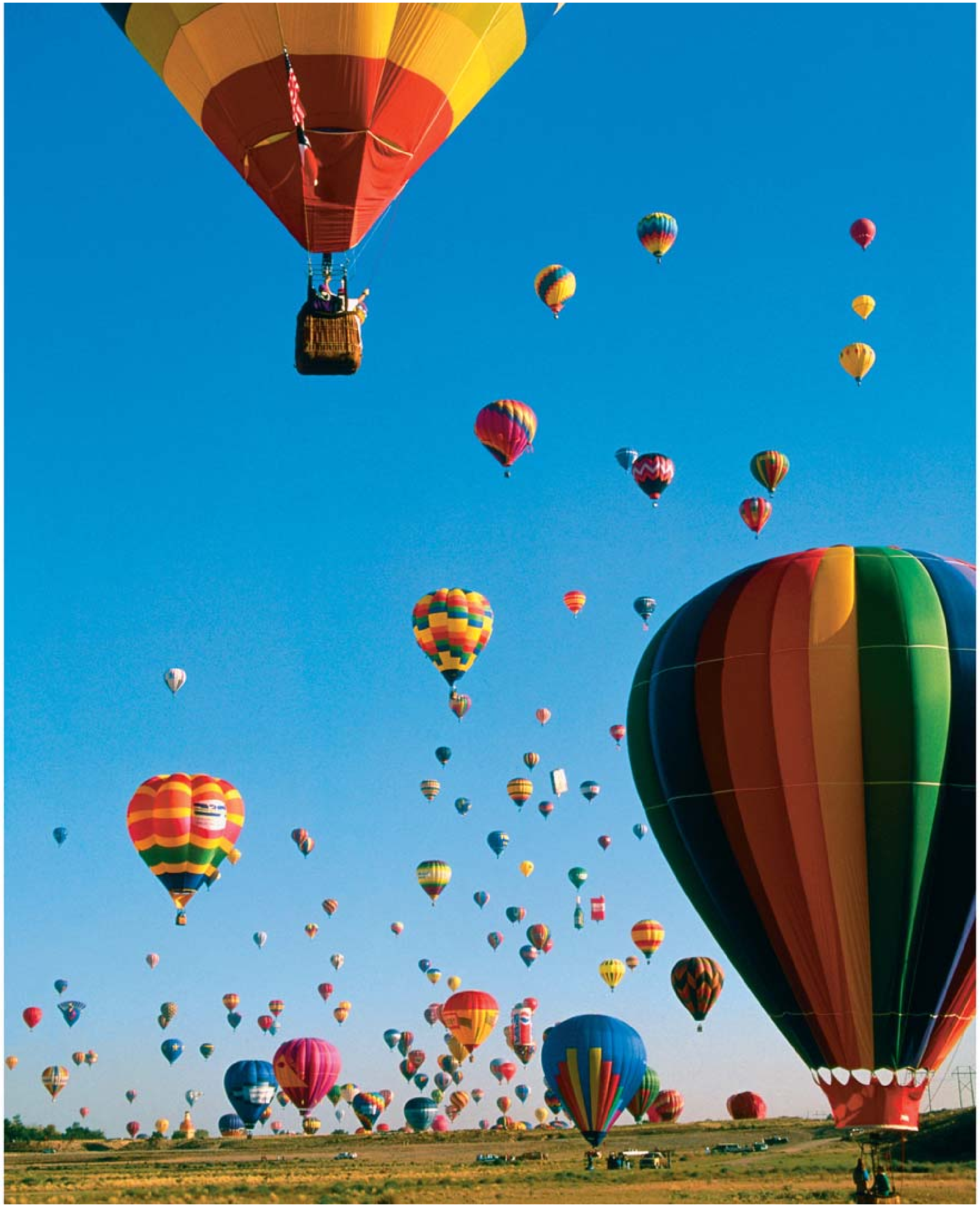



Warm air
Cold air


Uplifting
Converging winds
Converging winds

Convective lifting





Stability of Atmosphere

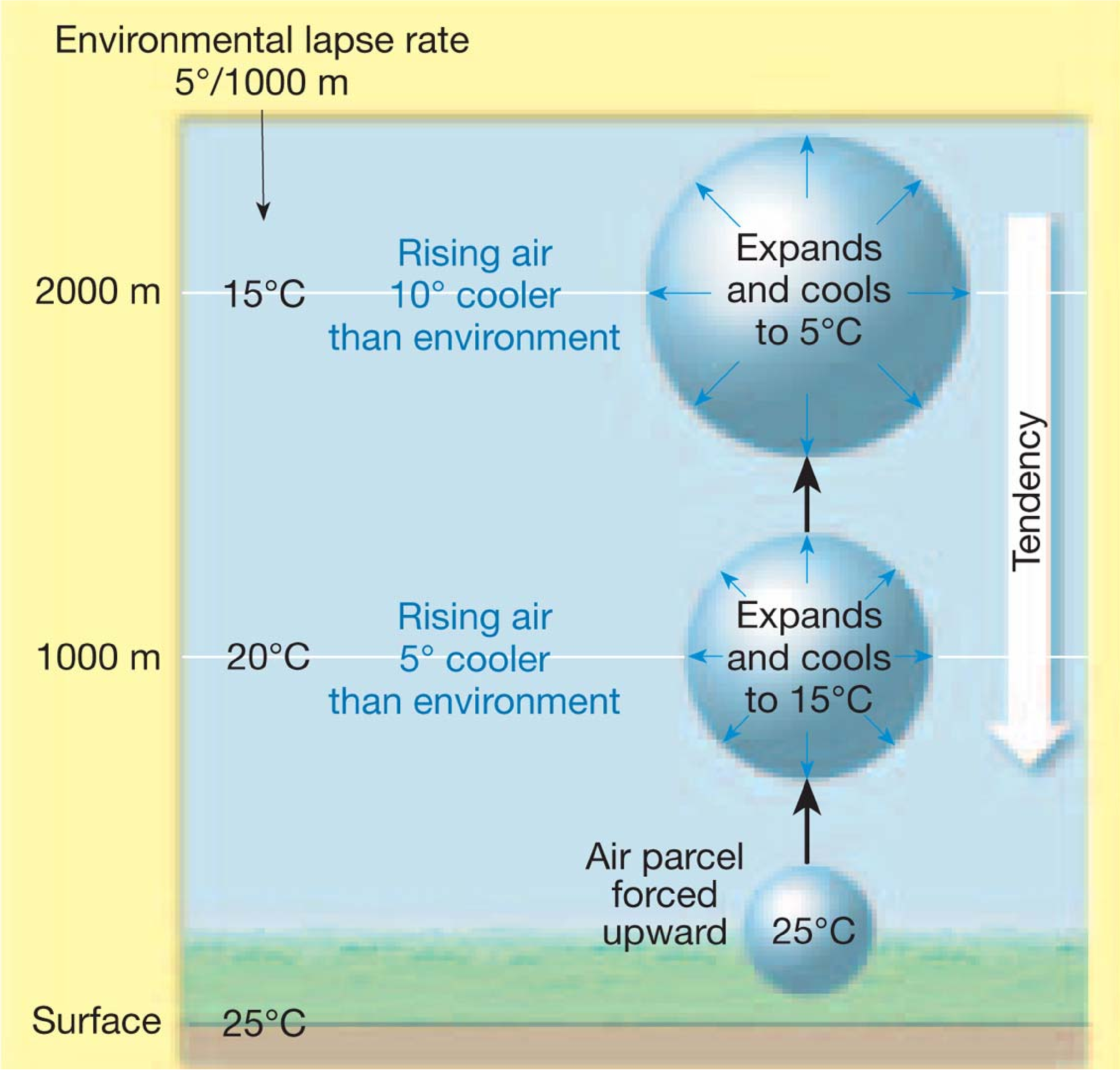
- Air rises due to a number of factors
- Expands as it rises: cools as it does so
  - Can calculate the new temperature with the adiabatic lapse rate:
    - Dry for unsaturated
    - Wet for saturated
  - Compare the temperature of the air that has risen to the temperature of the air at that height
    - Higher density air that has risen is stable (cooler)
    - Lower density air that has risen is unstable (warmer)

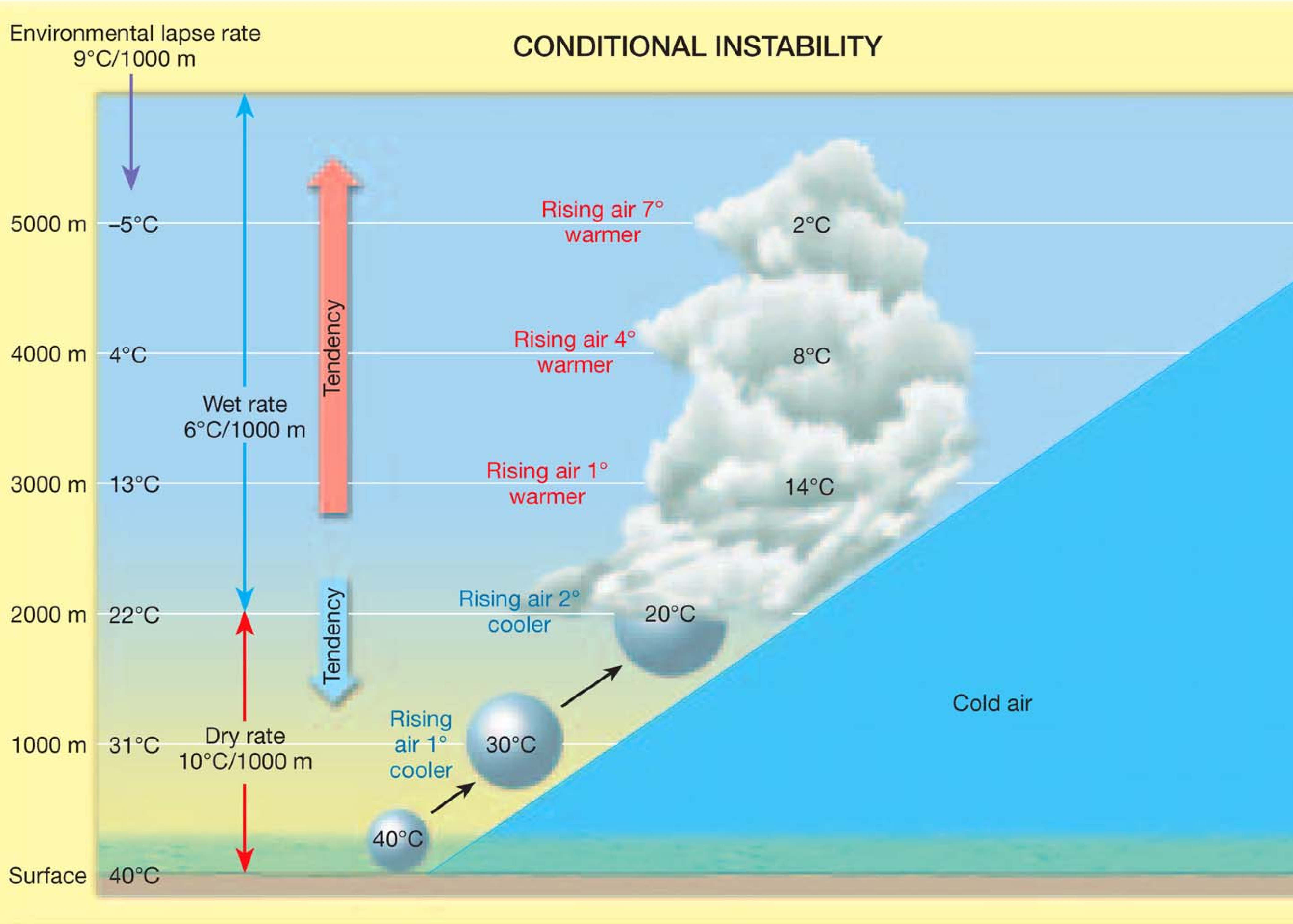
Environmental Lapse Rate

- Earth's atmosphere is heated from below
- Regularly cooler at greater distances from Earth's surface
- Varies with moisture, temperature, cloud cover, and other local conditions

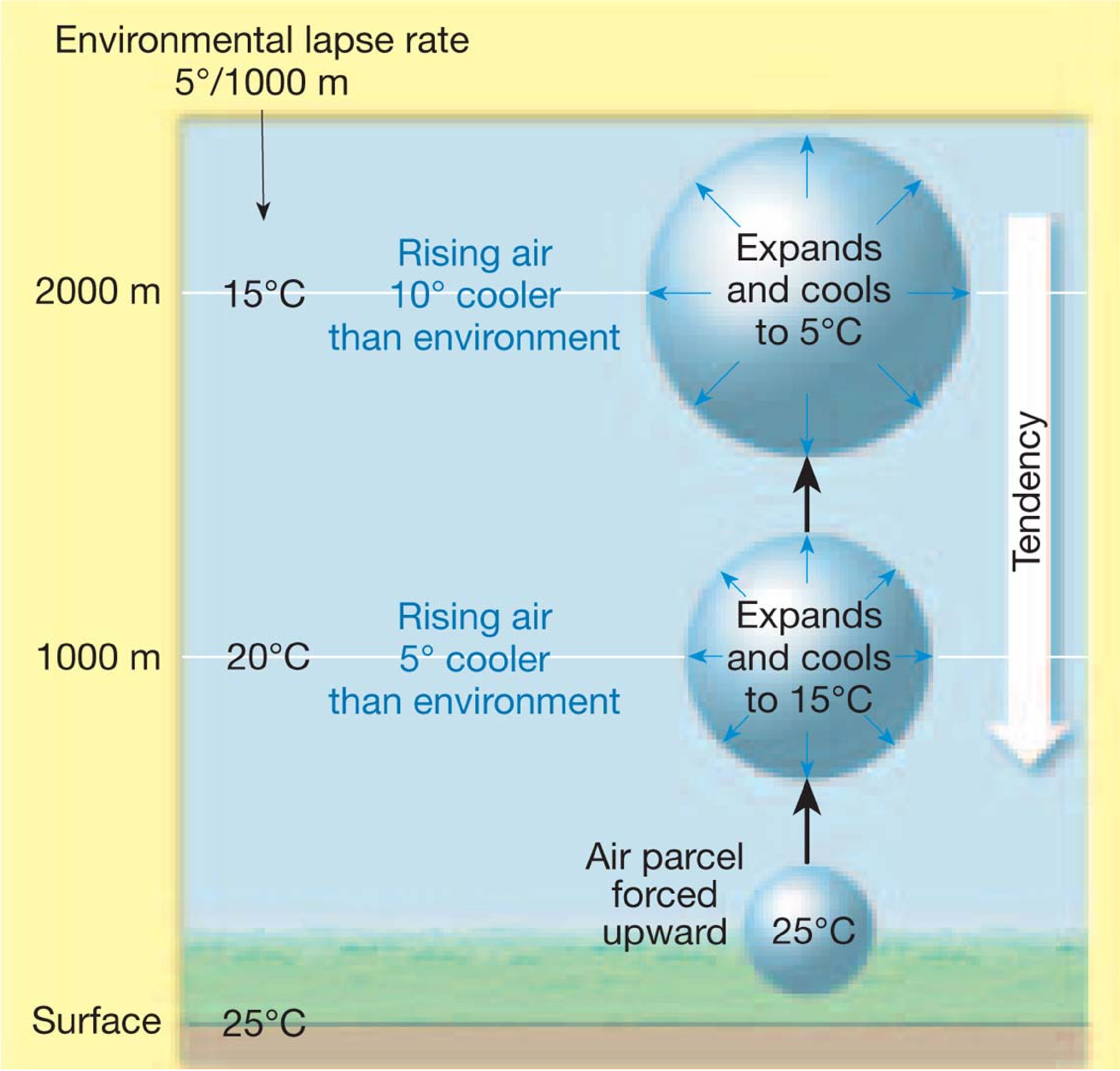
Adiabatic lapse rate

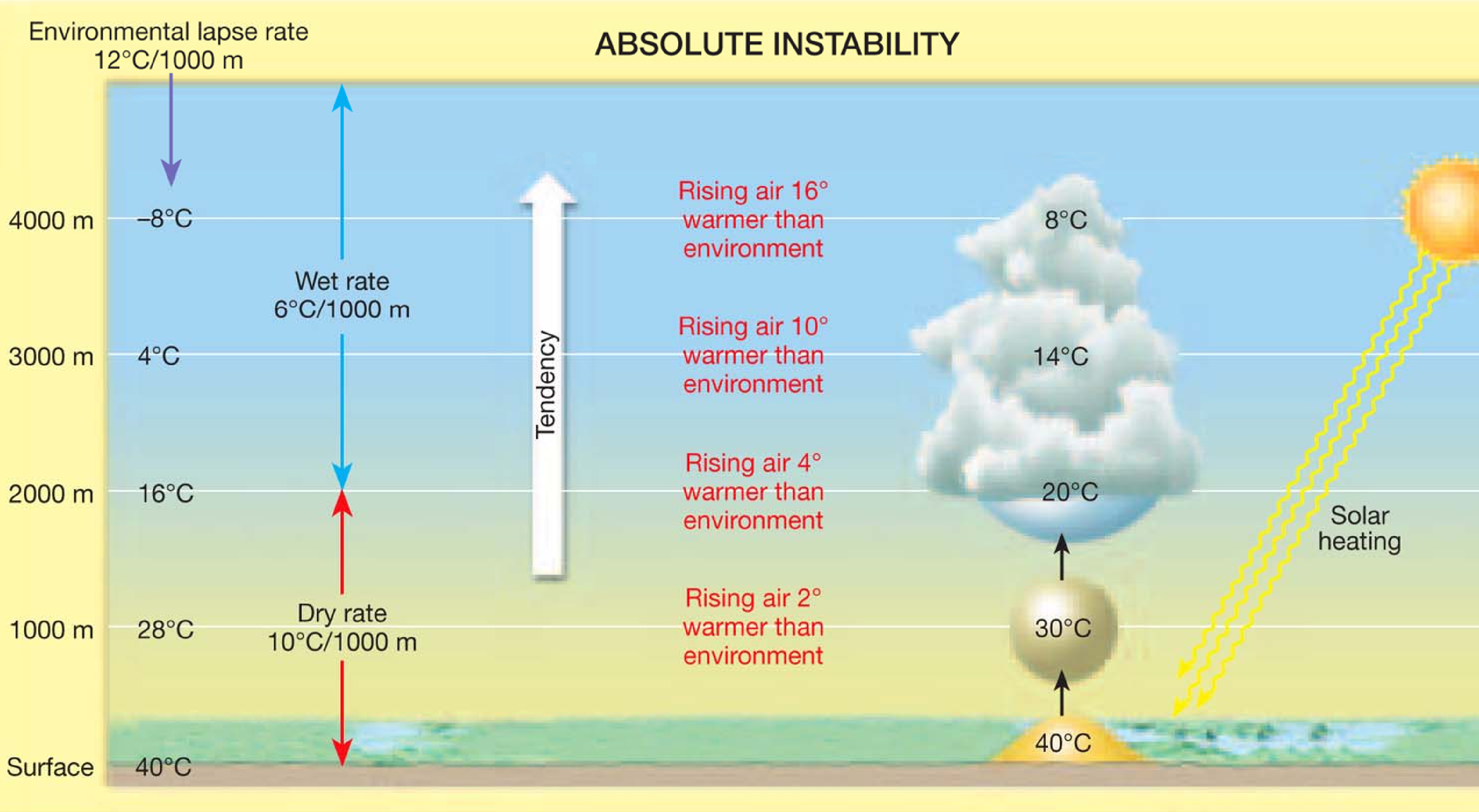
- Rate of temperature change depends on saturation
- Saturated air has condensation of water, which releases heat: warms environment
  - 10^{o} C / 1000 m if not saturated
  - 5^{o} C / 1000 m if condensation is occurring


Environmental lapse rate
5°/1000 m
2000 m
15°C
Rising air
10° cooler
than environment
Expands
and cools
to 5°C
Tendency
1000 m
20°C
Rising air
5° cooler
than environment
Expands
and cools
to 15°C
Air parcel
forced
upward
25°C
Surface
25°C

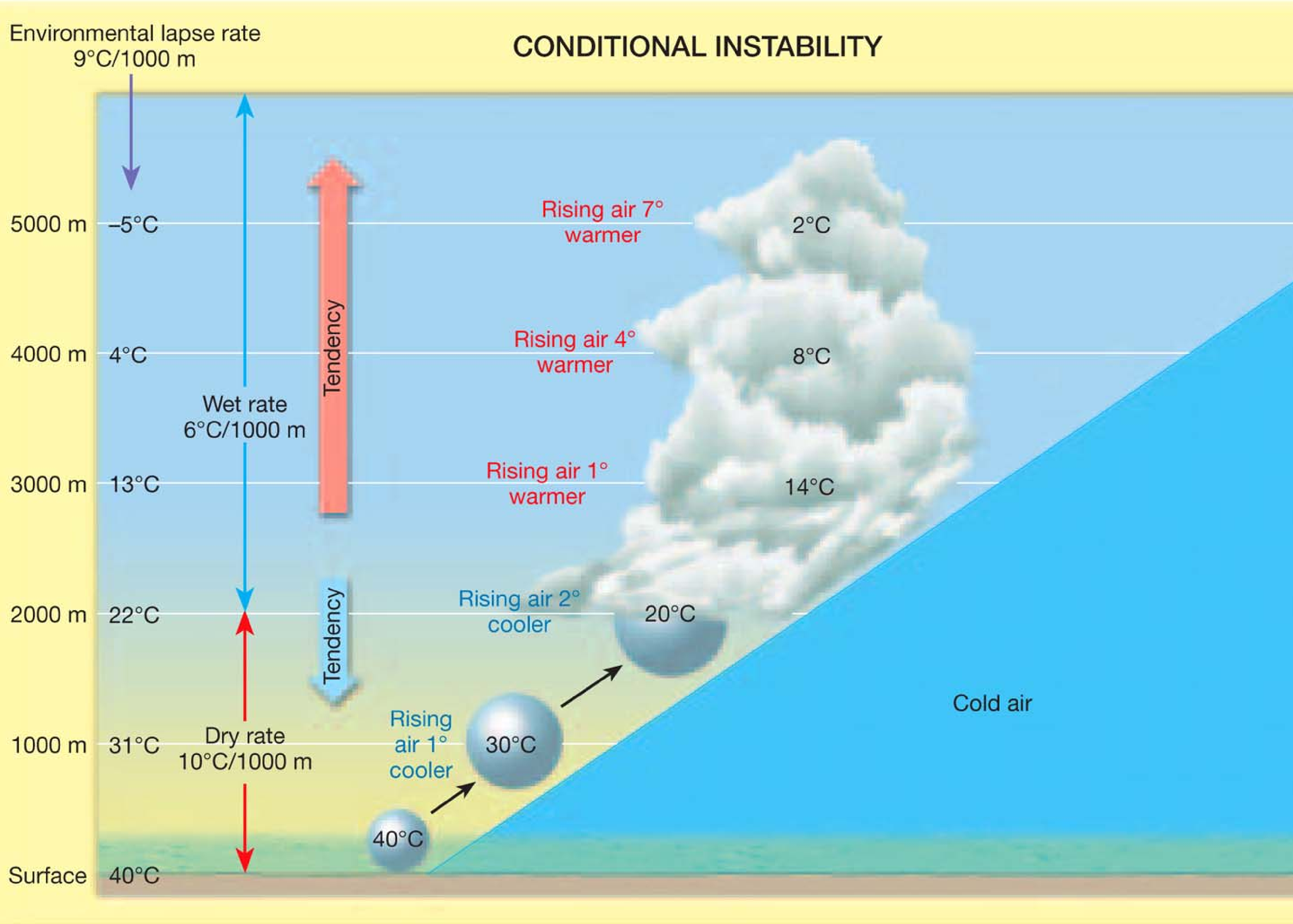


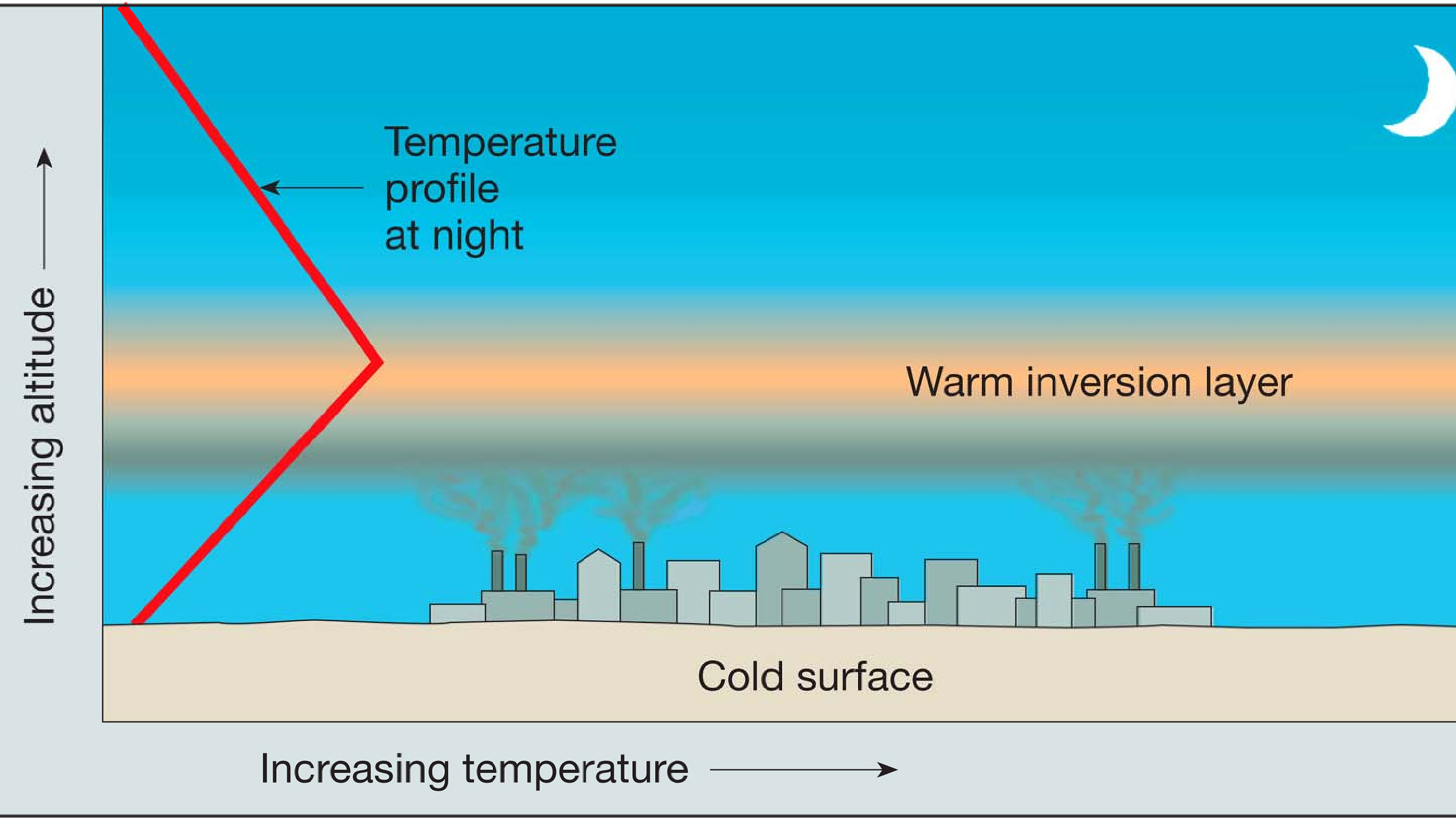
Environmental lapse rate
9°C/1000 m
CONDITIONAL INSTABILITY
5000 m
–5°C
4000 m
4°C
3000 m
13°C
2000 m
22°C
1000 m
31°C
Surface
40°C
Wet rate
6°C/1000 m
Dry rate
10°C/1000 m
Tendency
Tendency
Rising air 7°
warmer
Rising air 4°
warmer
Rising air 1°
warmer
Rising air 2°
cooler
Rising
air 1°
cooler
2°C
8°C
14°C
20°C
30°C
40°C
Cold air

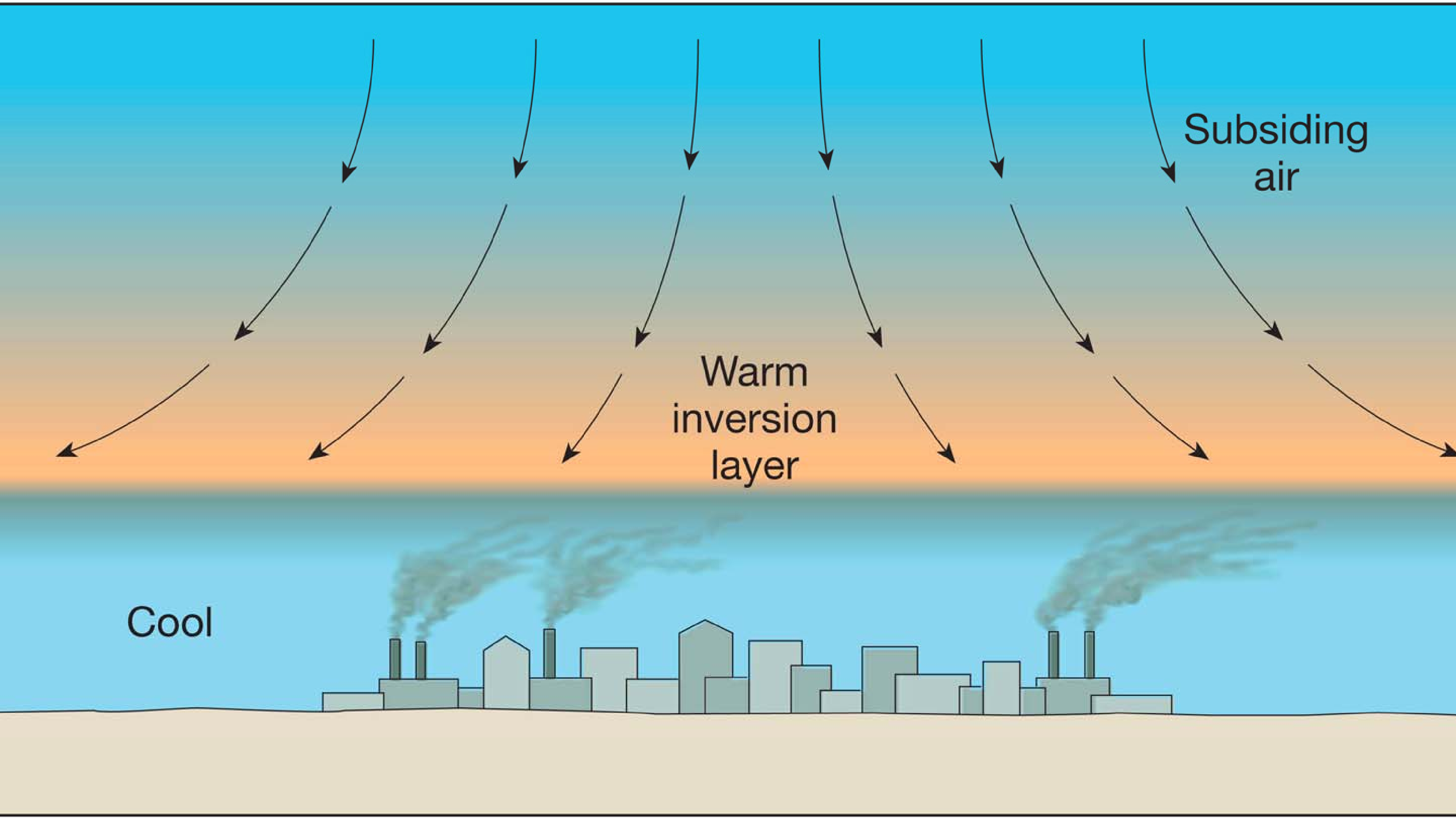

Environmental lapse rate
5°/1000 m
2000 m
15°C
Rising air
10° cooler
than environment
Expands
and cools
to 5°C
Tendency
1000 m
20°C
Rising air
5° cooler
than environment
Expands
and cools
to 15°C
Air parcel
forced
upward
25°C
Surface
25°C

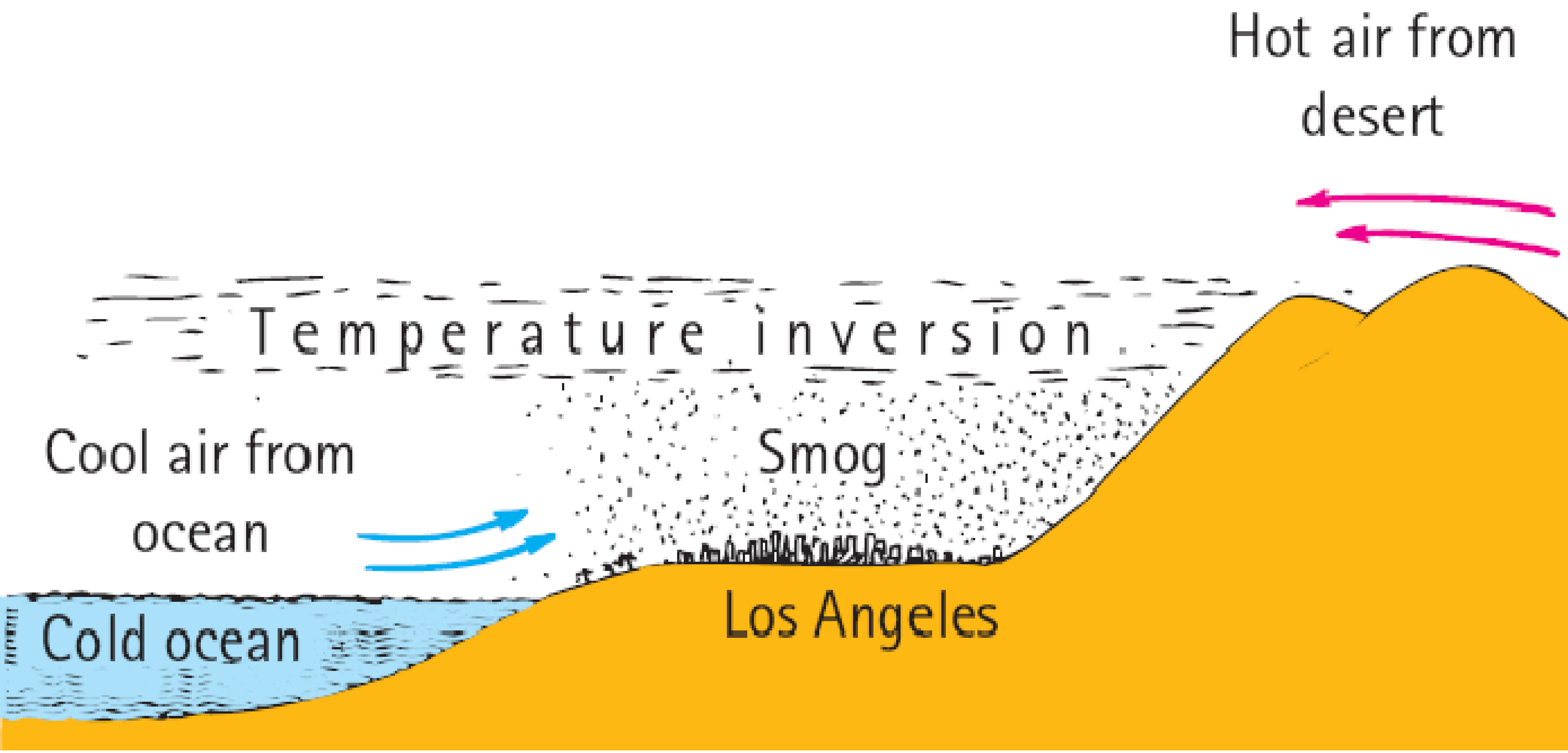


Environmental lapse rate
12°C/1000 m
ABSOLUTE INSTABILITY
4000 m
–8°C
3000 m
4°C
2000 m
16°C
1000 m
28°C
Surface
40°C
Wet rate
6°C/1000 m
Dry rate
10°C/1000 m
Tendency
Rising air 16° warmer than environment
Rising air 10° warmer than environment
Rising air 4° warmer than environment
Rising air 2° warmer than environment
8°C
14°C
20°C
30°C
40°C
Solar heating


CONDITIONAL INSTABILITY
Environmental lapse rate
9°C/1000 m
5000 m
–5°C
4000 m
4°C
3000 m
13°C
2000 m
22°C
1000 m
31°C
Surface
40°C
Wet rate
6°C/1000 m
Dry rate
10°C/1000 m
Tendency
Tendency
Rising air 7° warmer
2°C
Rising air 4° warmer
8°C
Rising air 1° warmer
14°C
Rising air 2° cooler
20°C
Rising air 1° cooler
30°C
40°C
Cold air


Temperature
profile
at night
Warm inversion layer
Cold surface
Increasing altitude
Increasing temperature


Subsiding air
Warm inversion layer
Cool


Hot air from
desert
Temperature inversion
Cool air from
ocean
Smog
Cold ocean
Los Angeles