Water

By-DhritiGhose

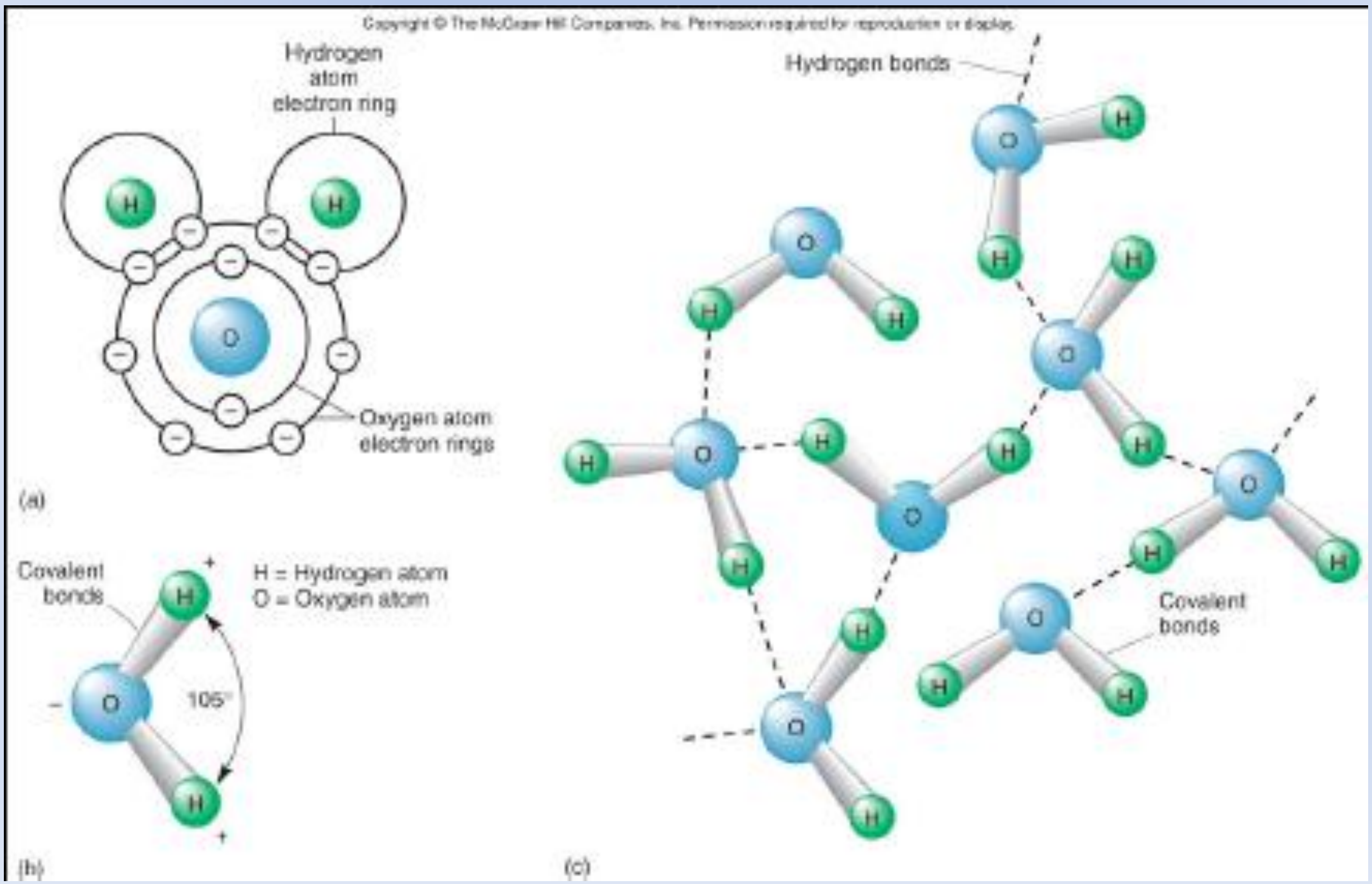
Assistant Professor

UG and PG Dept Of Botany

Raja Narendra Lal Khan Women’s College(Autonomous)

Water is the most **abundant substance in living systems,making up to70%** or more of the **weight** of most organisms. The **first Iiving organisms** on **Earth** doubtless arose in an **aqueous environment**, and the course of evolution has been shaped by the properties of the aqueous medium in which life began.

Chemically unique- Exists in **all three phases at atmospheric** temperatures and pressures(high melting and boiling points compared to molecules of similar size). It is the **only substance** that does this.



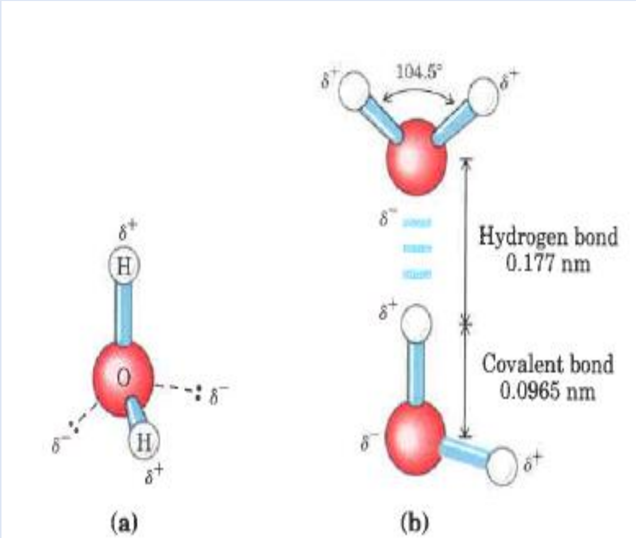
Hydrogen bonding gives water it's unusual properties-

Water has a **higher melting point, boiling point, and heat of vaporizationt** than most other commons solvents. **These unusual properties** are a **consequence of attractions between adjacent water molecules** that give liquid water **great internal cohesion**.
A look at the electron structure of the H2O molecule reveals the cause of these intermolecular attractions.

Each **hydrogen atom** of a **water molecule** shares an **electron pair with the central oxygen atom.** The **oxygen nucleus attracts electrons more strongly than does the hydrogen nucleus (a proton);** that is, **oxygen is more electronegative.**

This means that the **shared electrons** are more often in **the vicinity of the oxygen atom than of the hydrogen.** The result of this **unequal electron sharing is two electric dipoles in the water molecule, one along each of the H-O bonds**; each hydrogen bears a **partial positive charge (delta +),** and the **oxygen atom bears a partial negative charge equal in magnitude to the sum of the two partial positives (2delta-).**

As a result, there is an **electrostatic attraction between the oxygen atom of one water molecule and the hydrogen of another called a hydrogen bond.**



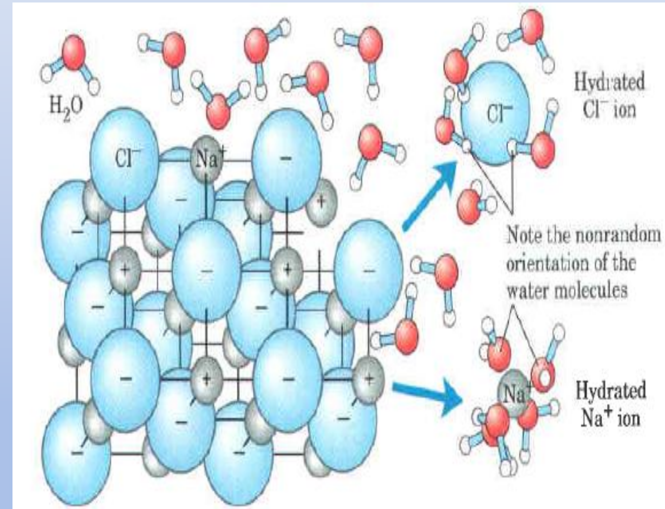
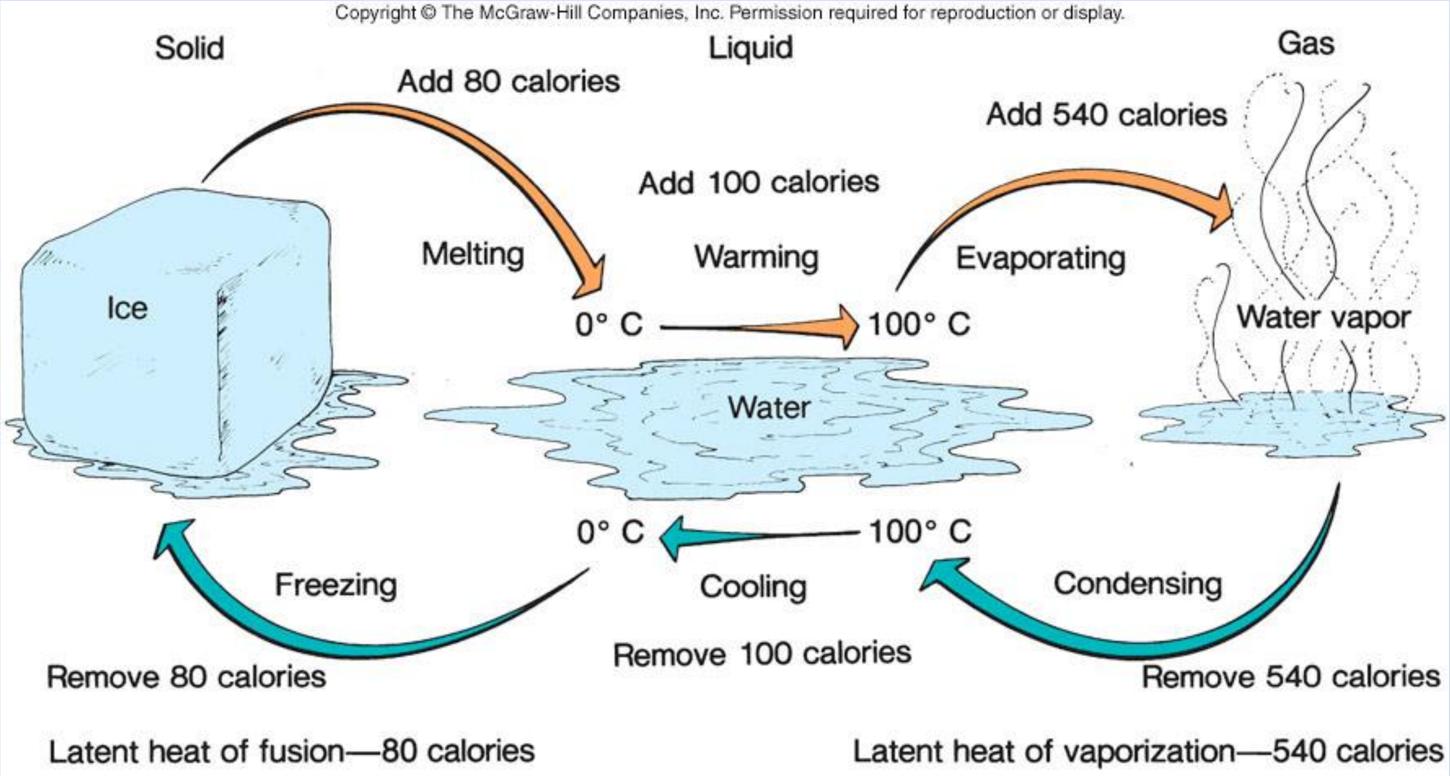


FIGURE 2–6 Water as solvent. Water dissolves many crystalline salts by hydrating their component ions. The NaCl crystal lattice is disrupted as water molecules cluster about the Cl^- and Na^+ ions. The ionic charges are partially neutralized, and the electrostatic attractions necessary for lattice formation are weakened.

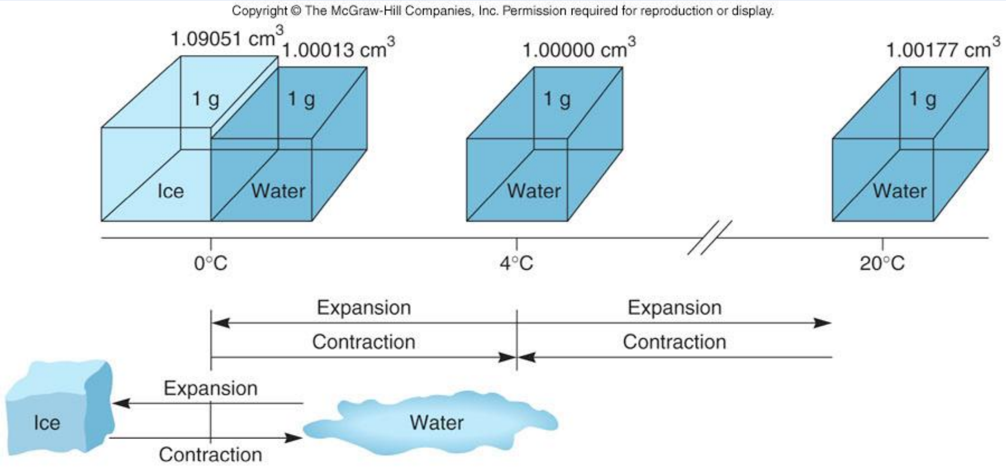
Water is capable of dissolving a variety of different substances, which is why it is such a good solvent. And, water is called the **"universal solvent" because it dissolves more substances than any other liquid.** This is important to every living thing on earth. It means that wherever water goes, either through the ground or through our bodies, **it takes along valuable chemicals, minerals, and nutrients.**

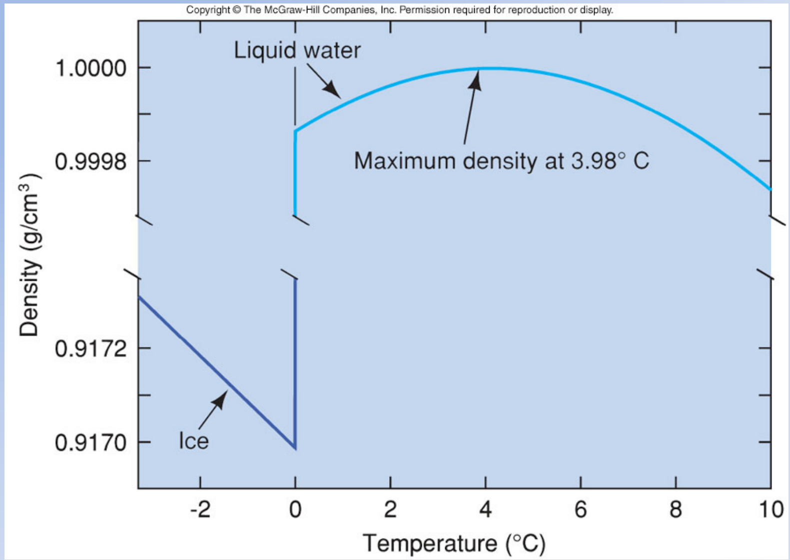
It is water's **chemical composition and physical attributes that make it such an excellent solvent**. Water molecules have a polar arrangement of the oxygen and hydrogen atoms—one side (hydrogen) has a **positive electrical charge and the other side (oxygen) had a negative charge**. This **allows the water molecule to become attracted to many other different types of molecules**. Water can become so heavily attracted to a different molecule, **like salt (NaCl), that it can disrupt the attractive forces that hold the sodium and chloride in the salt molecule together and, thus, dissolve it.**



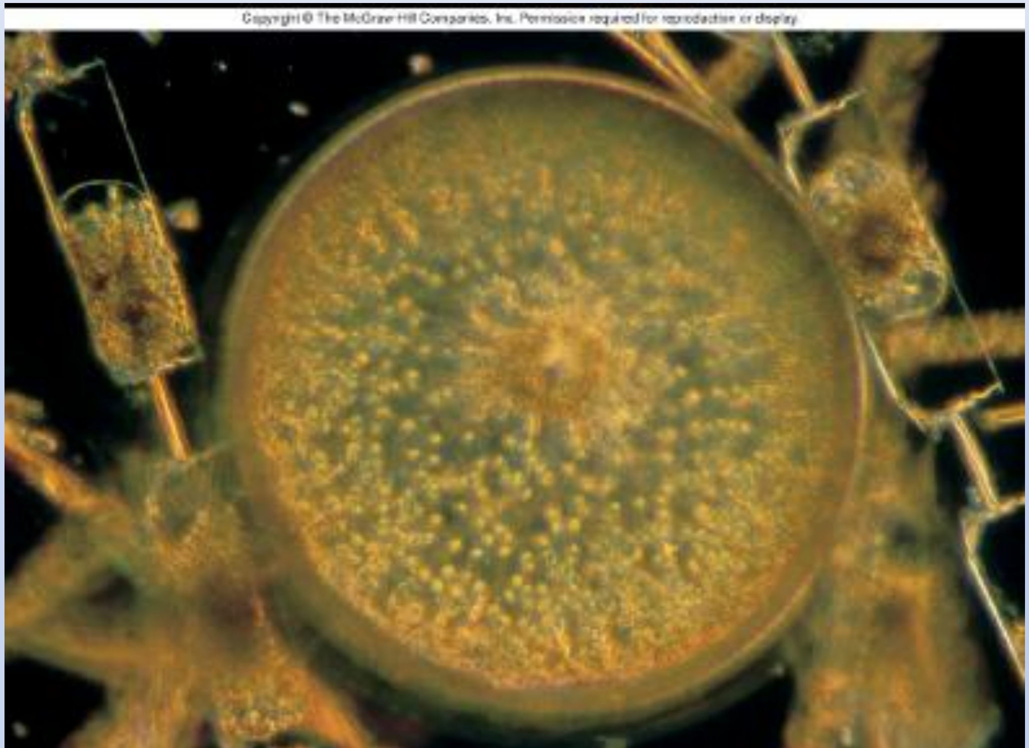
•High heat capacity (4.2 J/g/K). It stores a lot of heat energy which makes it a good medium for spreading the planet's heat

•High heat of fusion (solid to liquid ~ 335 J/g/K) and vaporization (liquid to gas ~ 2400 J/g/K) so more effectively transfers heat when changing phase in atmosphere/ocean





- Water is physically unique because it is less dense as a solid (ice) than as a liquid.
- The maximum density of liquid water occurs at 4ºC Physically

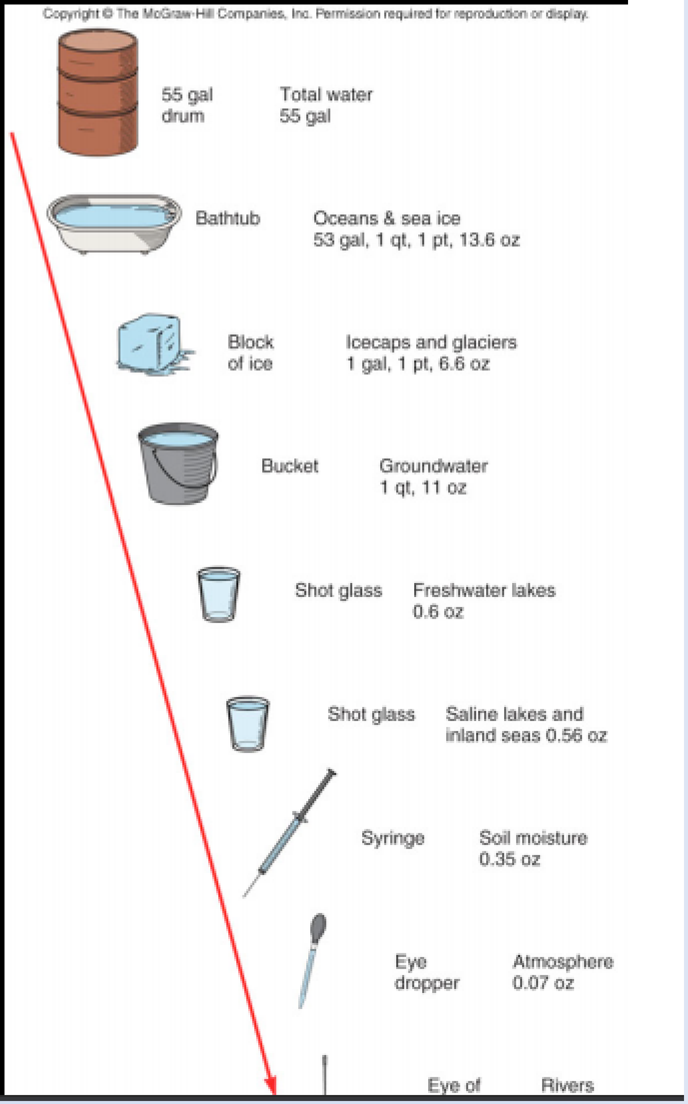


- High surface tension so it forms drops & helps make good cell membranes
- Dissolve other compounds very easily and so can transport chemicals (e.g., NaCl, nutrients)
- Mediates or facilitates most chemical reactions in living systems (e.g., takes water to photosynthesize) - neutral pH

State of water in the environment

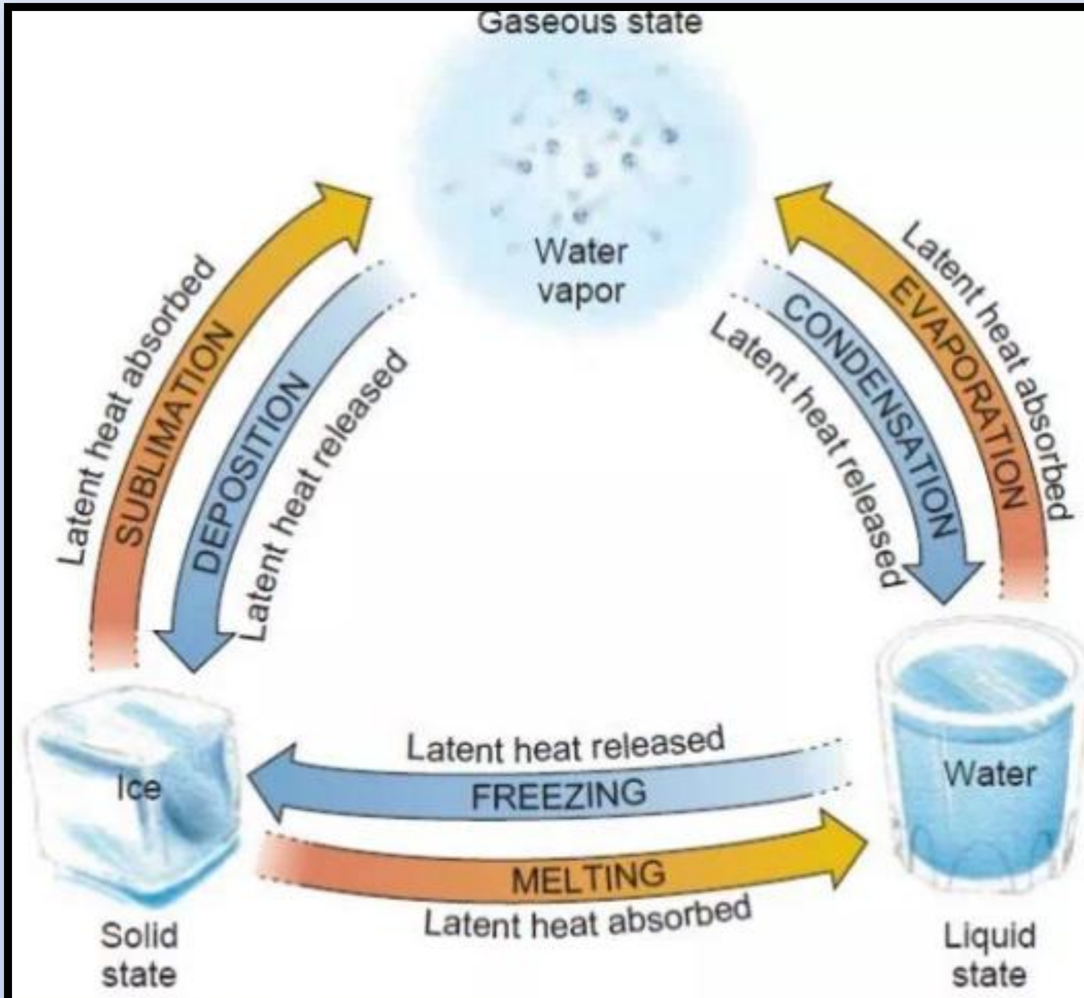
Distribution of water

Water source	Water volume, in cubic miles	Percent of total water
Oceans	317,000,000	97.24%
Icecaps, Glaciers	7,000,000	2.14%
Ground water	2,000,000	0.61%
Fresh-water lakes	30,000	0.009%
Inland seas	25,000	0.008%
Soil moisture	16,000	0.005%
Atmosphere	3,100	0.001%
Rivers	300	0.0001%
Total water volume	**326,000,000**	**100%**



THREE STATES OF WATER

Water can exist in three states—as a **solid (ice), as a liquid (water), or as an invisible gas (water vapor),** as shown in Figure. If we want to change the state of **water from solid to liquid, liquid to gas, or solid to gas, we must put in heat energy**. This energy, which is drawn in from the surroundings and stored within the water molecules, is **called latent heat.** When the change goes the other way, **from liquid to solid, gas to liquid, or gas to solid, this latent heat is released to the surroundings**. **Sublimation is the direct transition from solid to vapor.** Perhaps you have noticed that old ice cubes left in the freezer shrink away from the sides of the ice cube tray and get smaller. They shrink through sublimation—never melting, but losing mass directly as vapor. The term **deposition** **is used to describe the reverse process, when water vapor crystallizes directly as ice**. Frost forming on a cold winter night is a common example of deposition.



4.2 Three states of water

Arrows show the ways that any one state of water can change into either of the other two states. Heat energy is absorbed or released, depending on the direction of change.

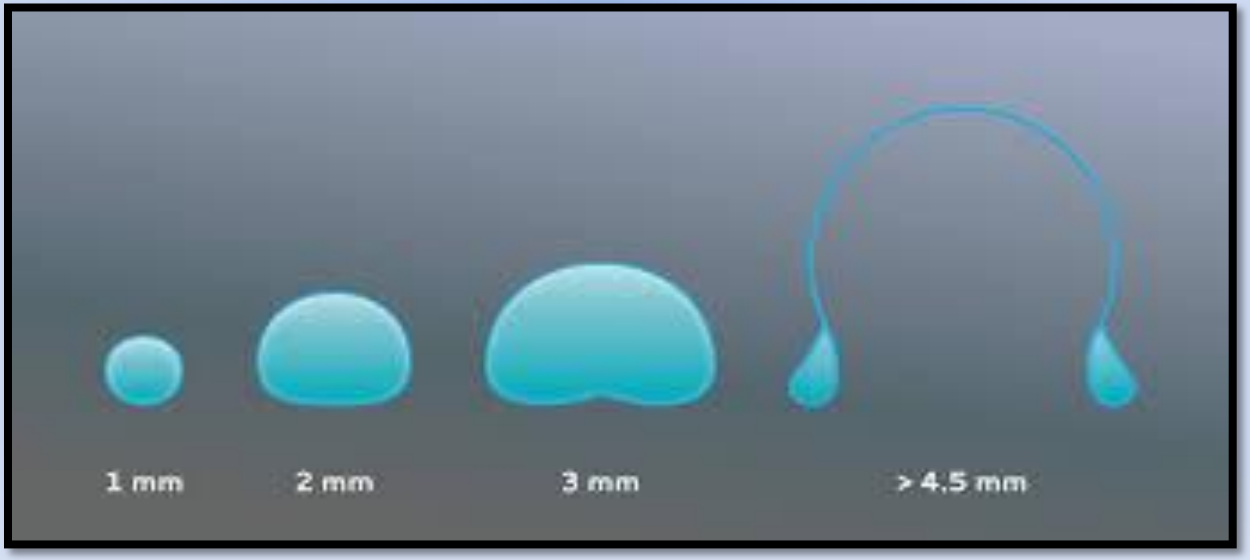
The Water Cycle

You may not be able to see water all around you, but it's there. Water exists in the air in different forms and changes from one form to another. This continual process is known as the water cycle.

Water changes from a liquid to a gas form, called **water vapor,** through a process called **evaporation.** As liquid is heated by the sun's warmth, it changes into a gas form and rises in the atmosphere. In the air, water vapor cools and returns to a liquid form. This process is called **condensation.** These water droplets cling together and form clouds. When the droplets become heavy enough, they fall to the ground as **precipitation.**

Some people find ***precipitation*** **simply means any particle of water—liquid or solid—that originates in the atmosphere and falls to the ground**. **Precipitation is the falling of water from the sky in different forms.** They all form **from the clouds which are raised about 8 to 16 kilometers (4 to 11 miles)** above the ground in the **earth's troposphere**.

There are some forms water can take, so there are a limited number of precipitation types. The main types include: **Rain,Fog,Snow,Hail,Dew**



Rain

Technically, rain isn't just any liquid that falls out of the sky. **Rain is defined as being water droplets of 0.5mm or greater.** Droplets smaller than half a millimeter are classified as drizzle. Raindrops often form **when small cloud particles collide and stick together, forming bigger drops.** Once the **drops get large enough, they are too heavy for rising air to support, gravity draws them down to the ground**. Rain, **which is liquid water droplets known as raindrops, is one of the few precipitation types that can occur during any season**. As long as air temperatures are above freezing (32 F), rain can fall. In air below 0 °C or 32F, raindrops may start as snow or ice crystals but melt when they fall into warmer air.

Sometimes rain evaporates before it reaches the ground, resulting in virga. If you look into the distance and see gray streaks below a cloud that don't reach the ground, you are seeing virga. Another reason rain may not reach the ground is updrafts. If the wind is blowing upward faster than the rain is falling, the rain cannot reach the ground.

Rainfall rates determine if the rain will soak into the soil or run off. According to the National Weather Service, **light rain is anything from .01 to .1 inches per hour, moderate is anything from .1 to .3 inches per hour and heavy rain is anything above .3 inches per hour.** Contrary to popular belief, raindrops are not teardrop shaped. Actually, **very small raindrops are perfect spheres, and larger drops get flatter as they get bigger. An average-sized raindrop has a flat bottom, if not a little concave, and the sides and top are rounded**. This shape has been described as looking like a hamburger bun, a parachute, or a jellyfish without tentacles..

Acid rain occurs when rain becomes mixed with pollutants such as **sulfur oxides and nitrous oxides.** It **kills plants and pollutes water sources**.

Hail- Hailstones are large **chunks of ice that fall from large thunderstorms**. hailstones originate **high in the atmosphere** where the air **is much colder than the surface**. They are highly **damaging to crops**, easily earning the nickname “**the white plague**”. Hail the size of grapefruits have been known to cause **extensive property damage and even fatalities**. But even small hail can cause **damage to crops and bruise or mark them, reducing their value**. Hail is **100% ice but is not necessarily a wintertime event.** It usually falls only during **thunderstorms.** Hail is **smooth, usually round (though parts can be flat or have spikes), and anywhere from pea-size to as large as a baseball.**

In Figure, you can see that a hailstone has layers like an onion. The **opaque layers** are created when the **hail is in the colder section of the cloud**, or gets caught in the downdrafts, and the **supercooled droplets freeze** onto the **hail so quickly tiny air bubbles get trapped**, causing the ice to look **milky**. When the **hail falls into the warmer portion of the cloud**, or into the warm **updrafts, the supercooled droplets freeze slowly enough** that the tiny **air bubbles have time to escape** before the **water freezes, resulting in a sheet of clear ice**.

Hail

Westend61/Getty Images

Figure B. A hailstone bisected to show the layers. (Image from Wikipedia).

FogHave you ever walked outside on a foggy day and wondered if you were stepping into a cloud? Fog is similar to clouds because **it is made of water vapor that has cooled, or condensed, to form tiny water droplets.**

However, unlike clouds, **fog forms from the ground up.** Fog is formed when **the air, which contains water vapor, is cooled by the ground or a body of water.**

Fog, generally considered an atmospheric hazard, is a **cloud with its base at or very near the ground.** Fogs formed by cooling include: **radiation fog** (from radiation cooling of the ground and adjacent air),

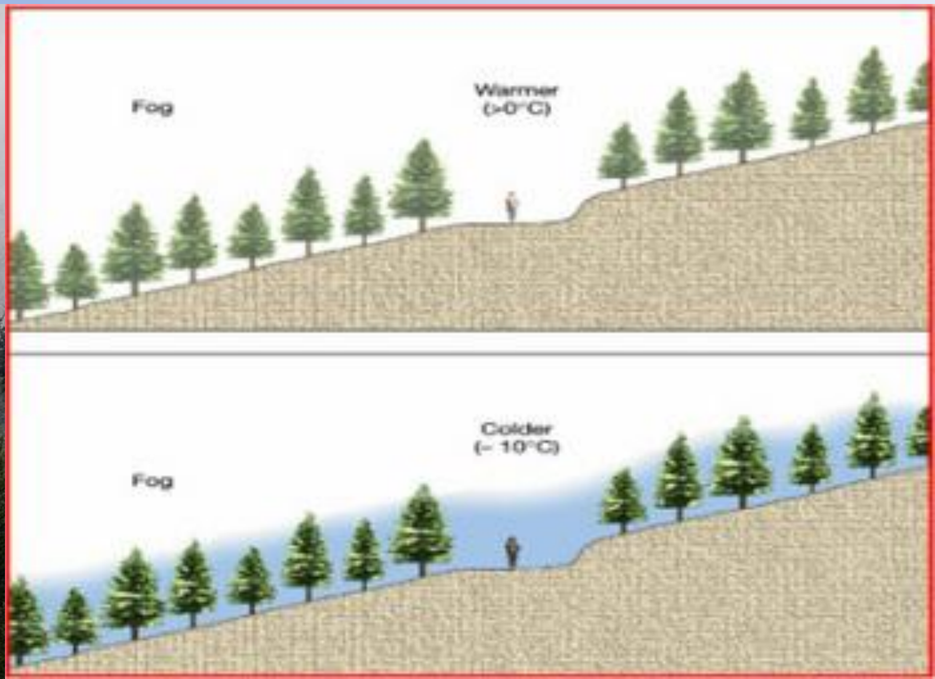
advection fog (when warm and moist air is blown over a cold surface),

and **up-slope fog** (created when relatively humid air moves up a slope and cools adiabatically).

Those formed by evaporation are:

steam fog (when rising water vapor over warm water condenses in cool air)

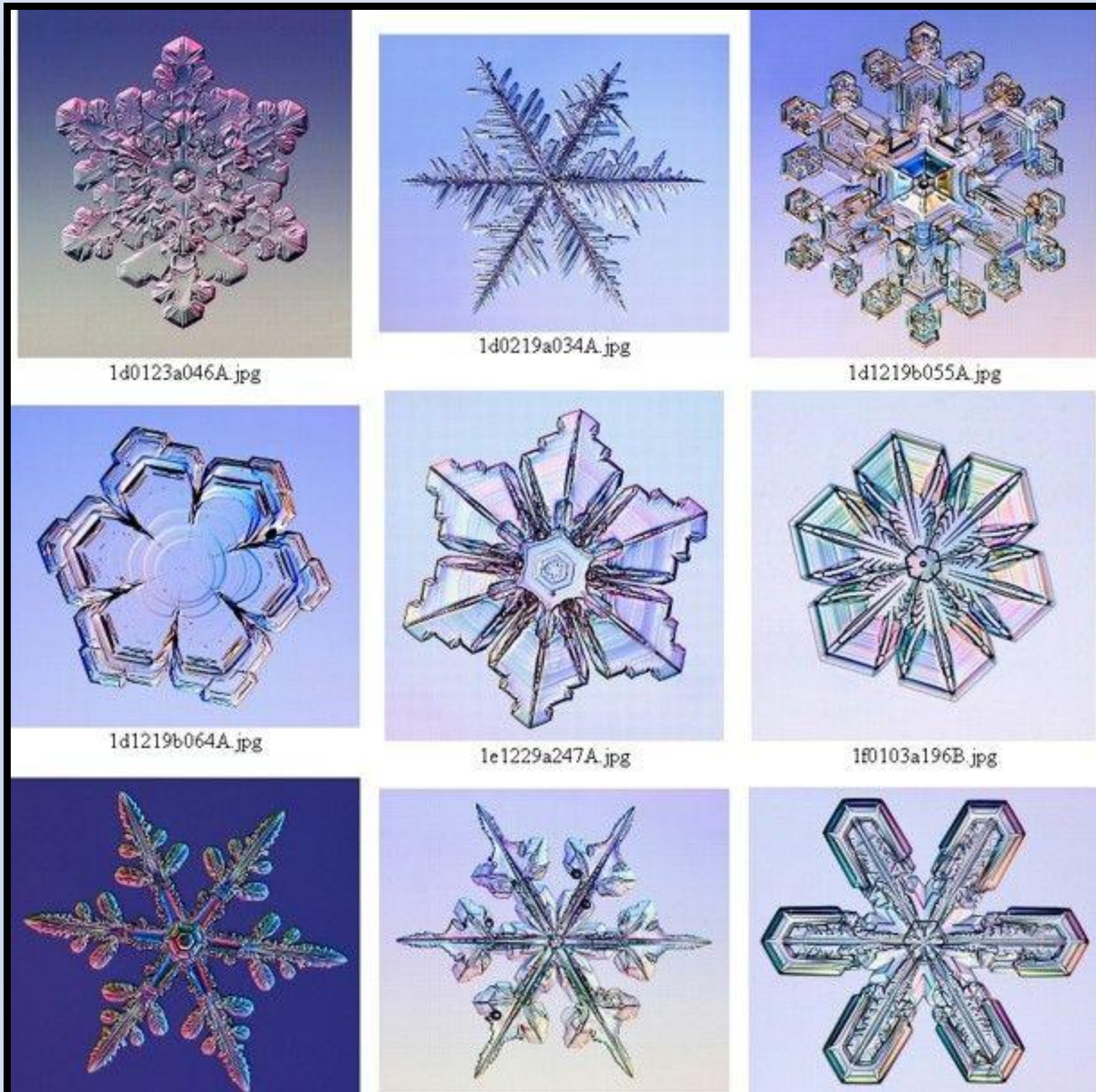
frontal fog (when warm air is lifted over colder air along a front).



Snow-While we tend to think of snow and ice as two different things, **snow is actually millions of tiny ice crystals that collect and form into flakes, which we know as snowflakes.** For snow to fall outside your window, air temperatures above the surface must be below freezing (32 F).

Snow **occurs almost every time there is rain**. However, snow often melts before it reaches the earth surface. It is precipitation in the form of virga or flakes of ice water falling from the clouds. Snow is normally seen **together with high, thin and weak cirrus clouds**. Snow can at times fall when the atmospheric temperatures are above freezing, but it mostly **occur in sub-freezing air.** When the temperatures are above freezing, the snowflakes **can partially melt** but because of relatively warm temperatures, **the evaporation** of the **particles occur** almost immediately.

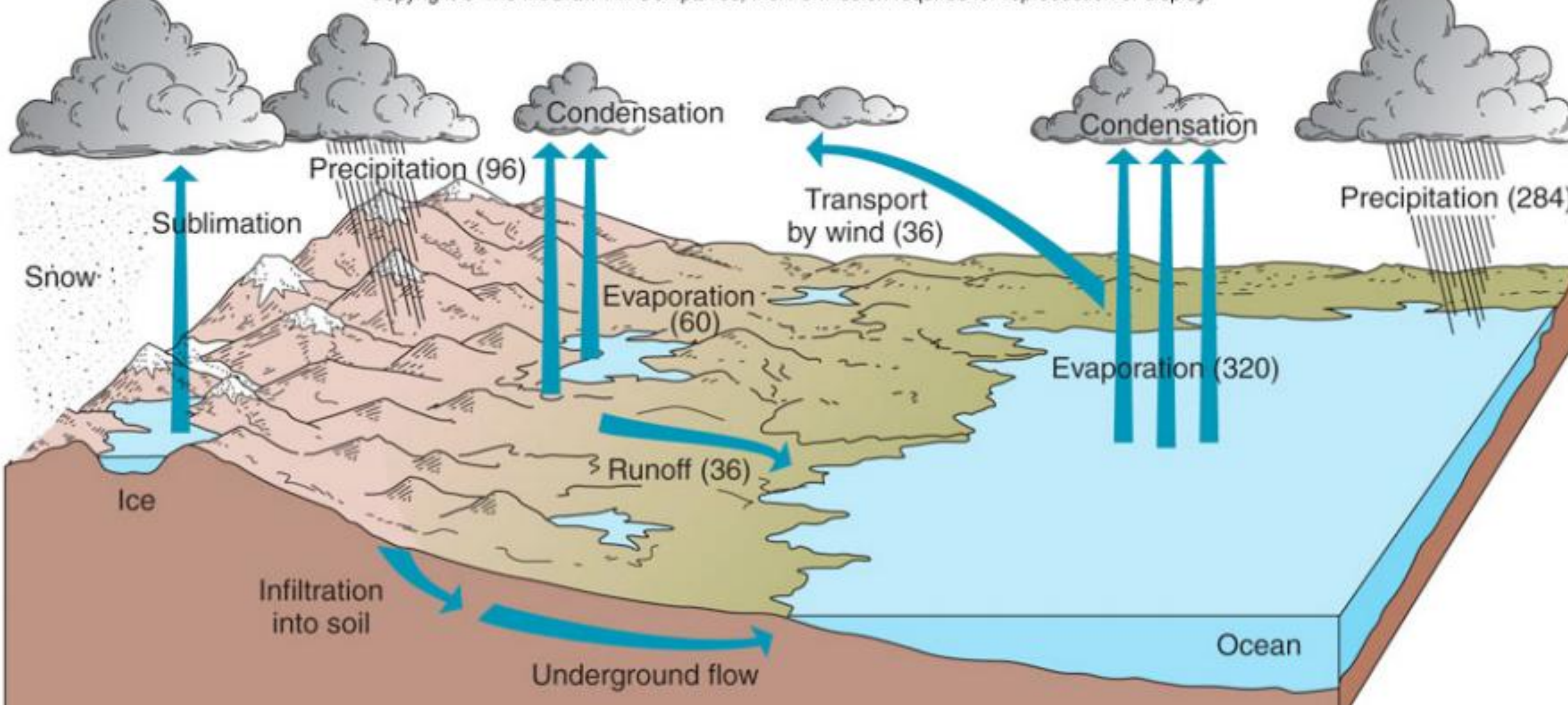
Snow has **fluffy, white and soft structure and its formation is in different shapes and ways, namely flat plates and thin needles**. Each type of snow **forms under specific combinations of atmospheric humidity and temperatures.** The process of snow precipitation is called **snowfall.**


1d0123a046A.jpg
1d0219a034A.jpg
1d1219b055A.jpg
1d1219b064A.jpg
1e1229a247A.jpg
1f0103a196B.jpg

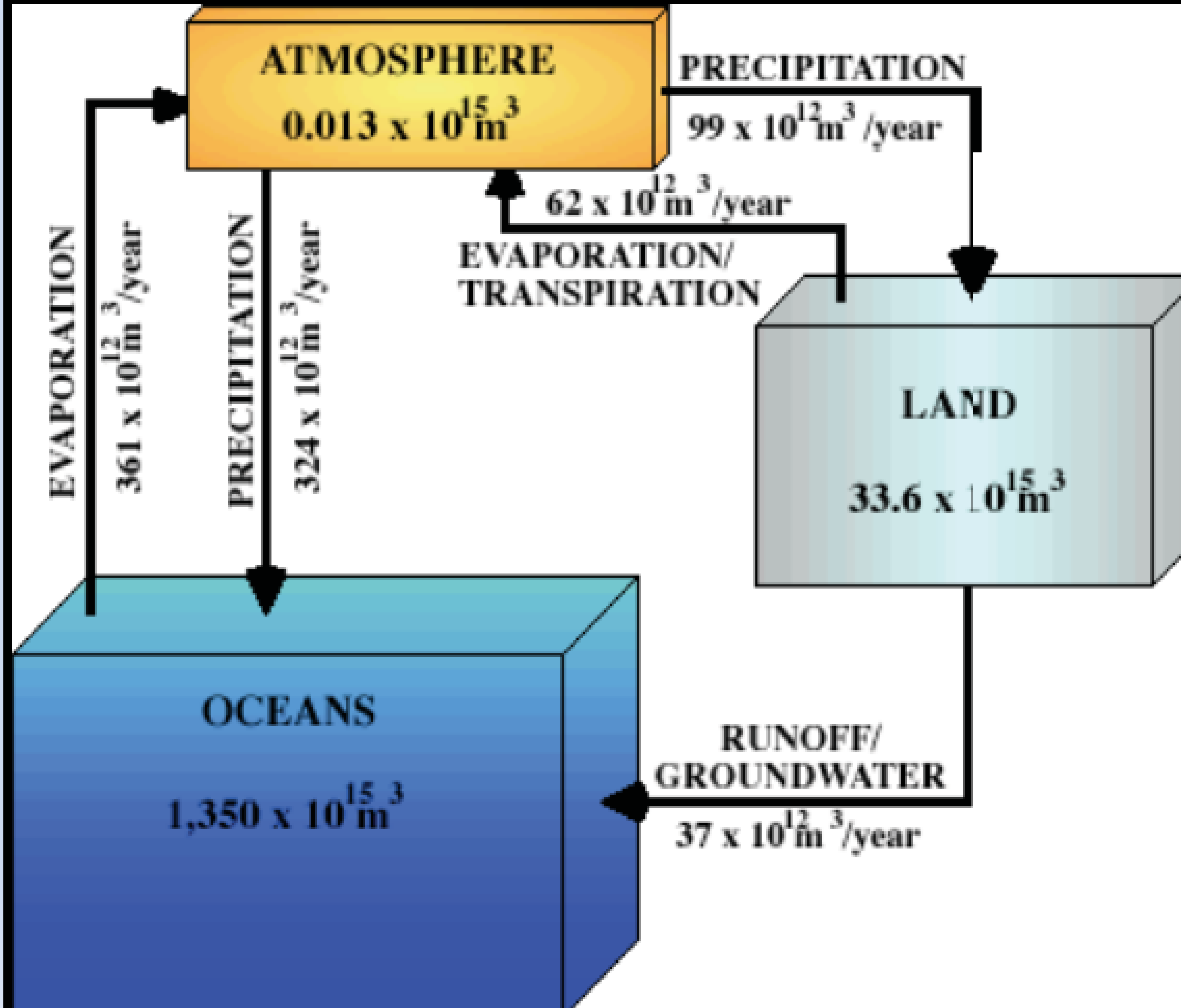
Dew is the moisture that forms at night when objects or the ground outside cool down by radiating, or emitting, their heat **.Dew forms when a surface cools through loss of [infrared radiation] down to a temperature which is colder than the [dewpoint] (**the temperature at which water vapor condenses.)**of the air next to that surface.** The dew point varies by area and even time of day. **Dew is made of liquid water that has [condensed] from some of the [water vapor] contained in the air.**

Dew on a spider web (photo: U.S. Fish and Wildlife service)

Hydrologic Cycle (in 10^3 km^3)



Quantitative Hydrological Cycle



The **hydrologic cycle, or water cycle**, moves **water from land and ocean to the atmosphere**. Water from the o**ceans and from land surfaces evaporates, changing state from liquid to vapor and entering the atmosphere**. Total evaporation is about **six times greater over oceans than land because oceans cover most of the planet** and because land surfaces are not always wet enough to yield much water. **Water vapor in the atmosphere can condense or deposit to form clouds and precipitation, which falls to Earth as rain, snow, or hail.** There is nearly **four times as much precipitation over oceans than precipitation over land.**

When it hits land, precipitation has three fates. First, it can **evaporate and return to the atmosphere as water vapor**. Second, it can **sink into the soil and then into the surface rock layers below.** Third, **precipitation can run off the land, concentrating in streams and rivers that eventually carry it to the ocean or to lakes**. This flow is known as runoff.

Because our planet **contains only a fixed amount of water,** a global balance must be maintained **among flows of water to and from the lands, oceans, and atmosphere**.

For the ocean, evaporation leaving the ocean is approximately **420 km3/yr (101 mi3/yr),** while the amount entering the ocean via **precipitation is 380 km3/yr (91 mi3/yr**). There is an imbalance between the amount of water lost to evaporation and the amount gained through precipitation. This imbalance is made up by the **40 km3/yr (10 mi3/yr)** that flows from the land back to the ocean.

Similarly, for the **land surfaces of the world, there is a balance**. Of the **110 km3/yr (27 mi3/yr**) of water that falls on the land surfaces, **70 km3/yr (17 mi3/yr)** is reevaporated back into the atmosphere. The remaining **40 km3/yr (10 mi3/yr**) stays in the form of liquid water and eventually flows back into the ocean.

When **rain or irrigation water is supplied to a field, it seeps** into the soil. This process is called infiltration.

Water in Soil

Soil moisture conditions

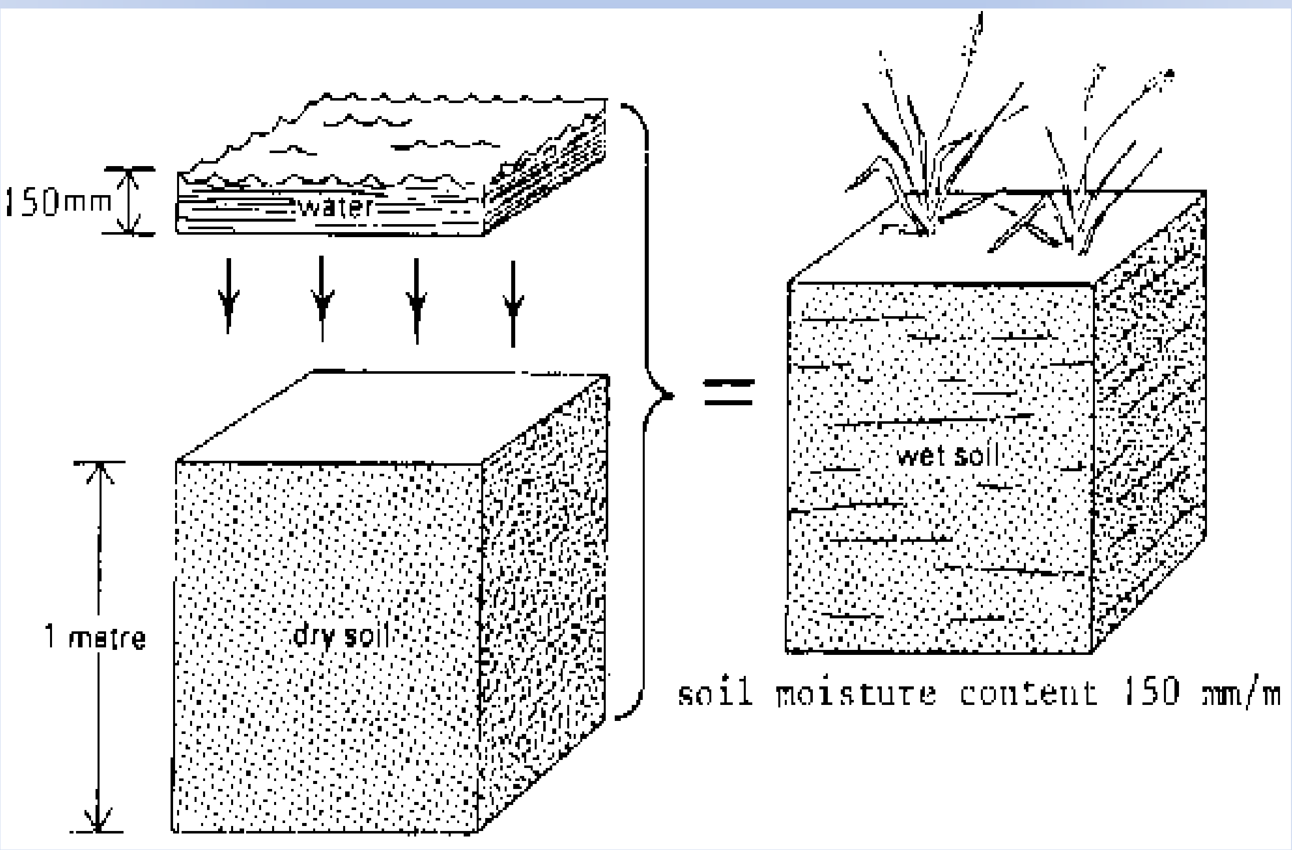
Soil moisture content

Saturation

Field capacity

Permanent wilting point

The soil moisture content indicates the **amount of water present in the soil**.
It is commonly expressed as the amount of water (in mm of water depth) present in a depth of one metre of soil.
For example: when an amount of water (in mm of water depth) of 150 mm is present in a depth of one metre of soil, the soil moisture content is 150 mm/m



Thus, a moisture content of 100 mm/m corresponds to a moisture content of 10 volume percent.

The soil moisture content can also be expressed in percent of volume. In the example above, 1 m^3 of soil (e.g. with a depth of 1 m, and a surface area of 1 m^2) contains 0.150 m^3 of water (e.g. with a depth of 150 mm = 0.150 m and a surface area of 1 m^2).

This results in a soil moisture content in volume percent of:

$$\frac{0.150\,m^3}{1m^3} \times 100\% = 15\%$$

Saturation

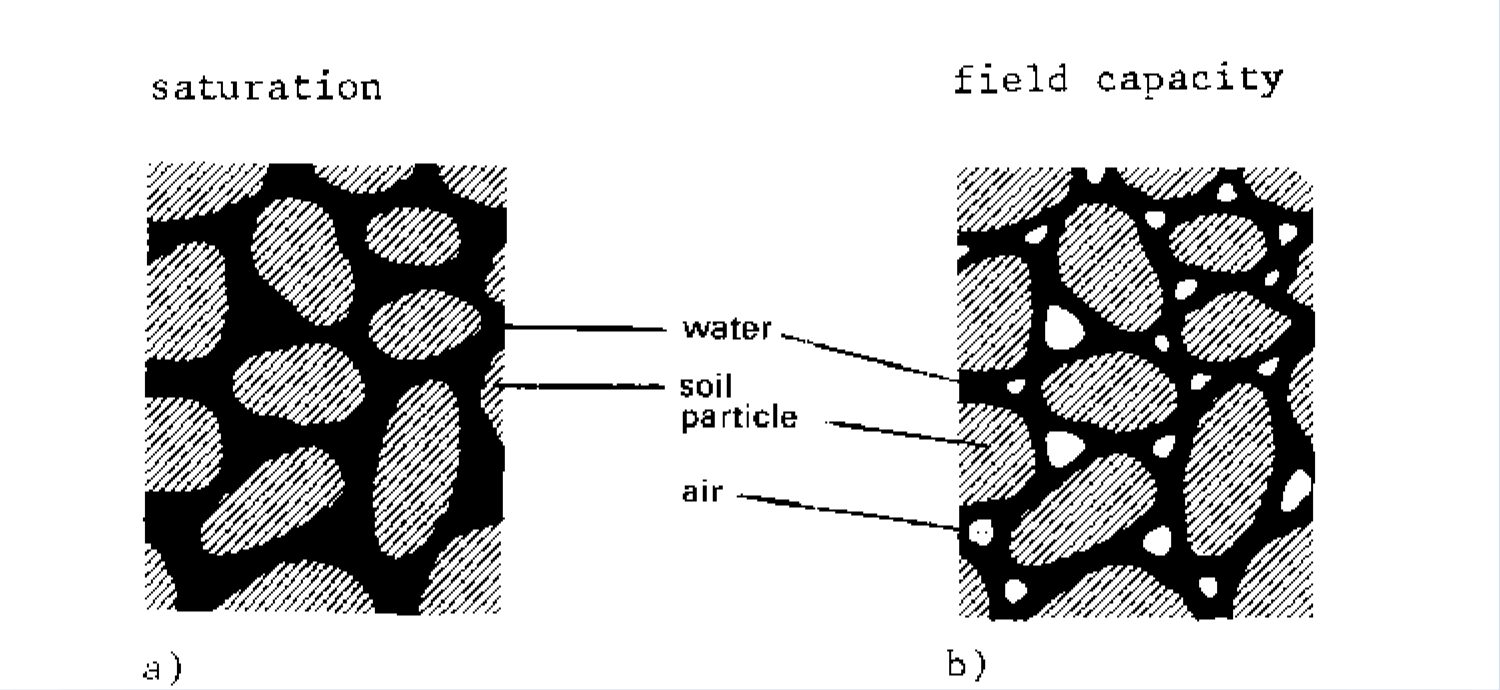
During a rain shower or irrigation application, the soil pores will fill with water. **If all soil pores are filled with water the soil is said to be saturated. There is no air left in the soil** (see Fig)It is easy to determine in the field if a soil is saturated. If a handful of saturated soil is squeezed, some (muddy) water will run between the fingers. **Plants need air and water in the soi**l. At saturation**, no air is present and the plant will suffer**. Many crops cannot withstand saturated soil conditions for a period of more than 2-5 days. Rice is one of the exceptions to this rule. The period of saturation of the topsoil usually does not last long. After the rain or the irrigation has stopped, part of the **water present in the larger pores will move downward**. This process is called **drainage or percolation.**

The water **drained from the pores is replaced by air**. In coarse textured (sandy) soils, drainage is completed within a period of a few hours. In fine textured (clayey) soils, drainage may take some (2-3) days.

Field capacity

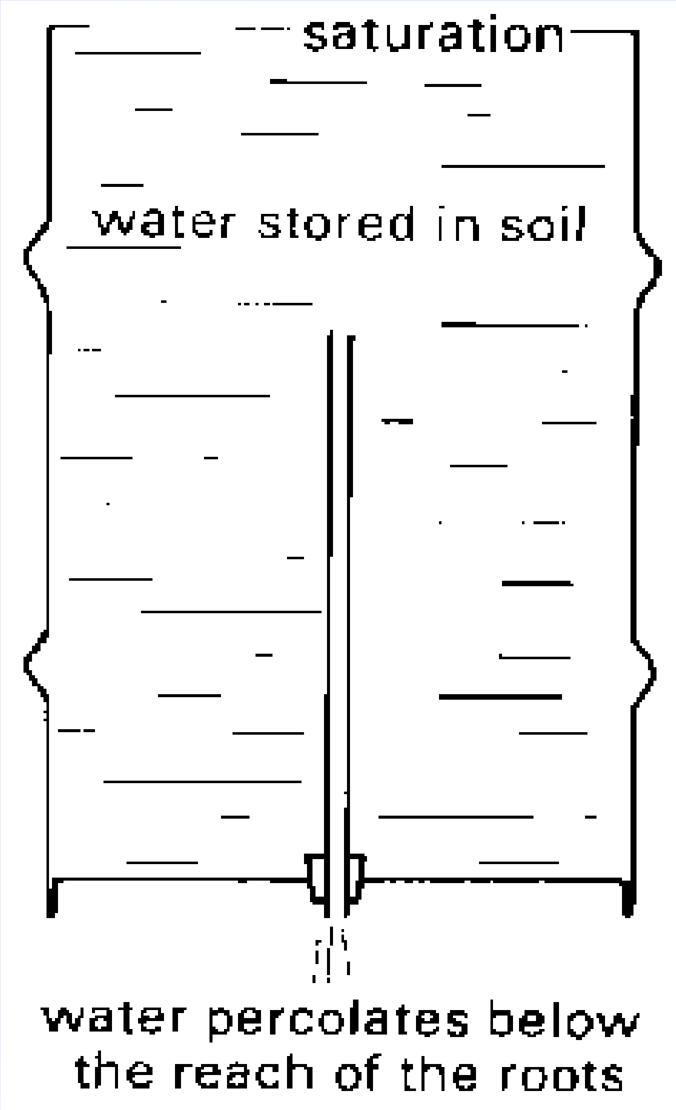
After the drainage has stopped, the **large soil pores are filled with both air and water while the smaller pores are still full of water**.

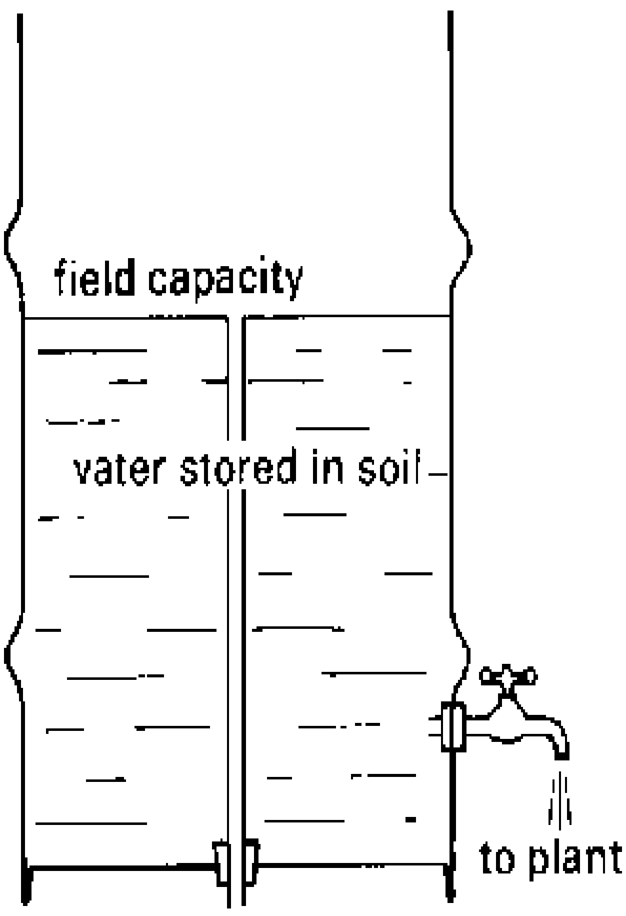
At this stage, the **soil is said to be at field capacity. At field capacity**, the water and air contents of the soil are considered to **be ideal for crop growth**



The soil can be compared to a water reservoir for the plants. When the soil is saturated, the reservoir is full. However, some water drains rapidly below the rootzone before the plant can use it

When this water has drained away, the soil is at field capacity. The plant roots draw water from what remains in the reservoir

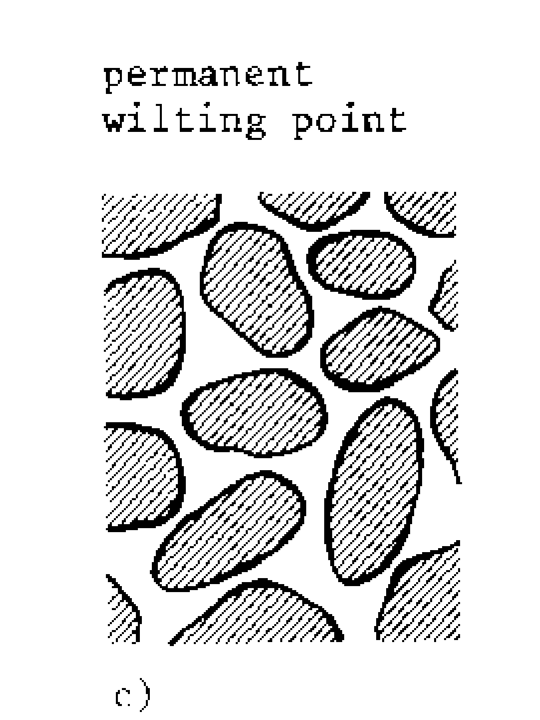


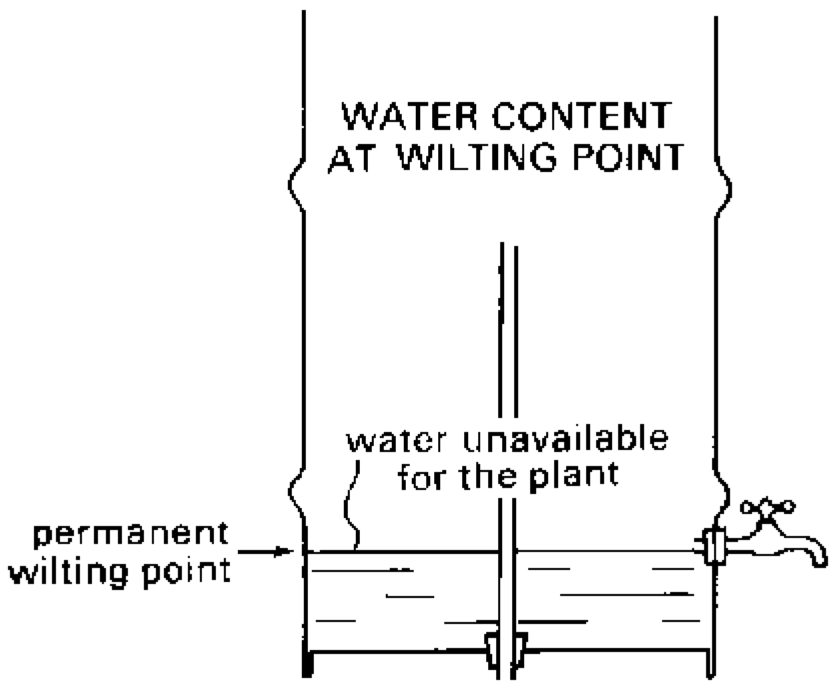


Permanent wilting point

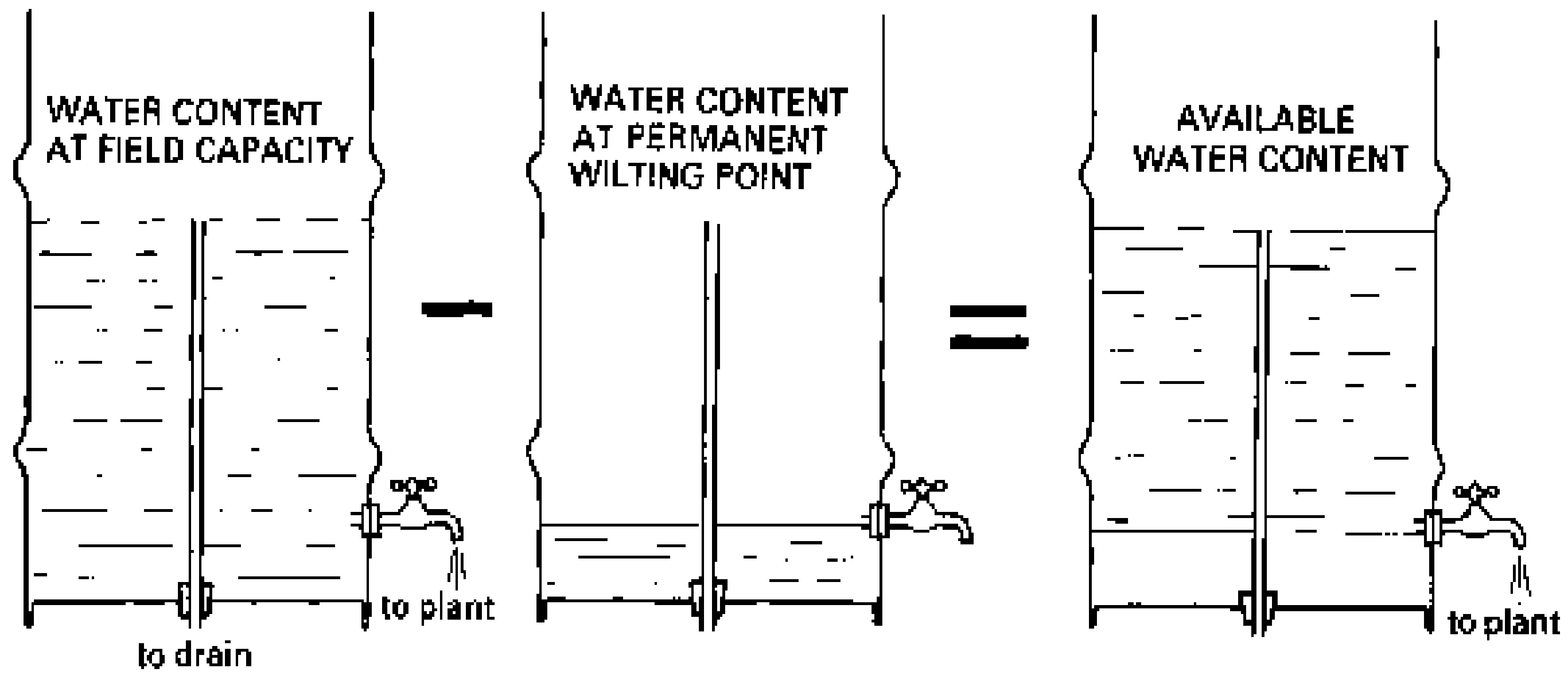
Little by little, the water stored in **the soil is taken up by the plant roots or evaporated from the topsoil into the atmosphere.** If no additional water is supplied to the soil, **it gradually dries out.**
The dryer the soil becomes, the **more tightly the remaining water is retained and the more difficult it is for the plant roots to extract it.** At a certain stage, the **uptake of water is not sufficient to meet the plant's needs. The plant looses freshness and wilts**; the leaves change colour from green to yellow. **Finally the plant dies.**
The soil water content at the stage where the plant dies, is **called permanent wilting point**. The soil still contains some water, but it is **too difficult for the roots** to suck it from the soil

When the soil reaches permanent wilting point, the remaining water is no longer available to the plant





The amount of water actually available to the plant is the amount of water stored in the soil at field capacity minus the water that will remain in the soil at permanent wilting point.



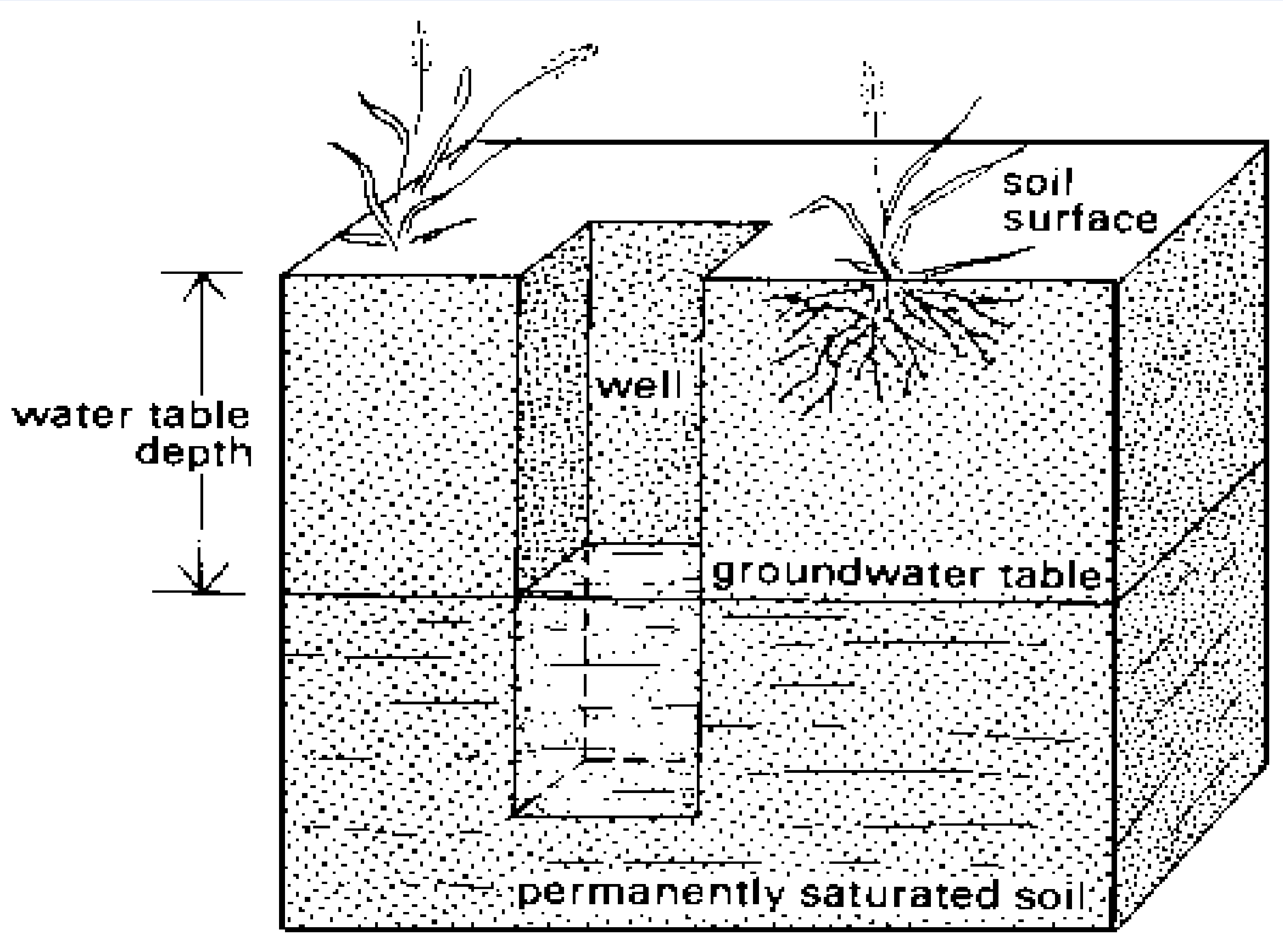
Available water content = water content at field capacity - water content at permanent wilting point

The **available water content** depends greatly on the **soil texture and structure**.
A range of values for different types of soil is given in the following table.
The **field capacity, permanent wilting point (PWP) and available water content are called the soil moisture characteristics.**
They are **constant for a given soil,** but vary widely from one type of soil to another.

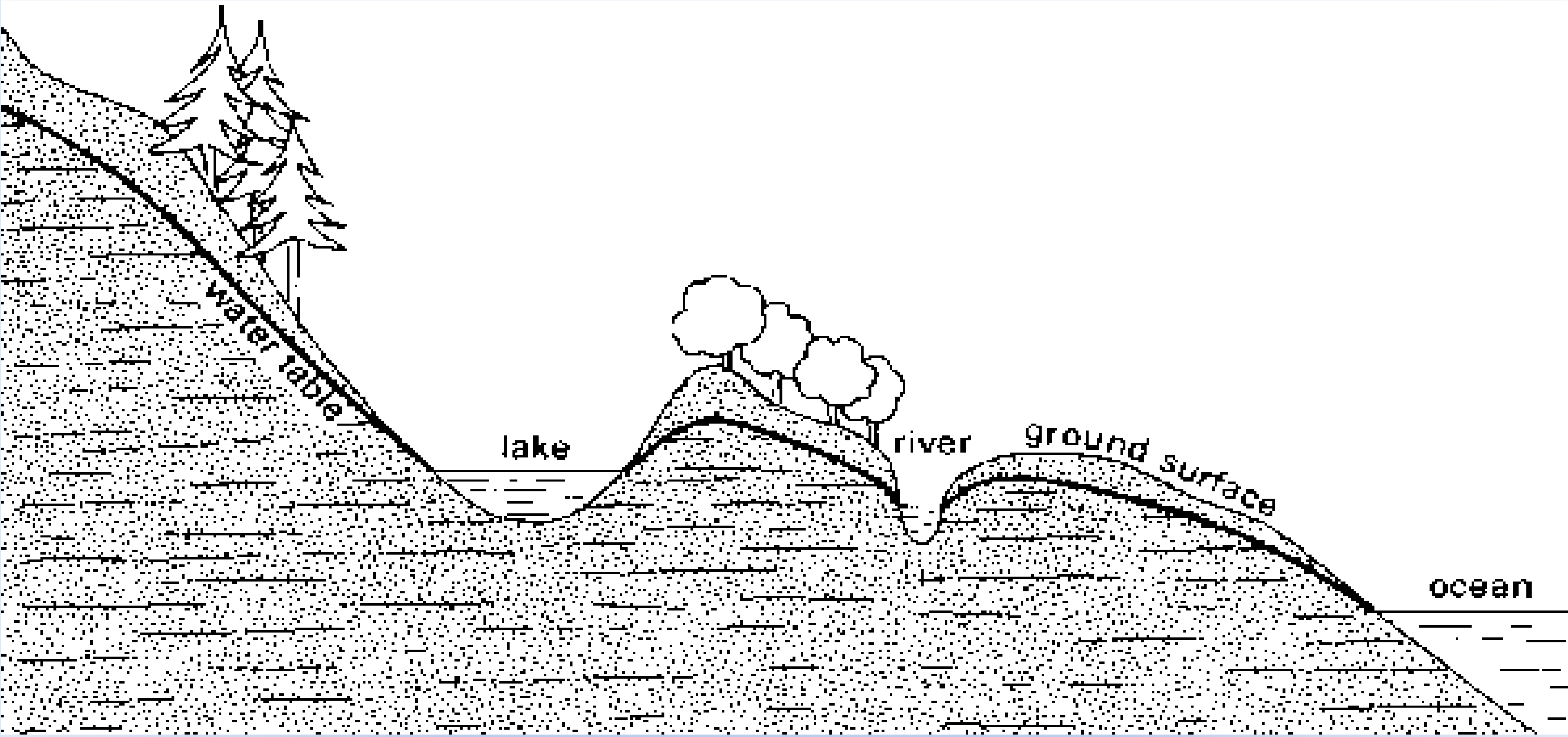
Soil Type	Available water content in mm water depth per m soil depth (mm/m)
sand	25 to 100
loam	100 to 175
clay	175 to 250

Part of the water applied to the **soil surface drains below the rootzone and feeds deeper** soil layers which are **permanently saturated**; the **top of the saturated layer is called groundwater table or sometimes just water table.**

Water table, also called **groundwater table**,is the **upper level of an underground surface in which the soil or rocks are permanently saturated with water.** The water table separates the **groundwater** **zone that lies below it** from the **capillary fringe**, **or zone of aeration, that lies above it.** The water table **fluctuates both with the seasons and from year to year** because it is affected by **climatic variations and by the amount of precipitation used by vegetation**. It also is affected by withdrawing excessive amounts of water from wells or by recharging them artificially.


soil
surface
well
water table
depth
groundwater table
permanently saturated soil

The **depth of the groundwater table varies** greatly from **place to place, mainly due to changes in topography of the area**



In one particular place or field, the depth of the groundwater table may vary in time. Following **heavy rainfall or irrigation, the groundwater table rises**. It may even reach and saturate the **rootzone.** If prolonged, this situation can be **disastrous for crops which cannot resist "wet feet" for a long period.** Where the groundwater table appears at the surface, it is called an **open groundwater table**. This is the case in **swampy areas**.

The **groundwater table can also be very deep** and distant from the rootzone, for example following a **prolonged dry period**. To keep the rootzone moist, **irrigation i**s then necessary.

References-

1.https://climate.ncsu.edu/edu/PrecipTypes

2.http://**kvgktrailblazers.weebly.com/forms-of-precipitation.html**

3.https://www.accuweather.com/en/weather-news/everything-you-need-to-know-about-hail/330487

4.https://www.eartheclipse.com/geography/different-types-of-precipitation.html

5.https://weatherstreet.com/weatherquestions/How_does_dew_form.htm

6.https://www.thoughtco.com/precipitation-types-3444529

7.https://www.usgs.gov/special-topic/water-science-school/science/water-qa-why-water-universal-solvent?qt-science_center_objects=0#qt-science_center_objects

8.https://geography.name/water-in-the-environment/

9. PRINCIPLES OF BIOCHEMISTRY-Lehninger

10. http://www.fao.org/3/r4082e/r4082e03.htm