BIO 101

Chapter #3

Notes :

1. this handout contains all important information and pictures of the book ..
2. Use dictionary not translator to know the meanings in Arabic ..

3.this handout is made by students ☺

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Chapter 3

Water and the Fitness of the Environment

Overview

water : The Molecule That Supports All of Life

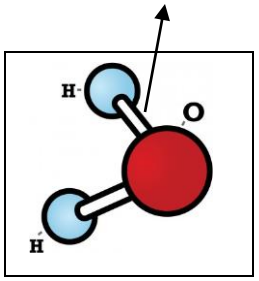
- Water is the biological medium on Earth , the abundance of water is the main reason in making the Earth habitable .
- All living organisms require water more than any other substances. Most cells are surrounded by water, and cells themselves are about 70–95% water .
- Water is the only common substance to exist in the natural environment in all three physical states of matter **(solid ,liquid, gas)** …..

Concept 3.1: The polarity of water molecules results in hydrogen bonding

- Water molecule (H2O) is
  1. inorganic molecule .
  2. polar molecule.

The Polarity of water

- water molecule is shaped like a wide (V)with its 2 hydrogen atoms joined to the oxygen atom by a **single covalent bonds**.
- **Covalent bond**: a type of strong chemical bonds which in two atoms share one or more pairs of valence electrons



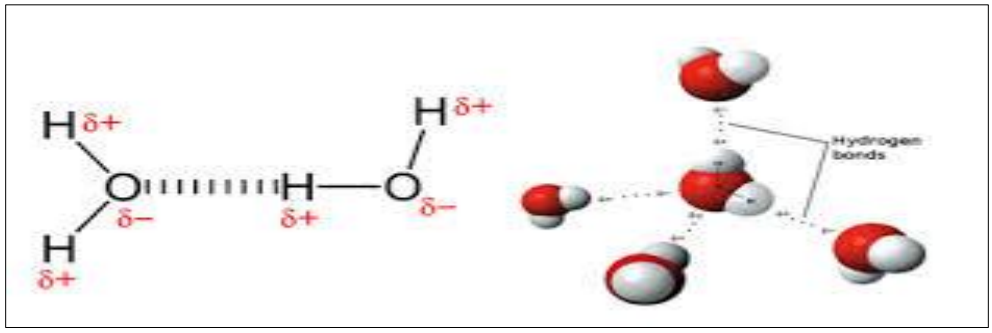
- **O** is **more electronegative** than **H**, So the electrons of the covalent bond spend more time closer to (**O**)than to (**H**) , because of that (**O**) atom will have a partial negative charge while **(H)** atoms will have a partial positive charges
- **Electro negativity** : is the attraction of an atom for the electrons of a covalent bond

Covalent bond → **2 atoms , one is more electronegative than the other** → **Polar molecule**

- **Polar molecule** : Two ends of the molecule have opposite charges .

  *Polarity allows water molecules to form hydrogen bonds with each other.

- **Figure 3.2 :**
  Hydrogen bonds between water molecules
  Each **1** water molecule bonding with **4 others ..**



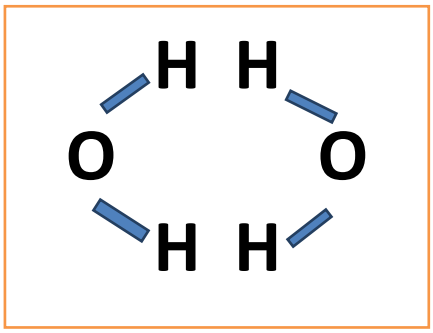
polar molecules → **Attaching between opposite charges of atoms in molecules** → **Polar Molecules attached by Hydrogen bonds**

Summary :

- Hydrogen bond depends on **polarity**.
- **Polarity** depends on <u>difference of electro-negativity</u> between bonded atoms .
- **How does electron negativity affect interaction between water molecules?**

because O is more **electronegative** than H , the o atom in H2o pulls electrons towards itself, resulting in partial negative charge on the o atom and partial positive charge hydrogen atoms ; oppositely charged ends of water molecules are attracted to each other and forming hydrogen bonds .

Q : **why is it unlikely that to neighboring water molecules would be arranged like this ??**

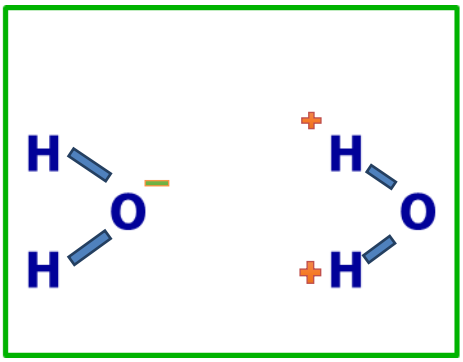


Answer :

The hydrogen atoms of one molecule with their partial positive charges , would rebel the hydrogen atoms of the adjacent molecule .

Right arrange of water molecules to form hydrogen bonds

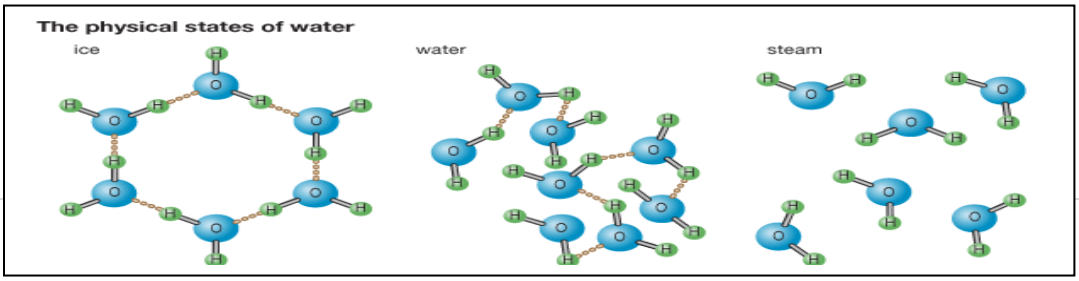
Back to figure 3.2 in page 2 ☺



- The hydrogen bonds of Water in the **liquid state** are very Fragile (each about 1/20 as strong as a covalent bond) .

- The hydrogen bonds form, break and reform with great frequency (each lasts only a few trillionths of a second).

- So, the arrangement of molecules in a sample at liquid water is constantly changing ,but at any moment many of molecules are linked by multiple hydrogen bonds.



Concept 3.2: Four emergent properties of water contribute to Earth's fitness for life

- **Four** of water's properties that facilitate an environment for life are:
  - **Cohesive behavior**
  - **Ability to moderate temperature**
  - **Expansion upon freezing**
  - **Versatility as a solvent**

Cohesive Behavior

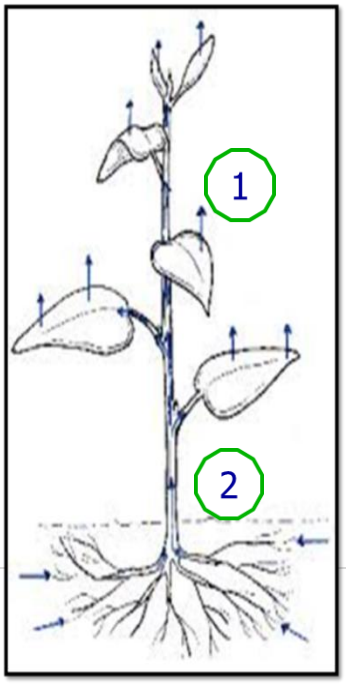
1. **Cohesion (التماسك)**

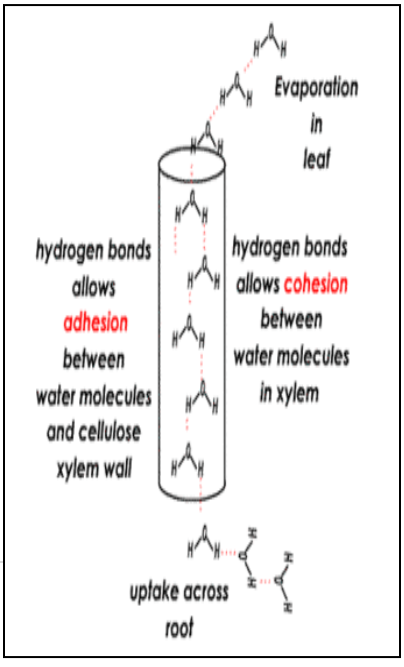
- As a result of **(H) bonding** , water molecules stay closer to each others.
- These linkages make water more structure than other liquids.
- The hydrogen bonds hold the substance together **(Cohesion)**
  Cohesion: phenomenon appeared when the H bond neighboring water molecules together

- **The importance of cohesion** :
  Contributes in transport of water molecules and dissolved nutrients against Gravity in plants
  How ?
  Water from the roots reaches the leaves through a network of water conducting cells , cohesion due to hydrogen bonds between water molecules helps hold them together(forming a column of water within the conducting cells).

How does water arise to leaves from roots ?

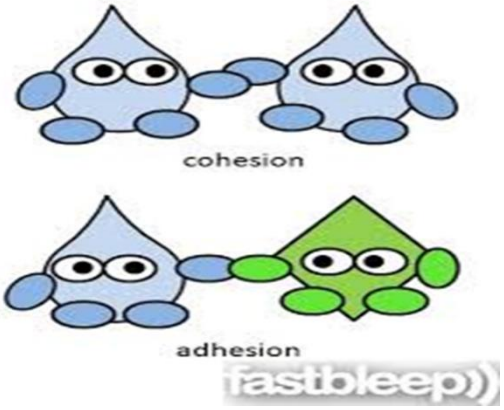
1. water evaporates from leaves .
2. hydrogen bonds cause water molecules leaving the veins to tug on(يسحب للأعلى) molecules farther down
3. The upward pull is transmitted through the water conducting cells all the way to the roots.

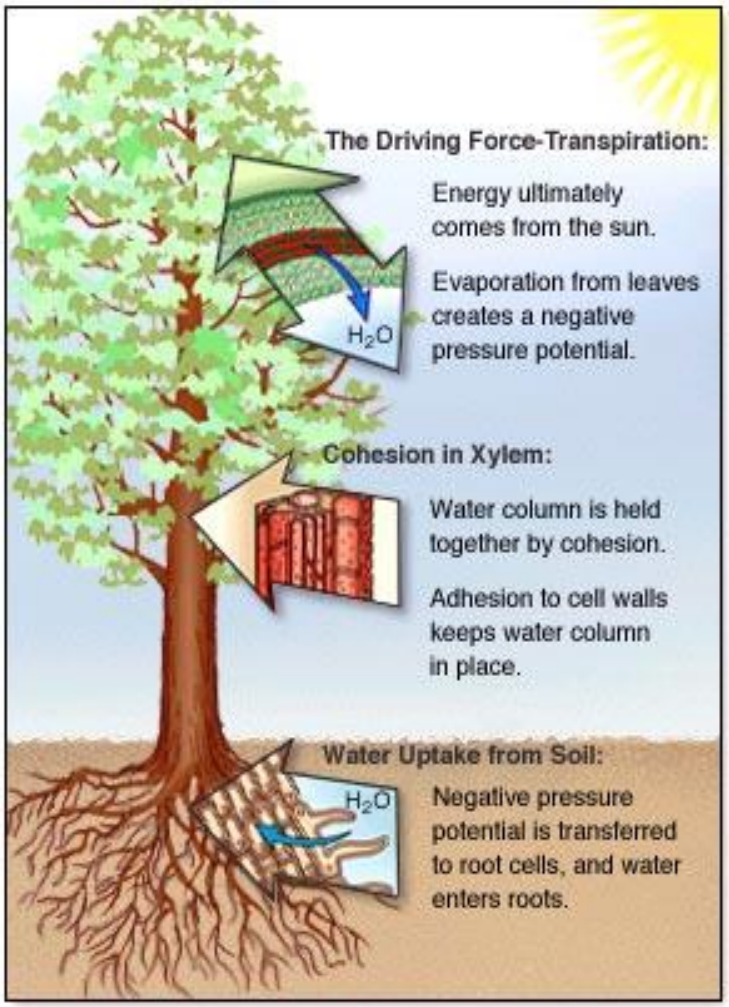


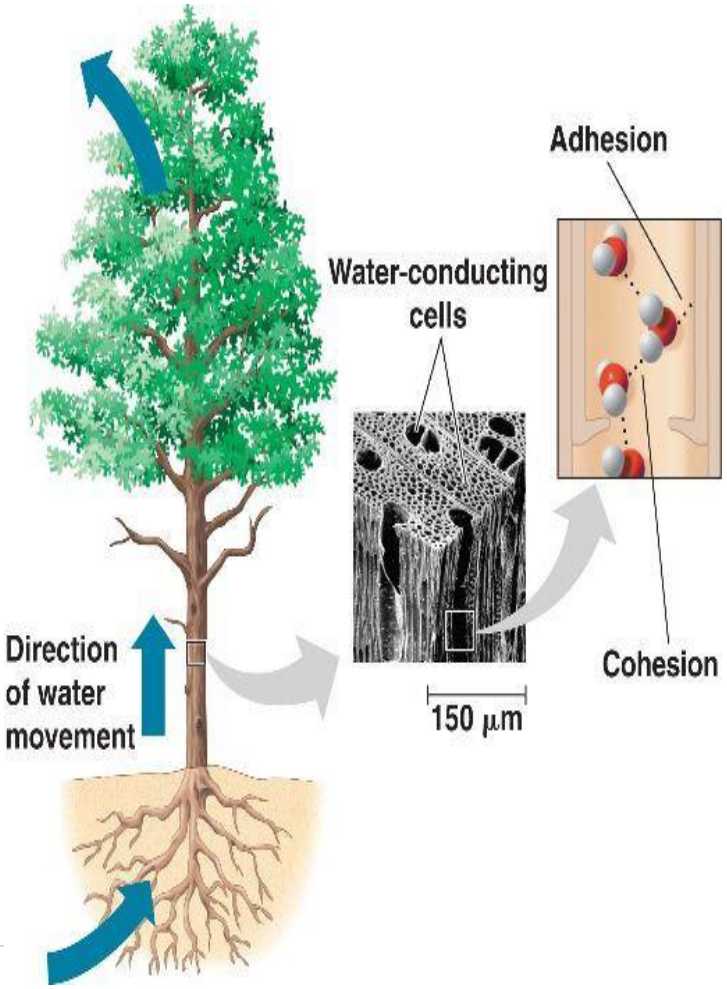


2. Adhesion

- **Adhesion** : the clinging of one substance to another .
- it happens between water and other(hydrophilic) substances(محب الماء), in plants the hydrophilic substance is cell walls .
- adhesion of water to cell walls by hydrogen bonds helps counter the down ward pull of gravity (resist gravity) .



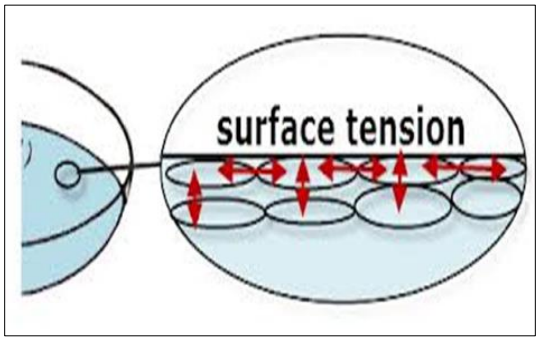




○ Surface Tension (التوتر السطحي)

- water has a greater surface tension(related to cohesion) than more other liquids.
- **Surface tension :** a measure of how difficult is to stretch or break the surface of liquid.
- at all interface between water and air is an ordered arrangement of water molecules (these molecules are hydrogen-bonded to one another and to the water below)

"مثال" ظاهرة وقوف الحشرات على سطح الماء



▪ moderation of temperature

- Water absorbs heat from warmer air and releases stored heat to cooler air. (water is like a heat bank)
- Water can absorb or release a large amount of heat with only a slight change in its own temperature.

☒ Heat and Temperature ☺:

- **Kinetic energy** is the energy of motion.
  **Anything move has kinetic energy (atoms and molecules) have kinetic energy because they are always moving .
  **The faster a molecule moves the greater it's kinetic energy

- **Heat** is a measure of the ***total*** **amount of kinetic energy** due to molecular motion; thus heat depends in part on the matters volume.

- **Temperature** measures the intensity of heat due to the ***average*** **kinetic energy** of molecules regardless of volume .
- Ex: when water is heated in a coffee maker, the **average speed** of the molecules increases and the thermometer records this as arise in temperature in a liquid .the amount of heat also increases in this case .
- Heat passes from the warmer to the cooler object until the two objects have the same temperature .

- Molecules in the cooler object speed up at the expense of the kinetic energy from the warmer object .
- An ice cube cools drink not by adding coldness to the liquid , but by absorbing heat from the liquid.

- **Energy units :**
- The **Celsius scale** is a measure of temperature using Celsius degrees (°C) .
- A **calorie (cal)** is the amount of heat required to raise the temperature of 1 g of water by 1°C .
- The "calories" on food packages are actually **kilocalories (kcal),** where 1 kcal = 1,000 cal .
- The **joule (J)** is another unit of energy where
  1 J = 0.239 cal, or 1 cal = 4.184 J

Water's High Specific Heat

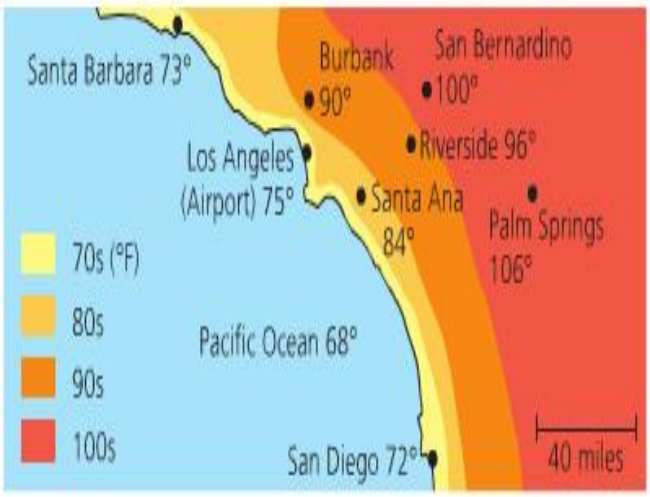
- The **specific heat** of a substance is the amount of heat that must be absorbed or lost for 1 g of that substance to change its temperature by 1ºC.
- Unit : **cal /gm/ C**
  - Water has usually **high** specific heat The specific heat of **water** = 1 calorie per gram per degree Celsius abbreviated as (1 cal/**1g**/C) .
- the ability of water to stabilize temperature caused by its high specific heat.
- Specific heat can be thought of as a measure of how well a substance resist changing its temperature when it absorbs or releases heat
- Water resists changing in its temperature >> when it's temperature is changed ,it must be absorbed or lost a relativity large quantity of heat for each degree of change .

- Heat must be **absorbed** in order to break hydrogen bonds and heat is **releases** when hydrogen bonds forms.

- A calorie of heat causes a relativity small change in the temperature of water because much of the heat is used to disrupt hydrogen bonds before the water molecules can begin moving faster, and when the temperature of water drops slightly , many additional hydrogen bonds form, releasing a considerable amount of energy in the heat form .

- **What is the relevance of water's high specific heat to life on earth ?**

1- a large body of water can absorb and store a huge amount of heat from the sun in the day time and during summer , while warming up for water is only a few degrees , and at night during winter , the gradually cooling water can warm the air . **This is the reason for making coastal areas generally have milder climates than inland regions** .



2- **stabilize ocean temperature** and so creating favorable environment .

3- **moderate Internal temperature of organisms' bodies .**

Evaporative Cooling

- Molecules of any liquid stay close together because they are attracted to one another . molecules moving fast enough overcome these attractions and they can depart the liquid and enter the air as gas . This transformation from liquid to a gas is called **vaporization or evaporation** .
- Even at low temperature the speediest molecules can escape into the air . Some evaporation occurs at any temperature .
- If a liquid is heated the average kinetic energy of molecules increases and the liquid evaporate more rapidly

- **Heat of vaporization** : is the quantity of heat a liquid must a absorb of 1g of it to be converted from the liquid to the gaseous state .
- Water has a **high** heat of vaporization relative to must other liquid .
  - Water needs a high heat of vaporization due to strong h-bond, it absorbs 580 cal to break these bonds.

Effects of (high heat of vaporization) of water

- **on Global scale** :
  Helps moderate earth's climate .
- **On Organismal scale** :
  Water's high heat of vaporization accounts for the severity of steam burns, these burns are caused by the heat energy released when steam condenses into liquid in the skin . (هذا هو سبب شدة الحروق التي يسببها بخار الماء)

Evaporative Cooling

- As a liquid evaporates, the surface of the liquid that remains behind cools down , a process called **evaporative cooling**
  -Evaporative cooling of water helps stabilize temperatures in organisms and bodies of water**.**

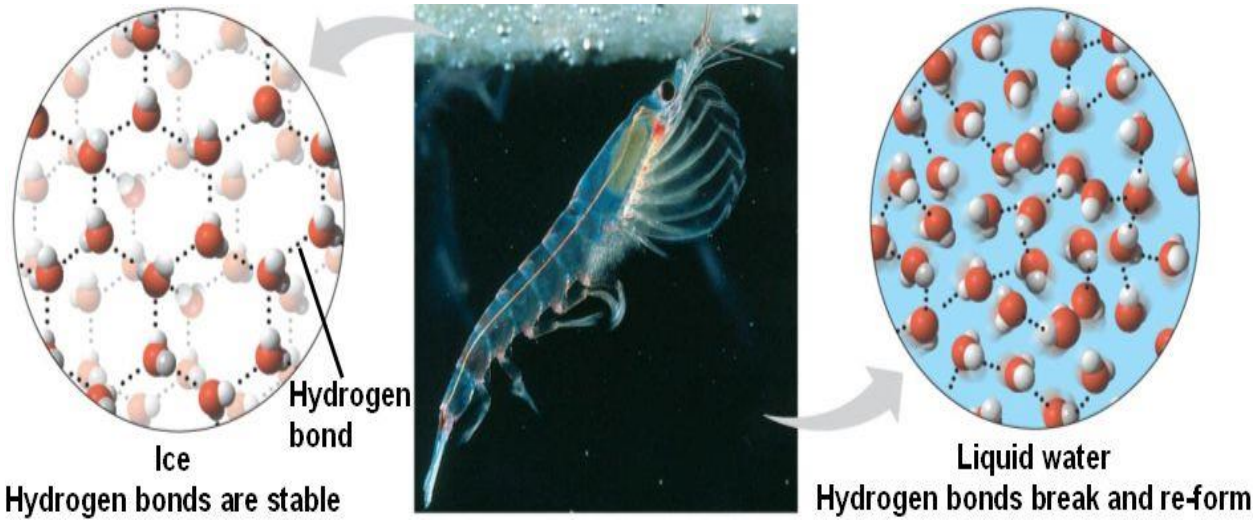
Evaporative cooling of water contributes to :

- stability of temperature in lakes and ponds , and also
  Provides a mechanism that prevent terrestrial organisms
  from overheating .
- evaporation of sweats from human skin dissipates body heat and help prevent overheating in a hot day or when excess heat in generated by strenuous activity .
  - [high humidity in a hot day increases discomfort because the high concentration of water vapor in the air inhibits the evaporation of sweat from the body . high humidity hampers cooling by suppressing the evaporation of sweat]

▪ Insulation of Bodies of Water by Floating Ice:

- Water is one of the few substance that are less dense as a solid than as a liquid (ice floats in liquid water)
  - Other materials contract when they solidify , while water expands ,the cause of this exotic behavior of water is H-bonding
- **At temperature above 4c**, water behaves like other liquid expanding as it warms and contracting as it cools .
- Water begins to freeze when its molecules are no longer moving vigorously enough to break there H-bonds.

- **Below 4c**
  The unusual behavior of water, it expands below 4°c to 0° when the Temperature goes down …
- **As a temperature falls to 0c**, water becomes looked into a crystalline lattice by H-bonds ..
- H-bonding cause water expands when it solidify so it becomes less dense than as liquid , and cause ice floats .
  Note : above 0 c , water molecules are bonded with unstable H-bonds , at freezing (0c) they became stable and form crystalline lattice (look to figure >>



So Water expands in 2 states :

- warming up (Temperature > 4 c)
- Cooling (Temperature <4 c)

- Density of ice is less 10% than density of water at 4c (That means 10% fewer molecules for the same volume) .
  - **The greater density of water is at 4c**

**** الماء عند درجة حرارة 4 تكون كثافته أكبر ما يمكن . لماذا ؟**

-لأن فوق درجة الحرارة 4 تقل كثافته بزيادة درجة حرارته .

(مثلا كثافة الماء عند 5 سلسيوس اكبر من كثافته عند درجة 6 سلسيوس فتكون كثافته عند 4 أكبر من كثافته عند درجات الحرارة الاكبر من 4)

- اقل من 4 سلسيوس يسلك الماء السلوك الشاذ وهو أن كثافته تقل اذا قلت درجة حرارته .

(مثال : كثافة الماء عند درجة حرارة 0 أقل من كثافته عند درجة حرارة 1

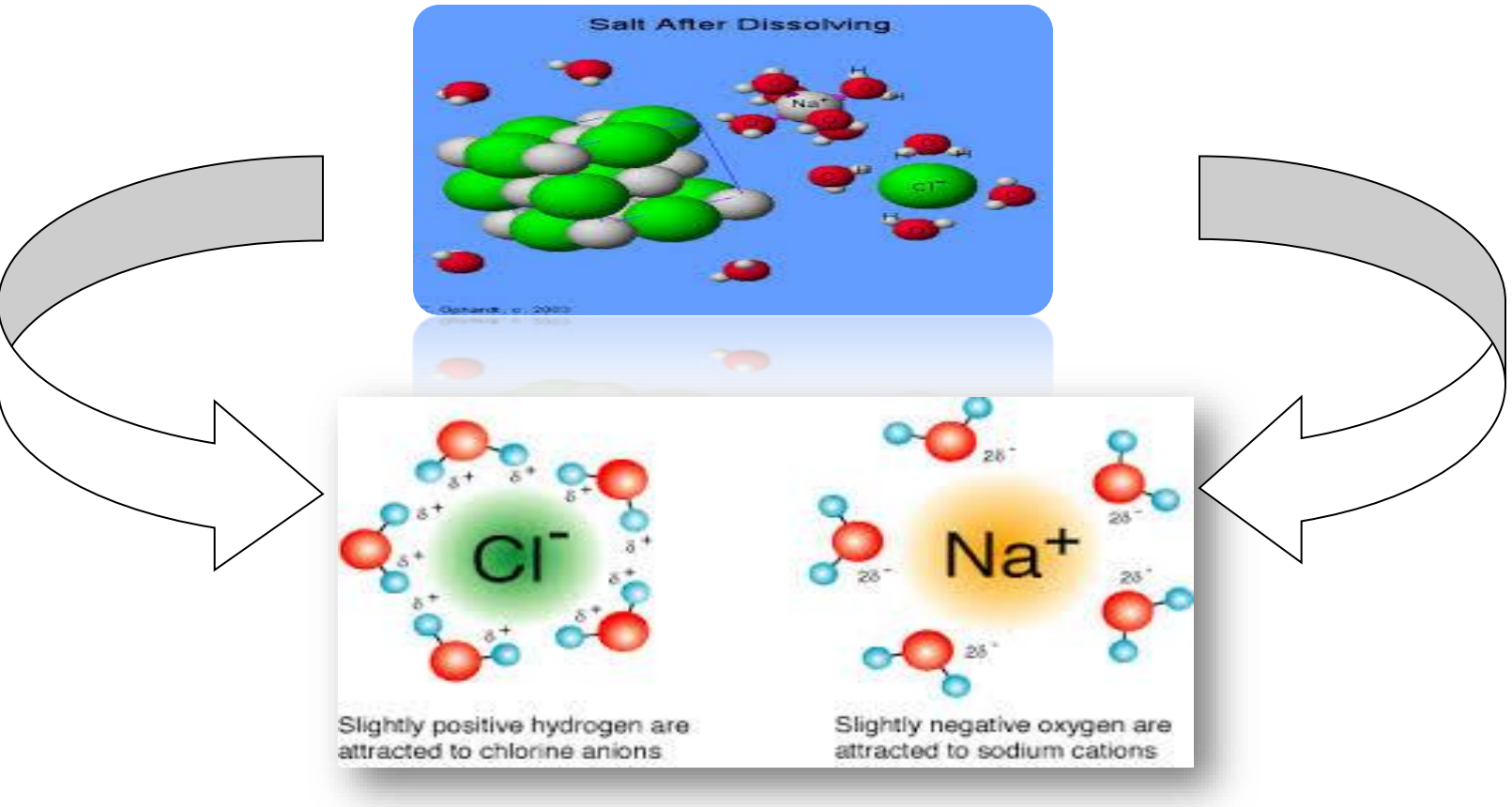
وبذلك تكون كثافته عند درجة حرارة 4 أكبر من كثافته عند اي درجة حرارة اقل من 4)

- The ability of ice to float because of the expansion of water as it solidities is an important factor in fitness of the environment .

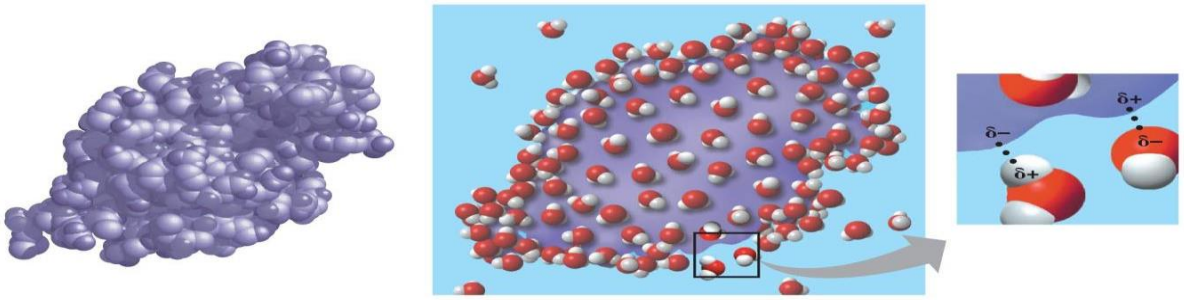
➢ if ice sank Oceans and lakes would be impossible to live in ,
(ice floats and water stayed bellow it without freezing)

The Solvent of Life :

- a **solution** is a liquid that is a homogeneous mixture of substances .
- A **solvent** is the dissolving agent of a solution .
- The **solute** is the substance that is dissolved.
- An **aqueous solution** is one in which water is the solvent .
- Water **is not** universal solvent , if it were ; it dissolve any container in which it was stored , including our cells .
- Water is a versatile solvent due to its polarity, which allows it to form hydrogen bonds easily .
- When an ionic compound is dissolved in water it will has Cation (الايون الموجب) & Anion (الايون السالب) , each ion is surrounded by a sphere of water molecules called a **hydration shell.**
- **Anion surrounded by O molecules**
- **Cation surrounded by H molecules**
- **Example : table salt (NaCl)** <<look to figure below>>



- Water can also dissolve compounds made of **nonionic polar molecules**.
  - By surrounding solutes molecules and forming H-bonds with them
- Even large polar molecules such as proteins can dissolve in water if they have ionic and polar regions.



Hydrophilic substances

- Are all The substance that have an affinity to water (form H-bonds with water)
- Hydrophilic substance in general its dissolved in water , but it may be insoluble if it is a large molecule..

So we have 2 types of hydrophilic substances **:**

- **Soluble Hydrophilic substances are** one of these
  1. polar compounds 2. ionic compounds 3.charged soluble
- **Insoluble Hydrophilic substances**:
  charged insoluble (because of large molecules)
  - These large molecules remain suspended in the Aqueous liquid of the cell . such a mixture is an example of a **colloid** (stable suspension of fine particles in a liquid) .
    another example : **cotton –** consists **of giant molecules of cellulose** , cellulose contain compound with numerous regions of partial positive & partial negative charges , so it can form H-bonds with water but can't be dissolved in it .

Hydrophobic substances

- Substances cant form H-bonds with water , (they rebel water)
- **Hydrophobic substances are :**
  1. non-ionic substances.
  2. non-polar substances.
- Hydrophobic molecules are major ingredients of cell membrane ..
- Example : oil

Chapter assignment :

Threats of water quality on earth

- **Acid precipitation** refers to rain, snow, or fog with a pH lower than 5.6
- Acid precipitation is caused mainly by the mixing of different pollutants with water in the air and can fall at some distance from the source of pollutant
- Acid precipitation can damage life in lakes and streams
- Effects of acid precipitation on soil chemistry are contributing to the decline of some forests

- Human activities such as burning fossil fuels threaten water quality !

➢ **CO_2 is released by fossil fuel combustion and contributes to:**

– **A warming of earth called the "greenhouse" effect**:
CO2 releases to atmosphere and stays in it , and prevents heat from radiating into outer space.

– **About 30% of CO2 gas absorbed by the oceans** , scientists worry that this absorption of so much CO2 will harm marine life and ecosystems.

– Acidification of the oceans; this leads to a decrease in the ability of corals to form calcified reefs .