LECTURE 5: Clouds Formation, Precipitation Processes & Hydrometeorology

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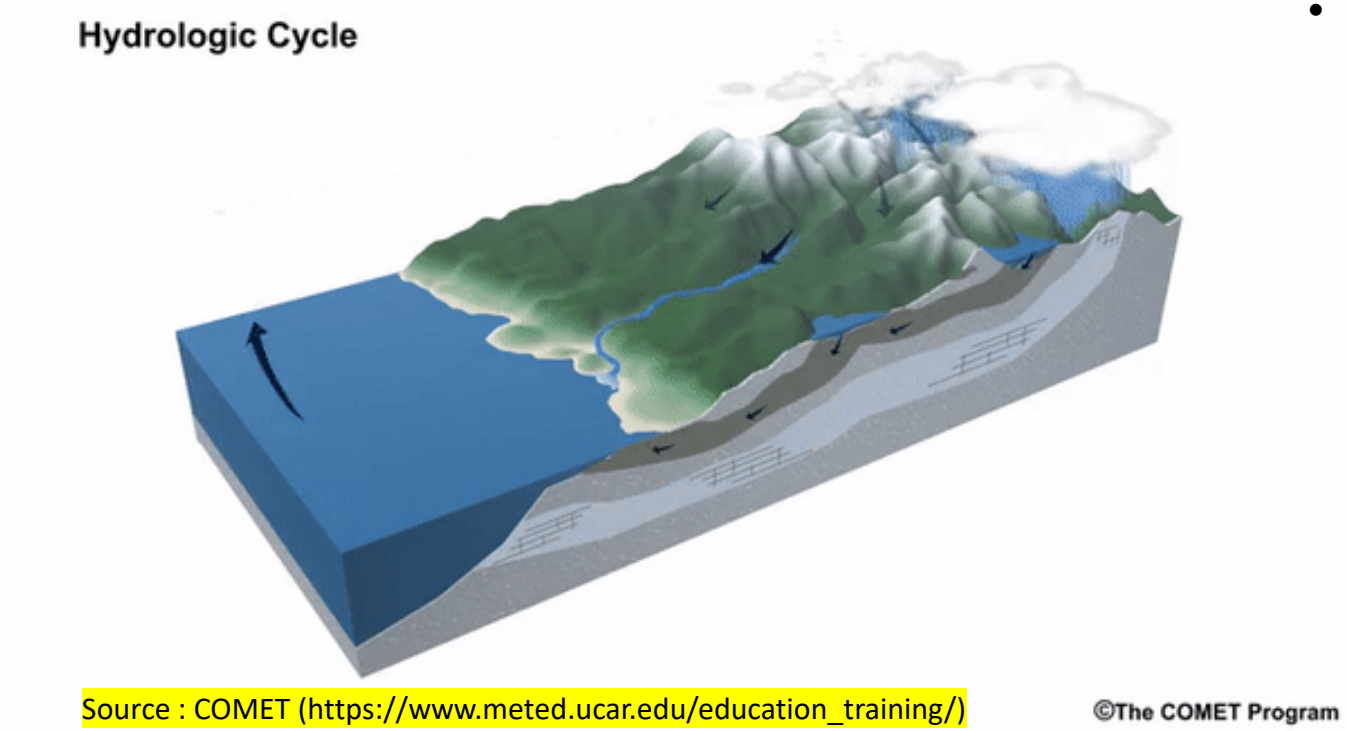


Source : COMET (https://www.meted.ucar.edu/education_training/)

- Precipitation is one of the most important aspects of meteorology.
- Precipitation is part of the water cycle. It recharges surface water lost to evaporation or runoff, and thus sustains life.
- Fixed quantity of water on Earth is distributed among various reservoirs .
- The ocean is the largest of these reservoirs, accounting for 97.2% of all water on the planet;
- most of the rest is tied up as ice sheets (2.15%).

TABLE 6.1
Water Stored in Reservoirs of the Global Water Cycle

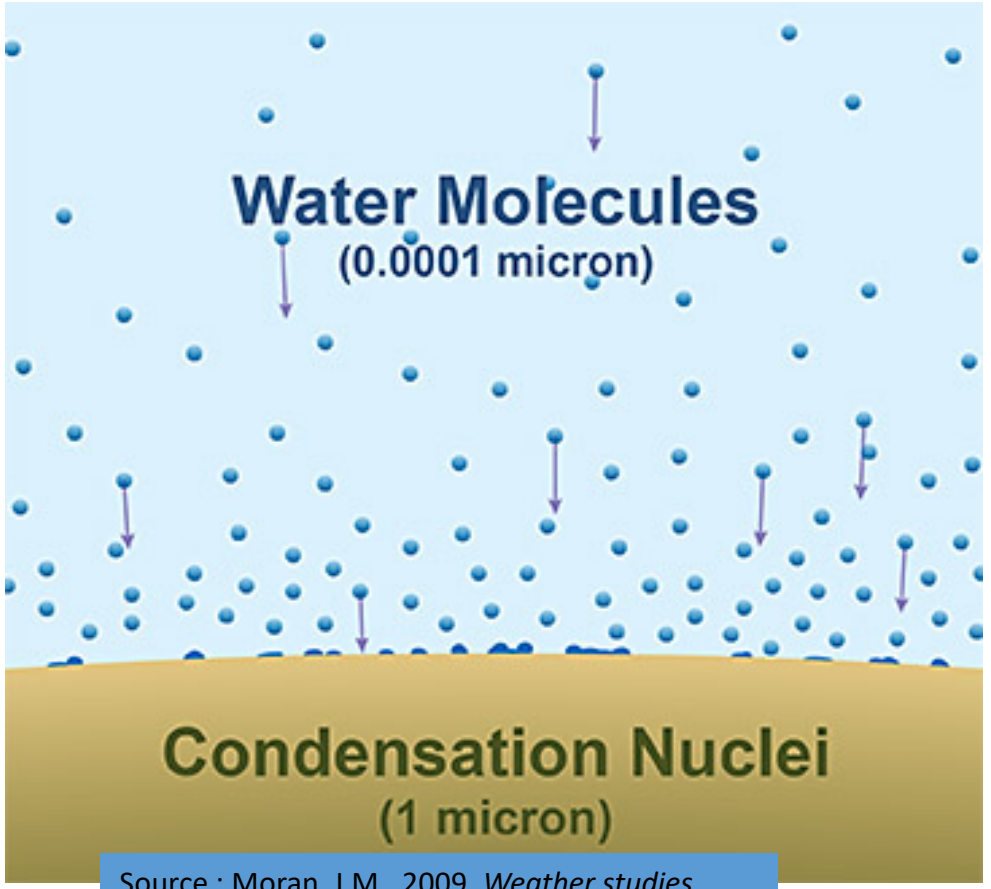
Reservoir	*Percent of total water*
Ocean	97.20
Ice sheets and glaciers	2.15
Groundwater	0.62
Lakes (freshwater)	0.009
Inland seas, saline lakes	0.008
Soil moisture	0.005
Atmosphere	0.001
Rivers and streams	0.0001
Living Organisms	0.00004

Source : Moran, J.M., 2009. *Weather studies*

- In brief, water vaporizes from ocean and land surfaces to the atmosphere, where winds can transport water vapor to other locations, Clouds form, and then rain, snow and other forms of precipitation may fall from clouds to Earth's surface, recharging the ocean and terrestrial (land-based) reservoirs of water. From terrestrial reservoirs, water flows into the ocean basins

How Clouds Form

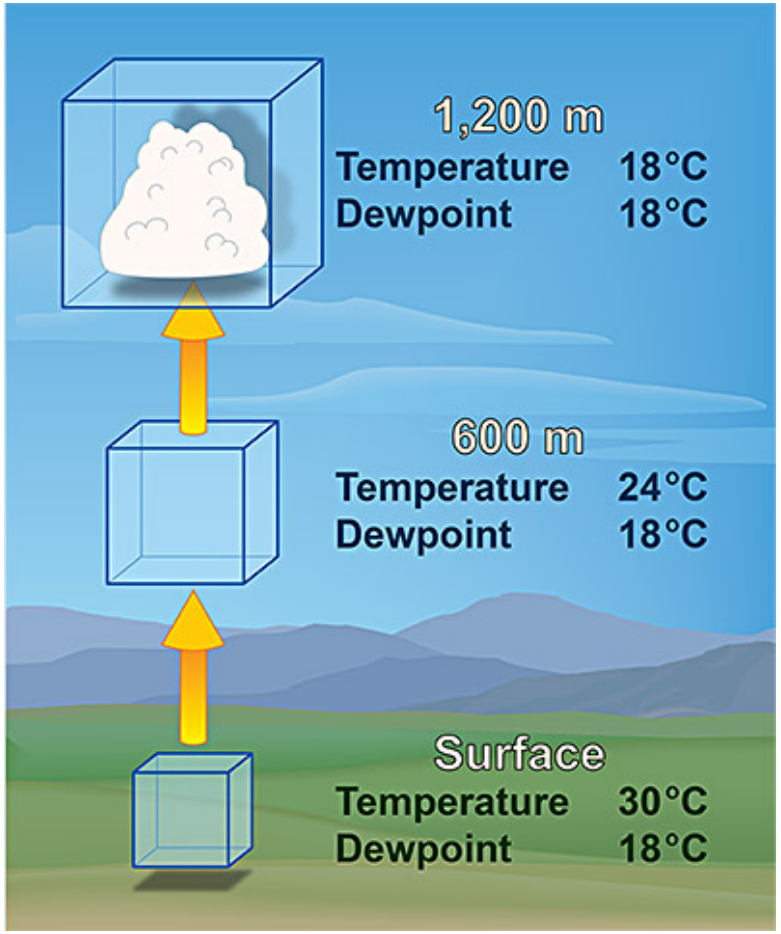
- Water vapor is an invisible component of air, but its condensation and deposition products (water droplets and ice crystals) are visible. it consists of a large and visible aggregate of minute water droplets and/or ice crystals.
- A **cloud** is the visible product of condensation or deposition of water vapor within the atmosphere
- There are two ingredients needed for clouds to become visible; **water vapour, and nuclei.**
- **Nuclei** – Water molecules in the atmosphere are too small to bond together for the formation of cloud droplets. They need a "flatter" surface, an object with a radius of at least one micrometer (one millionth of a meter) on which they can form a bond.
- Those objects are called nuclei. Nuclei are minute solid and liquid particles found in abundance. They consist of such things as smoke particles from fires or volcanoes, ocean spray or tiny specks of wind-blown soil. These nuclei are *hygroscopic* meaning they attract water molecules.
- "**cloud condensation nuclei**" -water-molecule-attracting particles are about 1/100th the size of a cloud droplet upon which water condenses.
- Within the atmosphere, water vapor can condense into cloud droplets that remain liquid even at temperatures well below 0 °C . Droplets at such temperatures are described as *supercooled* .



Source : Moran, J.M., 2009. *Weather studies*

To form clouds. air temperature needs to be below the saturation point. Called the dew point temperature, the point of saturation is where evaporation equals condensation.

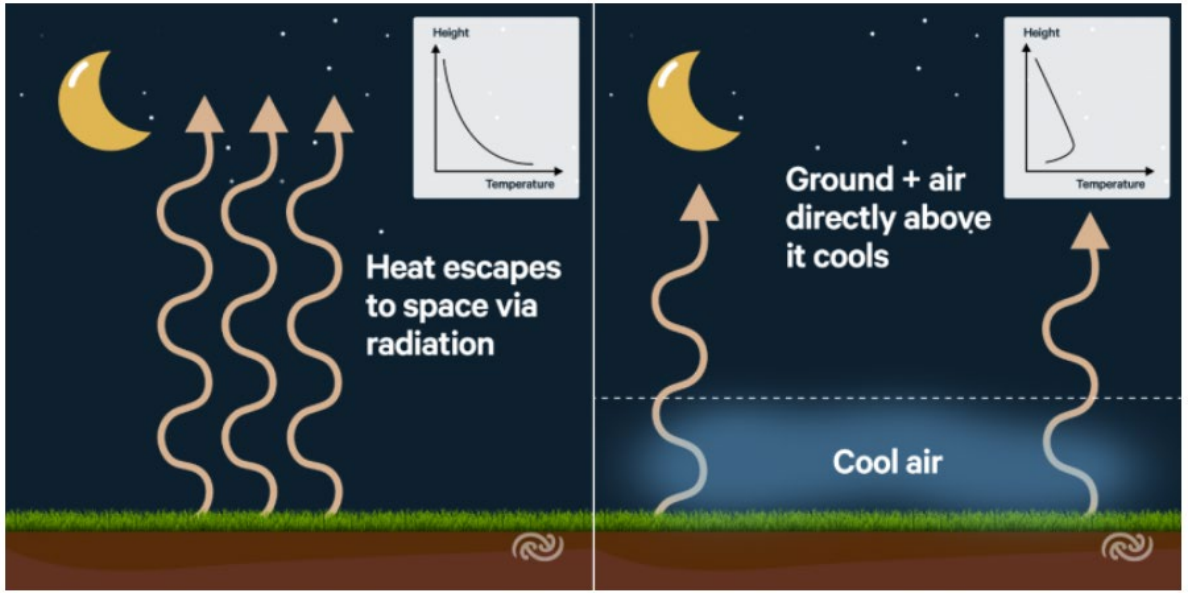
- a cloud form when air parcels containing water vapor has cooled below the point of saturation.
- Most common way to reach saturation through lifting of air from the surface up into the atmosphere.
- As air parcel rises it moves into lower pressure since pressure decreases with height. The result is the parcel expands in size as it rises. This requires heat energy to be removed from the parcel. Called an adiabatic process, as air rises and expands it cools.
- The *rate* at which the parcel cools with increasing elevation is called the "lapse rate". The lapse rate (the rate the temperature lapses or decreases) of unsaturated air (air with relative humidity <100%) is 10°C per kilometer. Called the *dry* lapse rate.
- Once the parcel reaches saturation temperature (100% relative humidity) water vapor will condense onto the cloud condensation nuclei resulting in the formation of a cloud droplet.

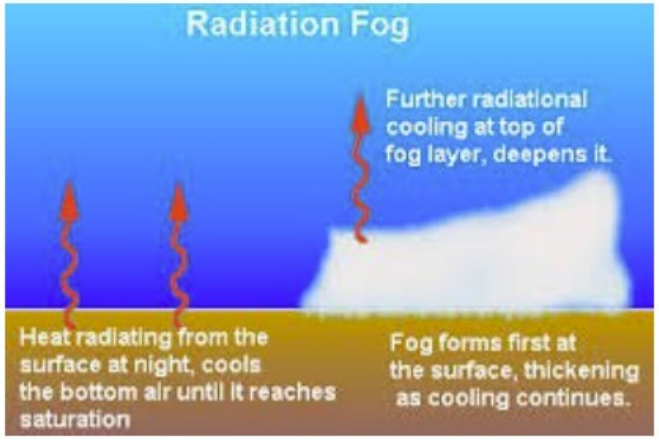


But the atmosphere is in constant motion. As air rises drier air is added (entrained) into the rising parcel so both condensation and evaporation are continually occurring. So, cloud droplets are constantly forming and dissipating.

Fog/Mist

- Fog is a cloud that forms at ground level, made of tiny water droplets or ice crystals (ice fog).
- It significantly restricts visibility, officially defined as 1000 meters or less.
- Dense fog can reduce visibility to below 100 meters.
- Fog can form due to:
  - Radiational cooling (clear nights, light winds, humid surface air)
  - Advective cooling (warm, moist air moving over a cooler surface)
  - Expansional cooling (rising, expanding air)
  - Radiation fog commonly forms under clear skies with light winds and high near-surface humidity.

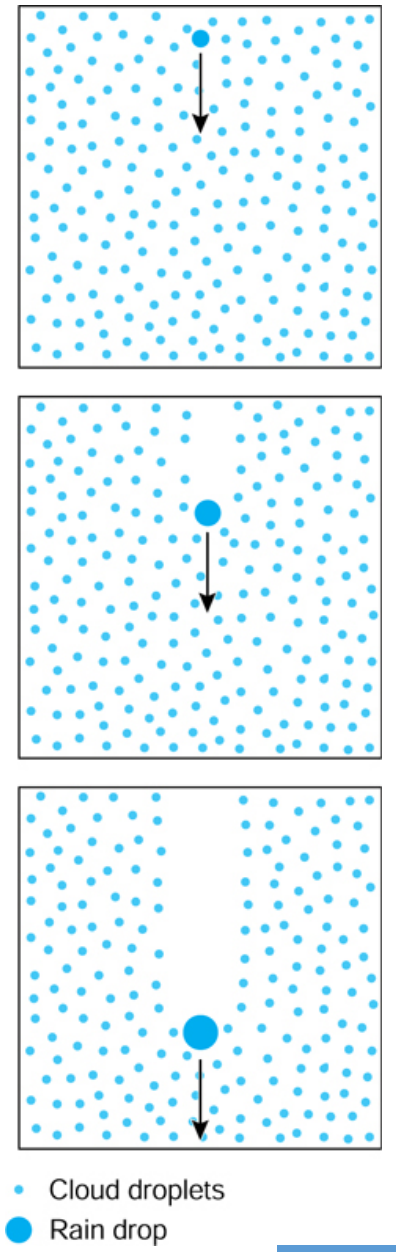


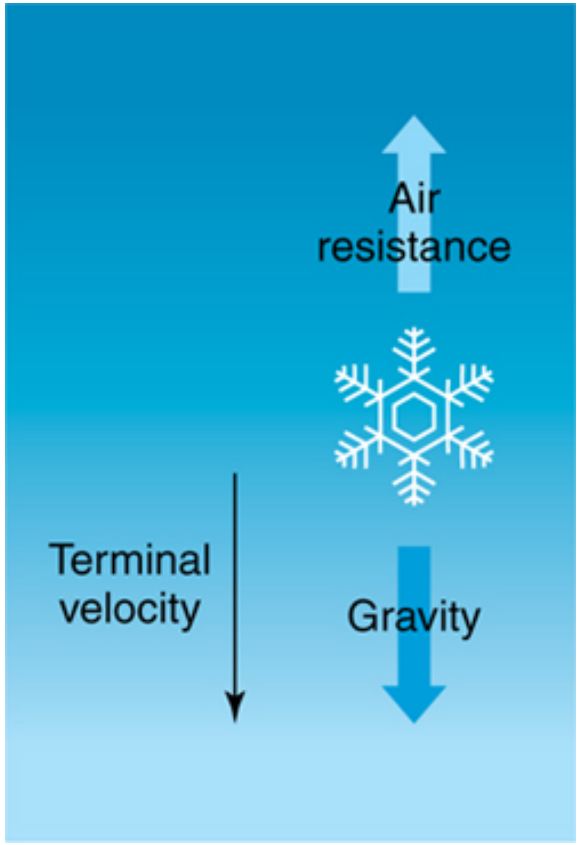


High humidity at low levels within the air is usually due to evaporation of water from a moist surface. Hence, radiation fog is most common over marshy areas or where the soil has been saturated by recent rainfall or snowmelt.

Precipitation Processes

- Clouds are no guarantee that it will rain or snow.
- For clouds to precipitate, cloud particles must grow large enough that their terminal velocities overwhelm the updraft
- Cloud droplets may grow by colliding and coalescing (merging) with one another in the **collision-coalescence process**
- Nimbostratus and cumulonimbus clouds produce the bulk of precipitation, but most clouds do not yield any significant rain or snow.
- **Precipitation** is water in solid or liquid form that falls from clouds to Earth's surface under the influence of gravity.
- Key to understanding the mechanisms of precipitation formation is the concept of terminal velocity, the speed of a falling particle.
- **terminal velocity**, steady speed achieved by an object freely falling through a gas or liquid.
- The speed of a falling cloud droplet or ice crystal (or any other particle) in calm air is regulated by
  - (1) **gravity**,
  - (2) the resistance offered by the air through which the particle is falling.





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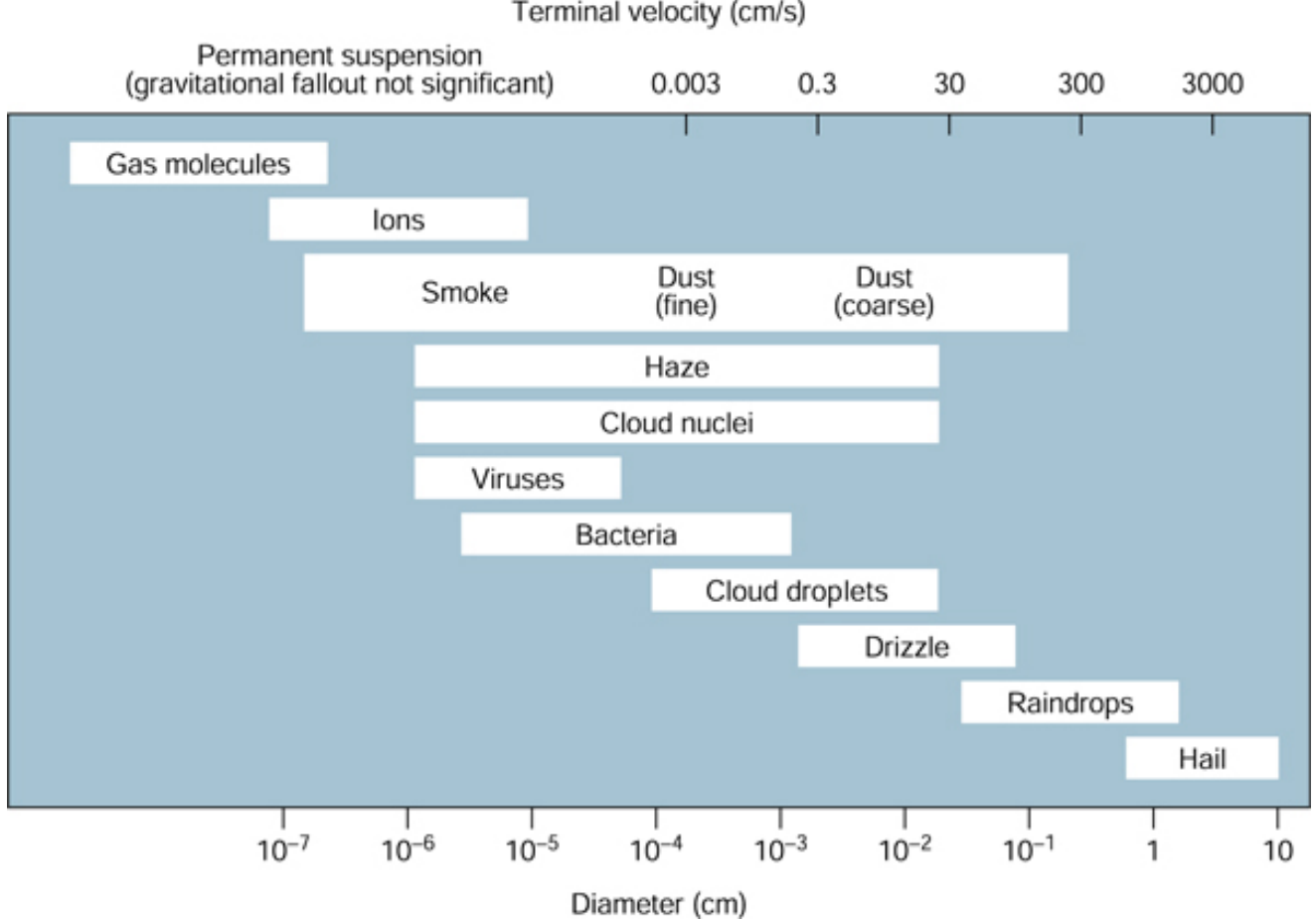

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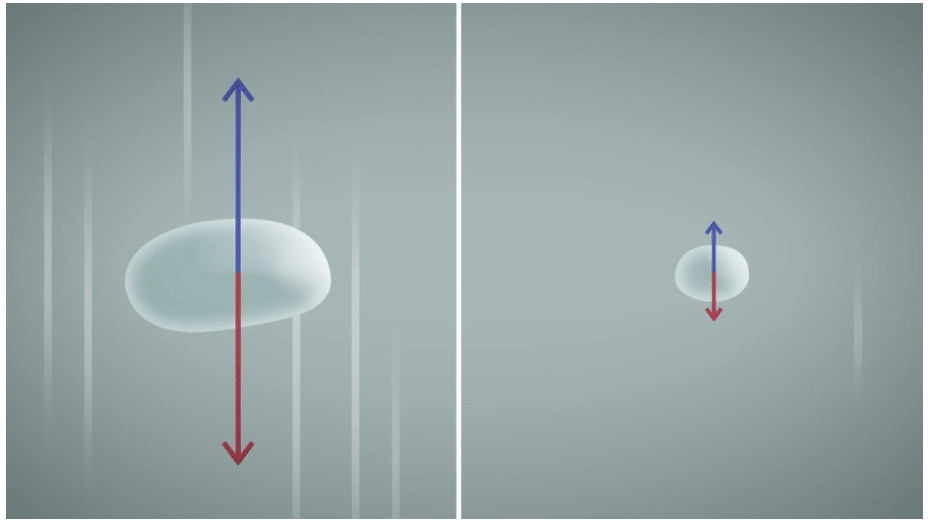

- The terminal velocity of a particle falling through air increases with the size of the particle.