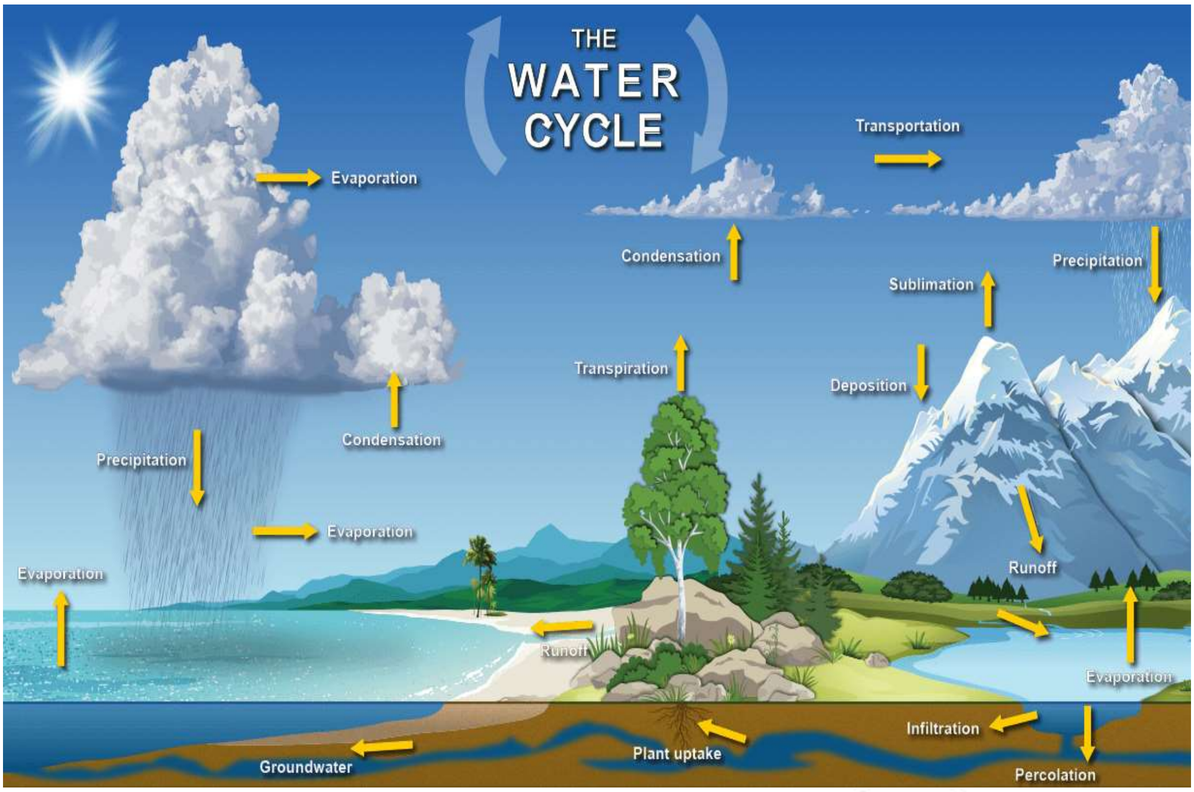

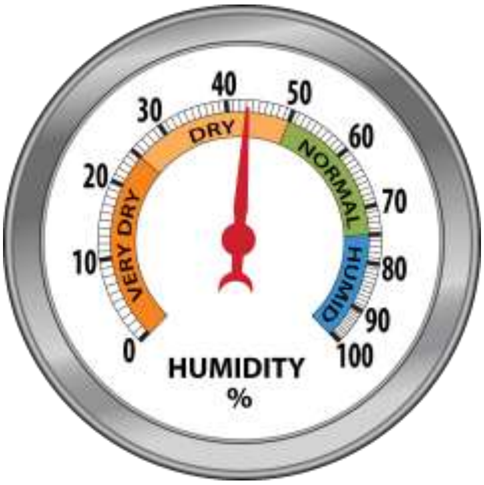

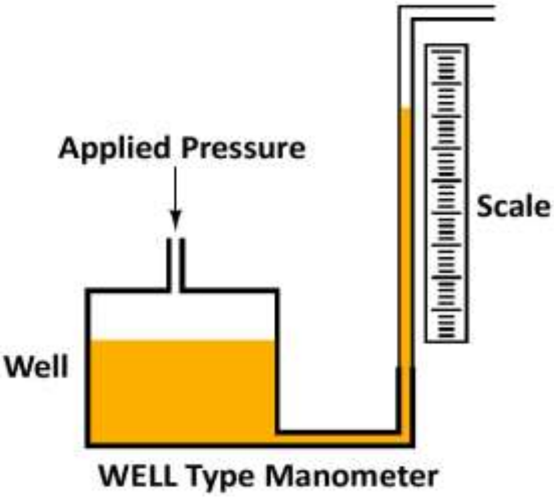

The Pressure in the Human Body

Third Lecture (3)

First semester / First year

By

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The Pressure in the Human Body

Pressure:

Pressure: is the force applied perpendicular to the surface of an object per unit area over which that force is distributed. Figure 1 shows the pressure exerted by particle collisions inside a closed container. The SI unit is Pascal ($Pa = N/m^2$). The formula for pressure is:

$$\mathbf{P} = \frac{F}{A} \ldots\ldots (1)$$

Where:

P: is the pressure

F: is the magnitude of the force

A: is the area of the surface.

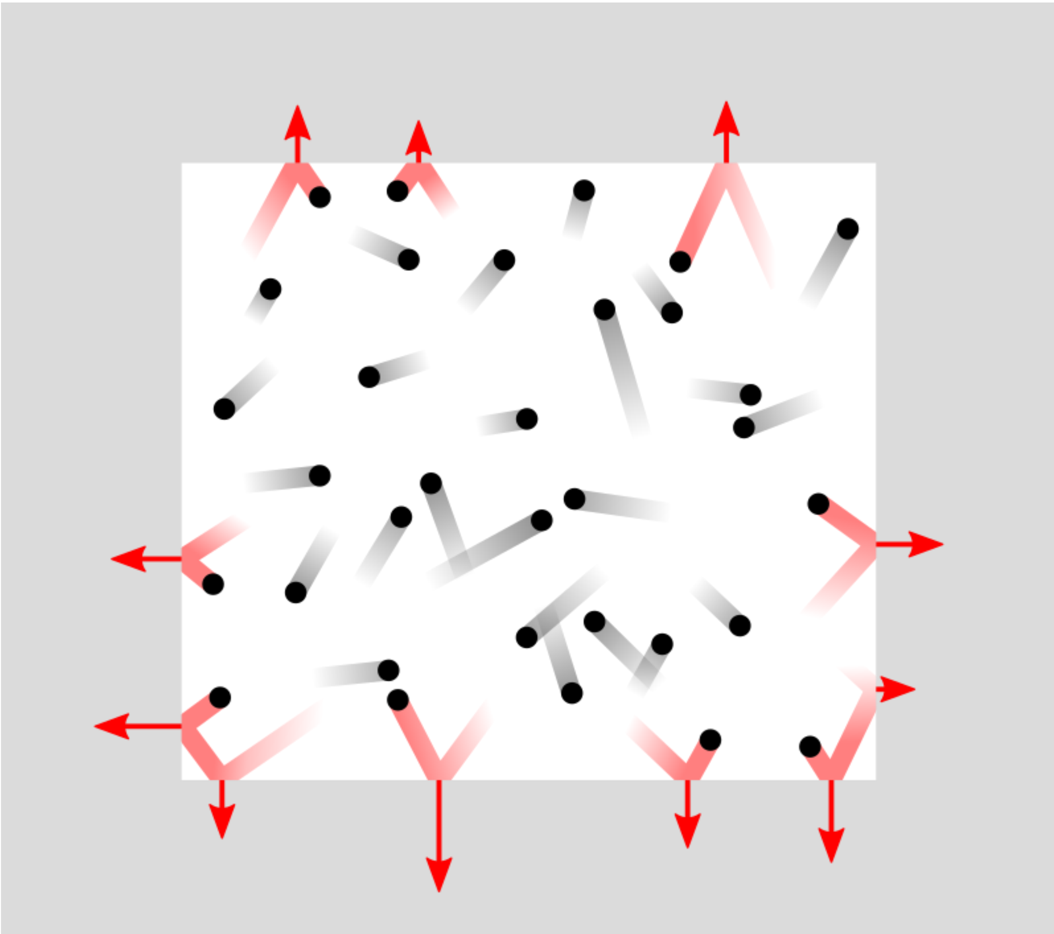

Figure (1): Shows the pressure exerted by particle collisions inside a closed container.

The term pressure is used when describing fluids (gases or liquids). It depends on the density of the liquid. An example of pressure is when a person swims under the water; water pressure is felt acting on the person's eardrums. If someone were submerged in a liquid more dense than water, the pressure would be correspondingly greater. Thus, we can say that the depth, density, and liquid pressure are directly proportionate. The most common method of indicating pressure in medicine is by the height of the mercury column (Hg). The pressure under a column of liquid can be calculated:

$$P = \rho\, g\, h \quad \text{..... (2)}$$

Where:

ρ: is the density of the liquid

g: is the acceleration due to gravity

h: is the height of the column.

Example of Liquid Pressure:

1. A force of 150 N is being applied over an area measuring 0.5 m^2. Calculate the pressure on the object, ensuring you give the correct units.

Solution:

The given values in the question are: F = 150 N, and A = 0.5 m^2.

$$P = \frac{F}{A}$$

$$P = \frac{150}{0.5}$$

P = 300 N/m^2

So, the amount of pressure is: P = 300 N/m^2.

2. The density of water is 1,000 kg/m^3. Calculate the pressure exerted by the water on the bottom of a 2.0 m deep swimming pool. (Gravitational field strength = 9.8 N/kg).

Solution:

The given values in the question are: ρ = 1000 kg/m^3, h = 2 m and g = 9.8 N/kg.

$P = \rho\, g\, h$

$$P = \frac{1000 \times 9.8}{2}$$

P = 4900 pa

So, the amount of liquid pressure is: P = 4900 pa.

3. The pressure in the atmosphere is about 10^5 Pa. Calculate the depth below the surface of the water. (The density = 1000 kg/m^3 and the gravitational field strength = 9.8 N/kg).

Solution:

The given values in the question are: p =10^5 pa, ρ = 1000 kg/m^3 and g = 9.8 N/kg.

$P = \rho\, g\, h$

10^5 (Pa) = 1000 (kg/m^3) x 9.8 (N/kg) x h

$$h = \frac{10^5}{1000 \times 9.8}$$

h = 10.2 m

So, the depth is: h = 10.2 m.

Measurement of Pressure:

The atmospheric pressure is measured using an instrument called a ***"Barometer."*** While, the fluid pressure is measured with respect to the earth's atmosphere using a device known as a ***"Manometer."*** The fluid used for the measurement of the pressure is mercury. But water or other low-density fluids can be used when pressure is relatively small.

Types of Manometers:

Manometers are classified into different types. These types of manometers can measure both positive and negative pressure. They are:

1. U-Tube Manometer
2. Enlarged-Leg Manometer
3. Well-Type Manometer
4. Inclined-Tube Manometer.

Measurement of Pressure in the Human Body:

The most common clinical instrument used to measure the pressure in the human body is the ***"Sphygmomanometer",*** which measures blood pressure. Arterial blood pressure is most commonly measured using this device, which uses the height of a column of mercury to reflect the circulating pressure. Blood pressure values are generally reported in millimeters of mercury (mmHg), though aneroid and electronic devices do not contain mercury.

For each heartbeat, blood pressure varies between systolic and diastolic pressures. An example of normal measured values for a resting, healthy adult human is 120 mmHg systolic and 80 mmHg diastolic (written as 120/80 mmHg and spoken as "one-twenty over eighty"). Figure 2 shows the types of Sphygmomanometer, (A) Digital, (B) Mercury, and (C) Aneroid Sphygmomanometer.

Figure (2): Shows (A) Digital Sphygmomanometer, (B) Mercury Sphygmomanometer, and (C) Aneroid Sphygmomanometer.

NOW, What are the Factors that the measurement of Pressure depends on?

i. Systolic and diastolic arterial blood pressures are not static but undergo natural variations
ii. From one heartbeat to another and throughout the day (in a circadian rhythm).
iii. They also change in response to stress, nutritional factors, drugs, disease, exercise, and momentarily from standing up.

"Hypertension" refers to arterial pressure being abnormally high, as opposed to ***"Hypotension",*** when it is abnormally low. Blood pressure is one of the four main vital signs routinely monitored by medical professionals and healthcare providers, along with temperature, respiratory rate, and pulse rate.

Boyle's Law:

Boyle's law: is an experimental gas law that describes the relationship between the pressure and volume of a confined gas. Mathematically, Boyle's law has been stated as: ***"For a fixed mass of an ideal gas kept at a fixed temperature, pressure and volume are inversely proportional."***

$P \propto \frac{1}{V}$ Pressure is inversely proportional to volume.

This means if the volume increases, then the pressure decreases, and vice versa when the temperature is held constant. Therefore, when the volume is halved, the pressure is doubled, and vice versa. Figure 3 shows Boyle's law.

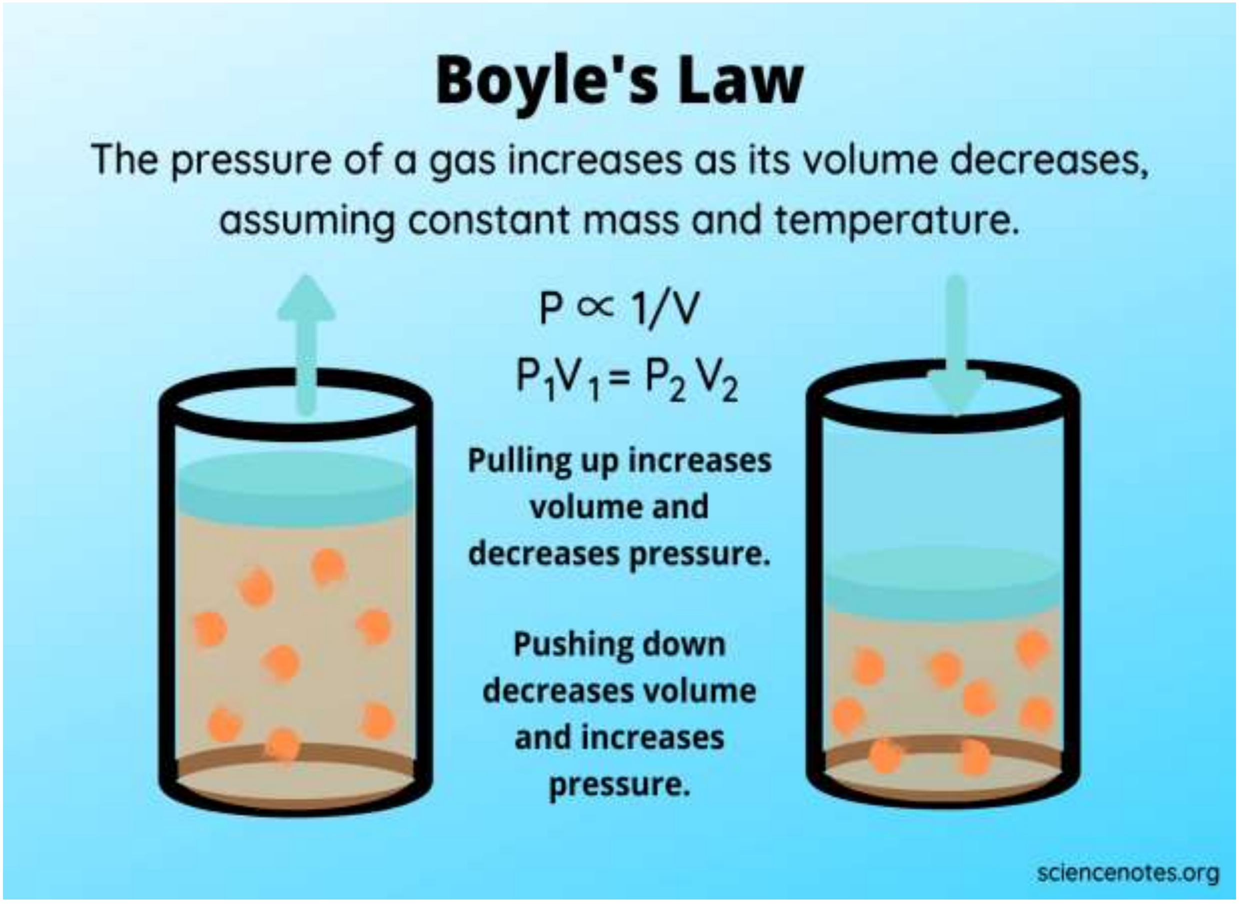

Figure (3): Shows Boyle's law.

Boyle's law can be stated as:

$P = k\frac{1}{V}$, $PV = K$

Where:

P: is the pressure exerted by the gas

V: is the volume of the gas

K: is a constant.

When comparing the same substance under two different conditions, the law can be expressed as:

$$\mathbf{P_1 V_1 = P_2 V_2 \ldots\ldots (3)}$$

Where:

P_1: is the initial pressure exerted by the gas, and **V_1:** is the initial volume occupied by the gas

P_2: is the final pressure exerted by the gas, and **V_2:** is the final volume occupied by the gas.

Examples of Boyle's Law:

1. **A fixed amount of gas with a volume of 1L and a pressure of 400 kPa. What is the pressure exerted by the gas if it is transferred into a new container with a volume of 3 liters?**

Solution:

The given values in the question are: $V_1 = 1$ L, $V_2 = 3$ L and $P_1 = 400$ kPa.

According to Boyle's law: $P_1V_1 = P_2V_2$

$P_2 = \frac{P_1 V_1}{V_2}$

$P_2 = \frac{1 \text{ x } 4000}{3}$

$P_2 = 133.33$ kPa

Therefore, the gas exerts a pressure of 133.33 kPa on the walls of the 3-liter container.

2. **A gas exerts a pressure of 3 kPa on the walls of container 1. When container 1 is emptied into a 10-liter container, the pressure increases to 6 kPa. Find the volume of the container.**

Solution:

The given values in the question are: $P_1 = 3$ kPa, $P_2 = 6$ kPa and $V_2 = 10$ L.

According to Boyle's law: $P_1V_1 = P_2V_2$

$V_1 = \frac{P_2 V_2}{P_1}$

$V_1 = \frac{6 \text{ x } 10}{3}$

$V_1 = 20$ L

Therefore, the volume of container 1 is 20 L.

Evaporation of Liquids:

Evaporation: the process that occurs on the surface of a liquid as it changes into the gas phase. When water is heated, it evaporates. The molecules move and vibrate so quickly that they escape into the atmosphere as molecules of water vapor. Areas with high temperatures and large bodies of water, such as tropical islands and swamps, are usually very humid for this reason. Water is evaporating but staying in the air as a vapor. Figure 4 shows the Evaporation process.

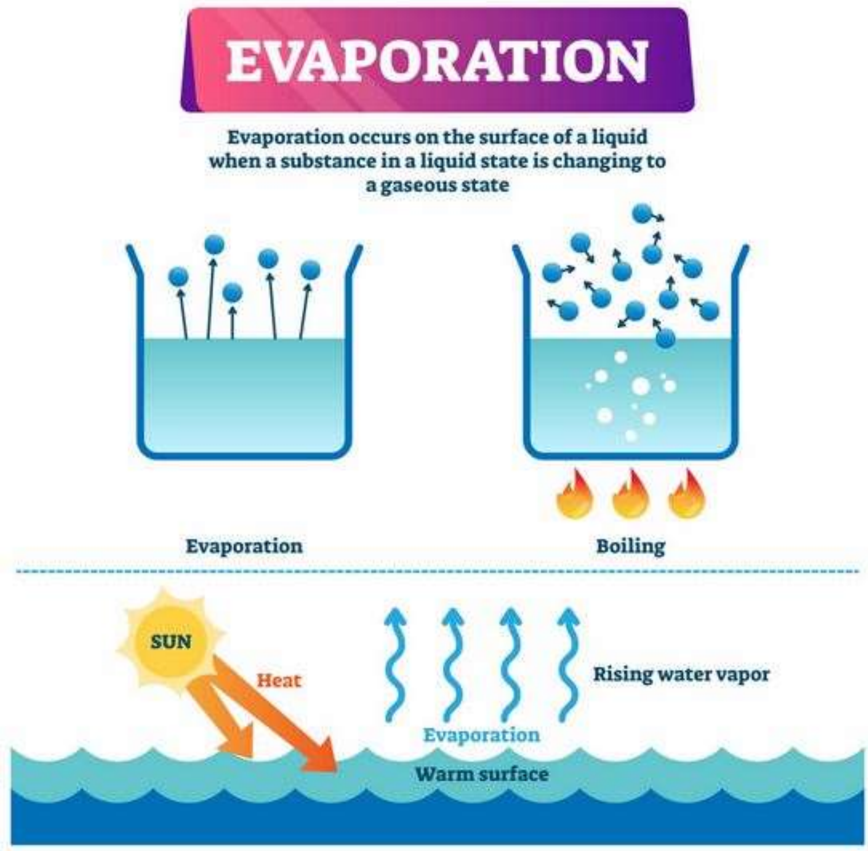

Figure (4): Shows the Evaporation process.

NOW, Under which conditions can the Evaporation process occur?

Many factors affect how evaporation happens, such as:

- If the air is already clogged, or saturated, with other substances, there won't be enough room in the air for liquid to evaporate quickly.
- When the humidity is 100 percent, the air is saturated with water. No more water can evaporate.

Vapor Pressure:

Vapor Pressure: is the pressure exerted by a vapor in thermodynamic equilibrium with its condensed phases (solid or liquid) at a given temperature in a closed system. The vapor pressure is an indication of a liquid's thermodynamic tendency to evaporate. The vapor pressure of any substance increases non-linearly with temperature, often described by the ***"Clausius–Clapeyron Relation."***

Humidity:

Humidity: it is the amount of water vapor in the air. Water vapor is the gaseous state of water. It is the ratio between the water vapor pressure in the air and the vapor pressure at saturation. Humidity indicates the likelihood for precipitation, dew, or fog to be present. Humidity is expressed at different levels, depending on certain factors. However, there is no official or special SI unit for humidity measurement. Humidity depends on the temperature and pressure of the system.

Types of Humidity:

There are three primary measurements of humidity that are widely employed:

1. **Absolute Humidity:** is expressed as either the mass of water vapor per volume of moist air or dry air. Absolute humidity describes the water content of the air and is used to measure the weight of water vapor per unit volume of air. The absolute humidity unit is given as g/m^3, which are units of grams of water vapor per cubic meter of air. Usually expressed as:

$$\mathbf{H_A = Mass_{H2O} / Volume\ of\ air}$$

2. **Relative Humidity:** is defined as the ratio between the amounts of moisture in the air at a particular temperature and the maximum moisture the air can withstand at the same temperature. Often expressed as a percentage, the relative humidity is 100% during rainy seasons. Figure 5 shows Relative Humidity.

$$\mathbf{H_R\ (\%) = 100 \times P_{H2O}/SVP_{H2O}}$$

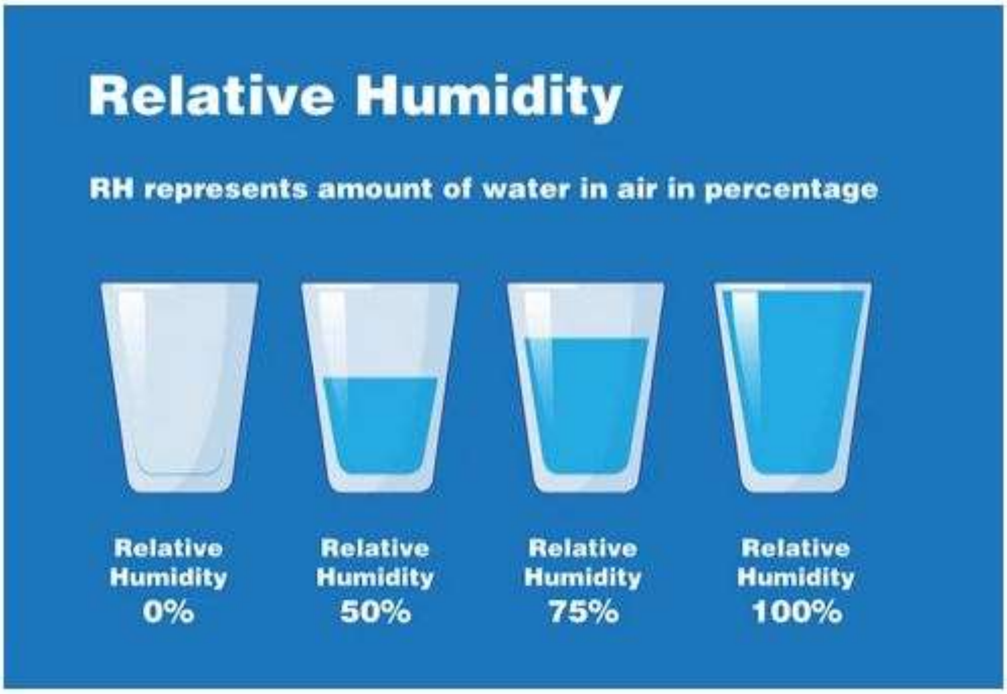

Figure (5): Shows Relative Humidity.

Where:

P_{H2O}: is the partial pressure of water vapor in the gas mixture

SVP_{H2O}: is the saturated vapor pressure of water at the temperature of the gas mixture. SVP depends on the temperature.

3. **Specific humidity:** is the ratio of water vapor mass to total moist air parcel mass. The specific humidity unit is the most reliable unit of measurement for humidity.

Measurements of Humidity:

A Hygrometer: is an instrument that measures the humidity of air or some other gas. It means measuring how much water vapor it contains. Humidity measurement instruments usually rely on measurements of other quantities such as temperature, pressure, mass, and mechanical or electrical changes in a substance as moisture is absorbed.

Through calibration and calculation, these measured quantities can lead to a measurement of humidity. Modern electronic devices use the temperature of condensation called the ***"Dew Point",*** or they sense changes in electrical capacitance or resistance to measure humidity differences.

NOW, What is Dew Point?

The Dew Point: is the temperature at which water vapor will turn into liquid water droplets. Figure 6 shows the formation of droplets. This process is called ***"Condensation."*** Condensation is what causes clouds to form, which can then lead to precipitation such as rain, snow, and hail. The dew point will always be the same or lower than the actual outside temperature.

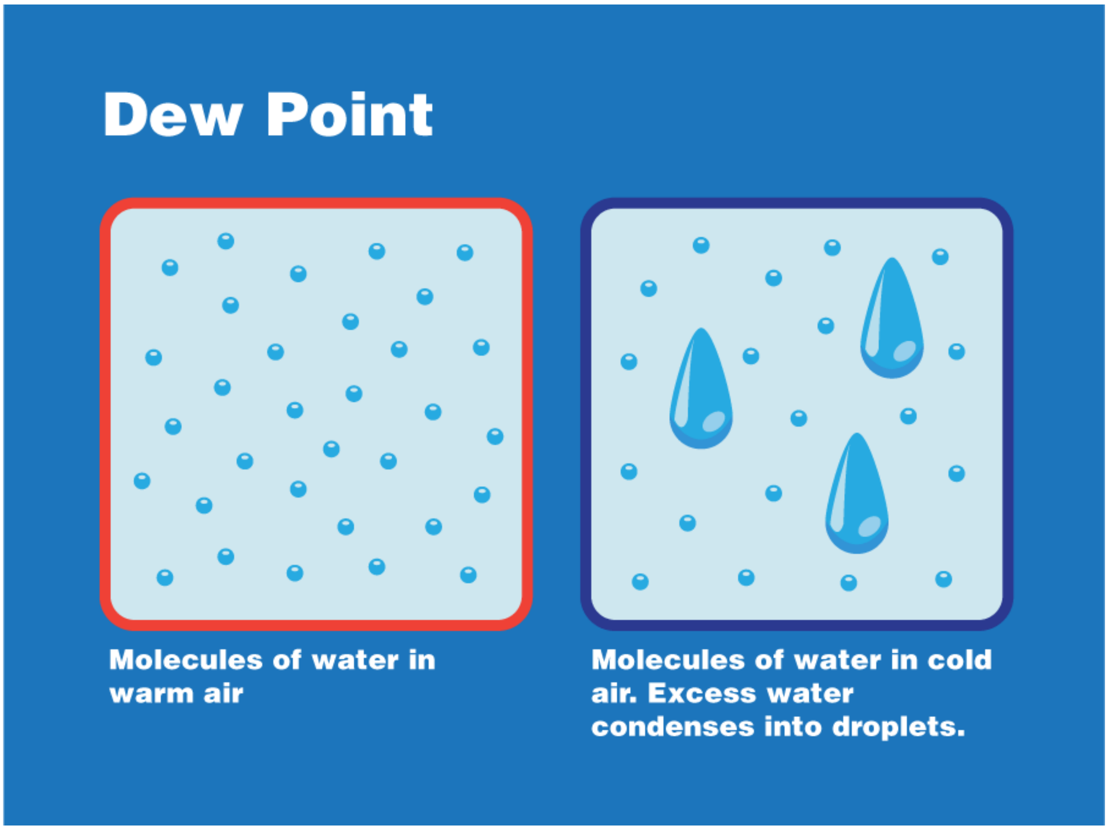

Figure (6): Shows the formation of droplets.

The higher the dew point rises, the greater the amount of moisture in the air, as shown in figure 7. This affects how comfortable it will feel outside.

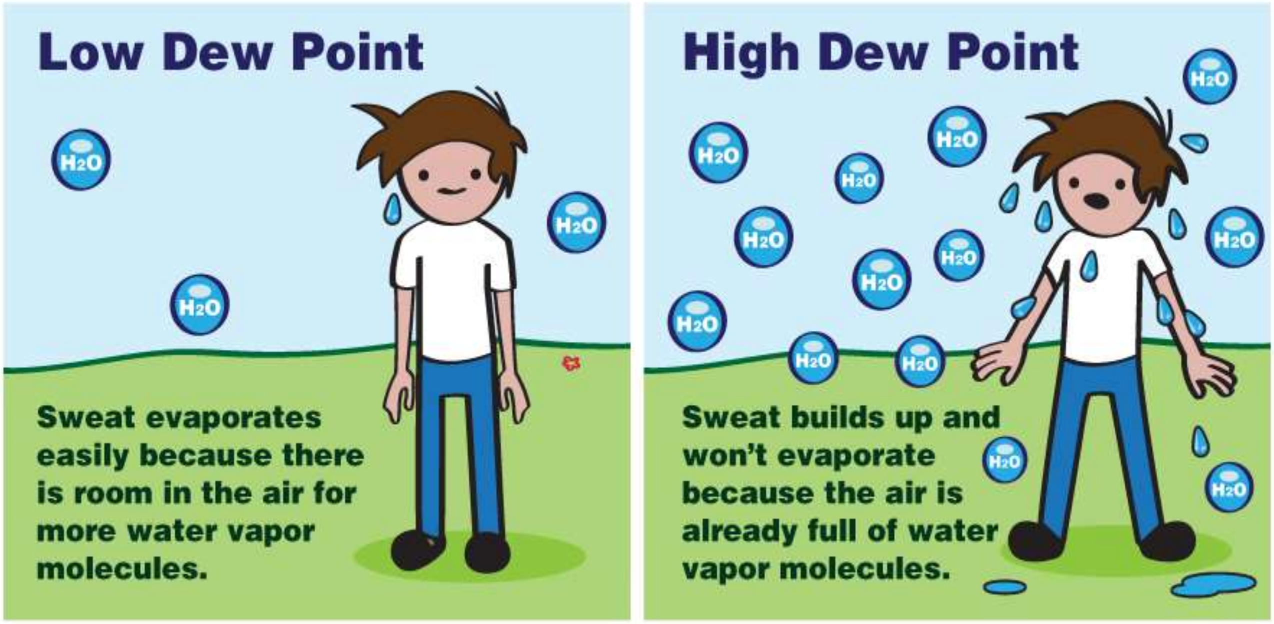

Figure (7): Shows high and low Dew points.

The chart below shows the general comfort levels using the dew point that can be expected during the summer months.

Table (1): Shows the general comfort levels using dew point.

Dew Point	Feeling
Less than or equal to 55	Dry and comfortable
Between 55 and 65	Becoming "sticky" with muggy evenings
Greater than or equal to 65	A lot of moisture in the air, very humid and uncomfortable