WATER

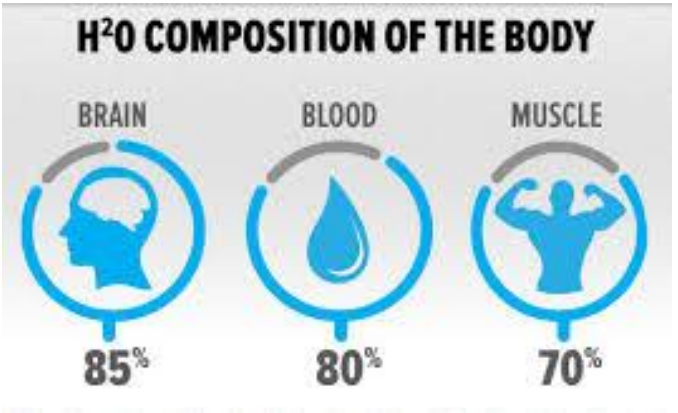
Water,
The Essential Nutrient

What is water?

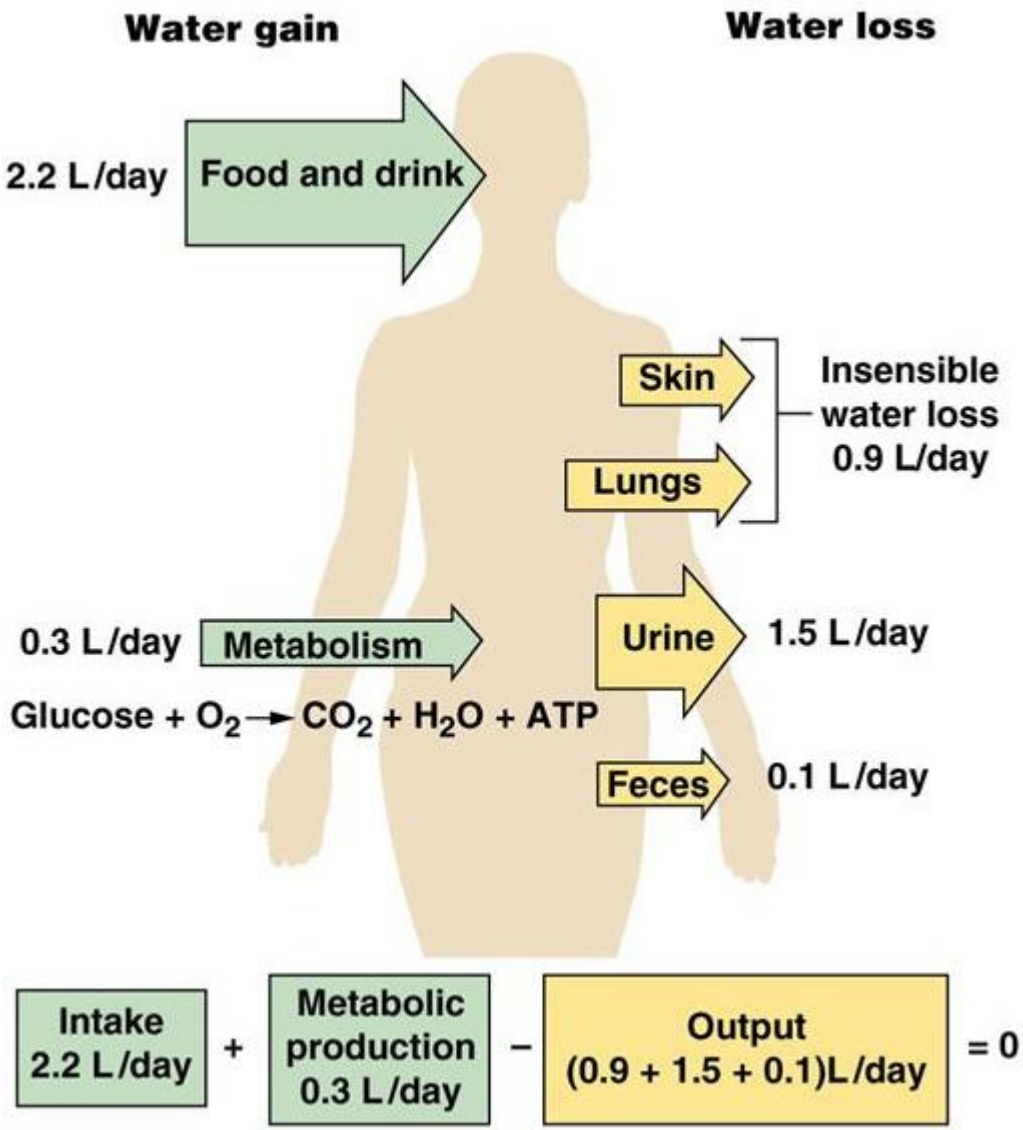
The body's most **indispensable** nutrient

Functions

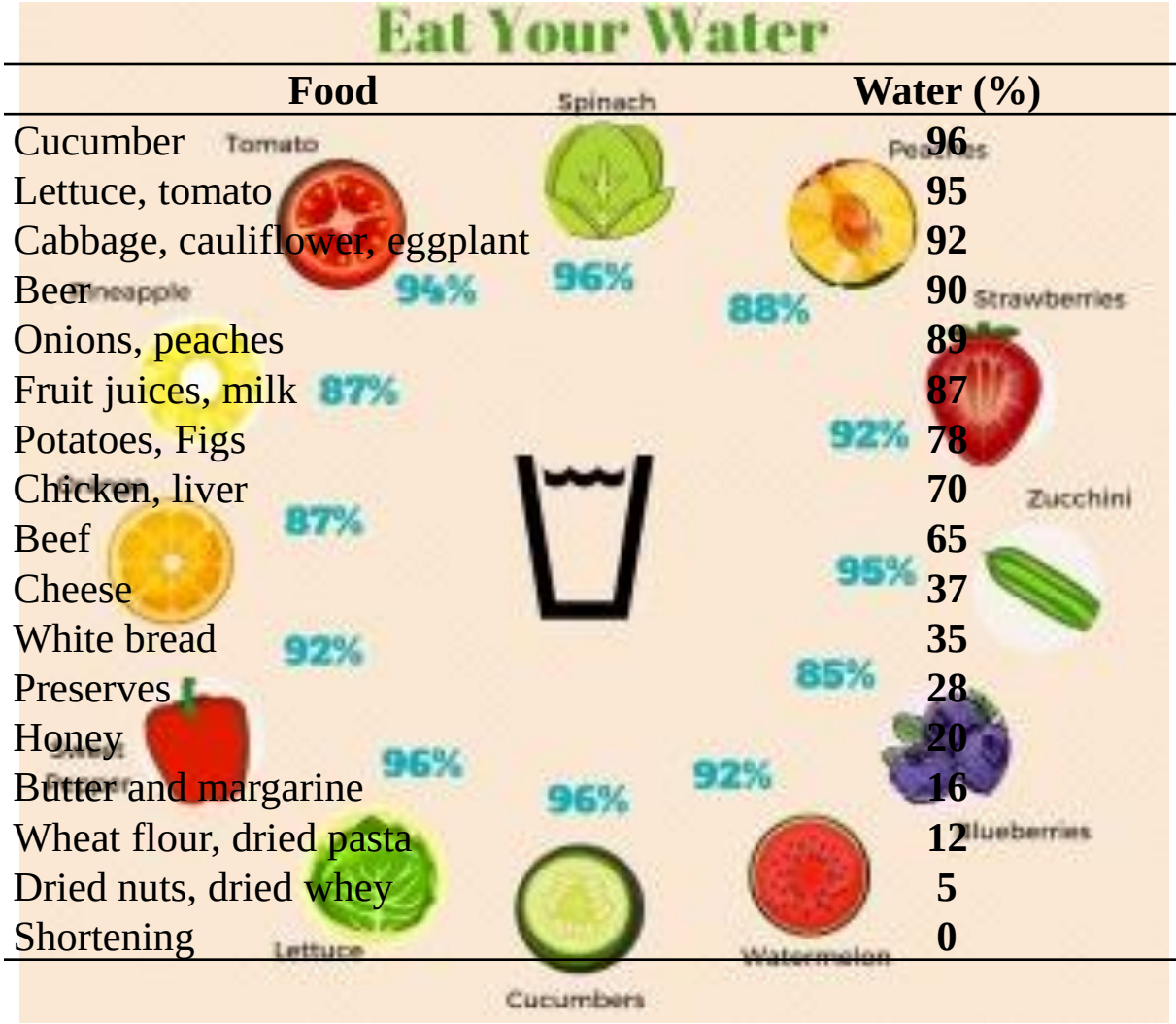
- **Carries** nutrients to all parts of the body
- Helps the body get **rid** of **waste**
- **Lubricates** and **cushions** joints
- Regulates **body temperature**



Water Balance in the Body



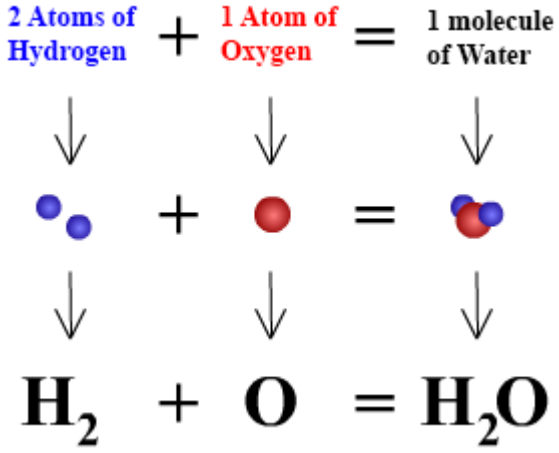
Typical Water Content in Food and Drinks

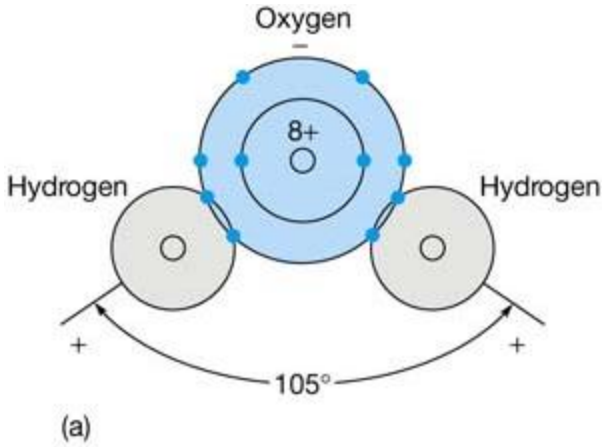


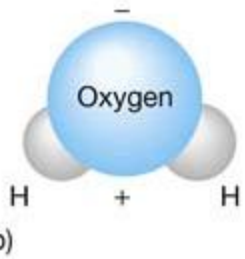
Food	Water (%)
Cucumber	96
Lettuce, tomato	95
Cabbage, cauliflower, eggplant	92
Beer	90
Onions, peaches	89
Fruit juices, milk	87
Potatoes, Figs	78
Chicken, liver	70
Beef	65
Cheese	37
White bread	35
Preserves	28
Honey	20
Butter and margarine	16
Wheat flour, dried pasta	12
Dried nuts, dried whey	5
Shortening	0

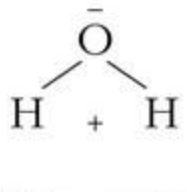
Water Structure

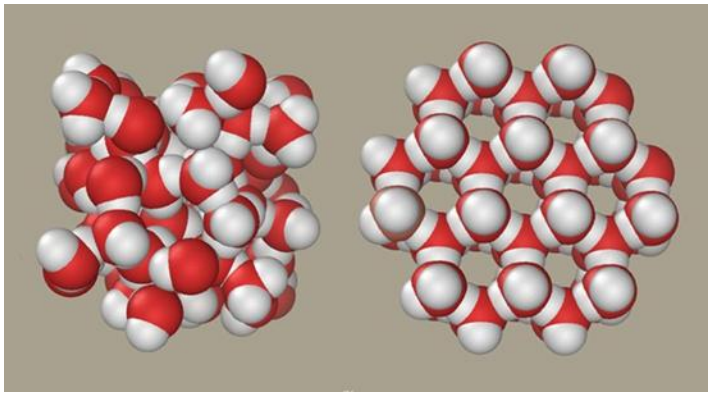
Water is a nonlinear, **polar** molecule containing an oxygen atom bonded to two hydrogen atoms by **covalent bonds**





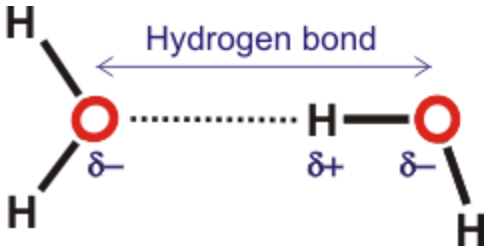


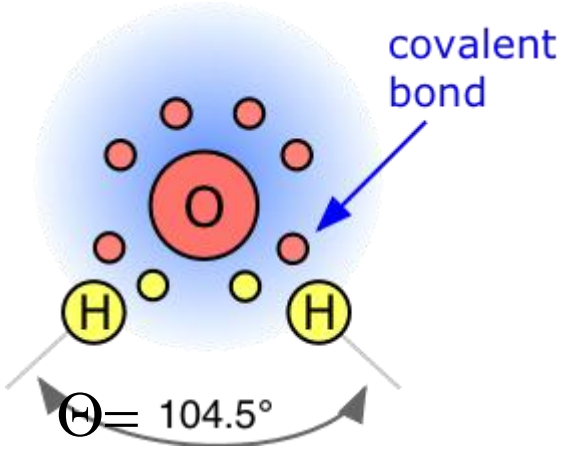




It is thought that in the liquid and solid states water molecules associate together in some way so that their effective molecular weight appears to be much higher

Water Structure and Bonding

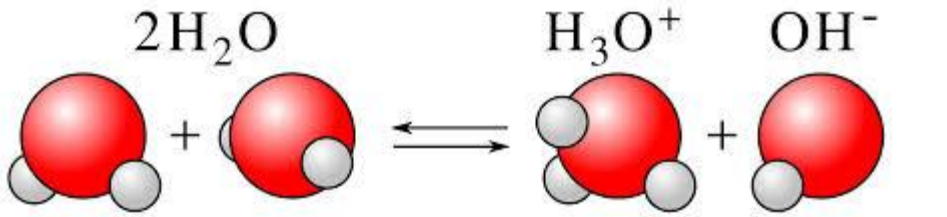




Θ	Bonding
104.5	H-O-H (vapor)
105	H-O-H (liquid)
109.5	H-O-H (ice)
180	O-H- O

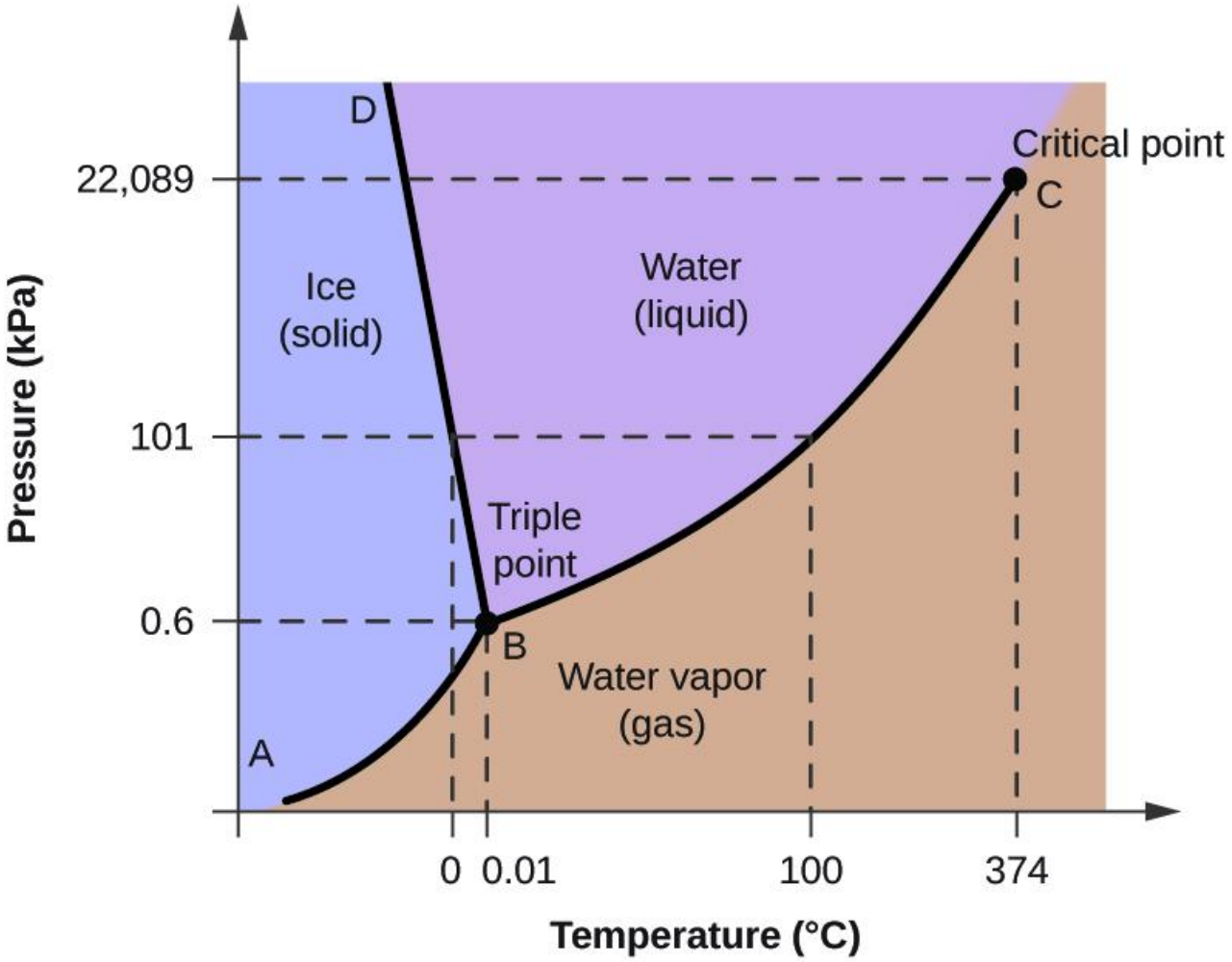
Molecular ions of water and Ionization of water

At neutral pH and 25ºC one water molecule in every 10 million becomes ionized through the bonding of one of its protons to another water molecule:

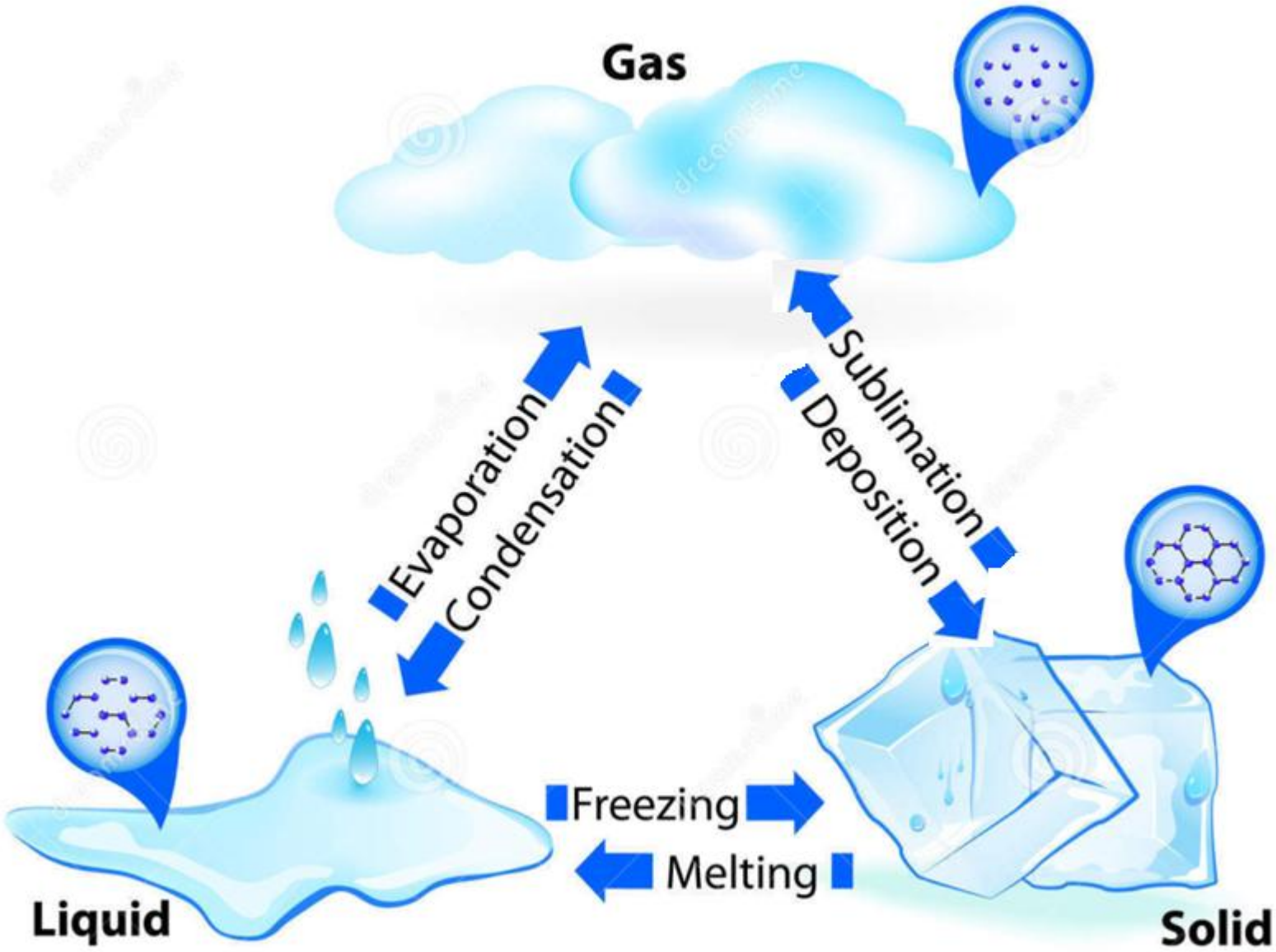


Hydronium ion Hydroxyl ion

Phase Transitions of Water

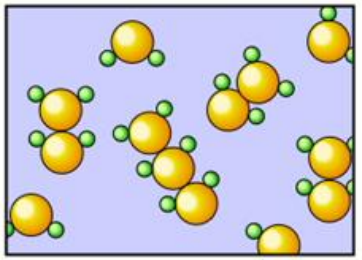


Phase Transitions of Water

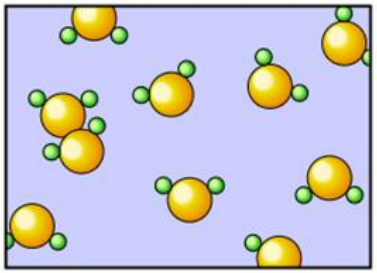


Phase Transitions of Water

Hydrogen bonds are weak electrostatic links which are easily broken, and in water such bonds are constantly being formed, broken and re-formed. If water is heated the thermal energy of the molecules is increased, and their resulting increased motion favors the breaking rather than the formation, of hydrogen bonds.



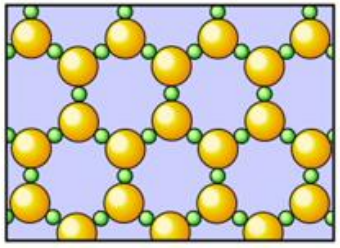
Semi-Ordered Molecular Structure of Liquid Water



Random Molecular Structure of Vaporized Water

In water vapor no hydrogen bonds are present and the water exist as single units. On the other hand, if liquid water is cooled the loss of thermal energy and the resulting decreased motion of the water molecules favors the formation of hydrogen bonds.

In ice hydrogen bonding is so extensive that all the water molecules are linked together by hydrogen bonds so forming a rigid and regular structure.



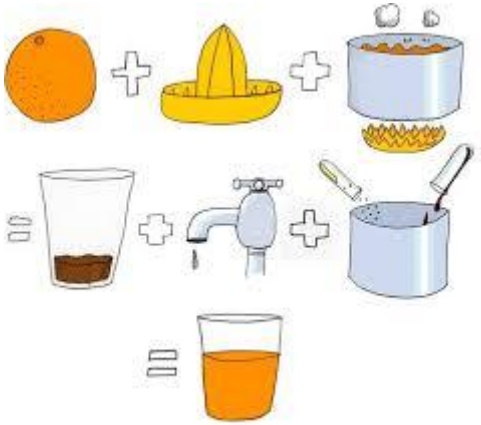
Ordered Molecular Structure of Frozen Water

Phase change and importance in food industry

Evaporation and food processes

- Tomato paste production

- Fruit juice concentrate



- Evaporated milk

- Drying of fruits

Freezing and food processes

- Fish, meat, vegetable, fruit, .. freezing

Effect of freezing in foods

- Destabilization of emulsions
- Flocculation of proteins
- Increased lipid oxidation
- Meat toughening
- Cellular damage
- Loss of water holding capacity

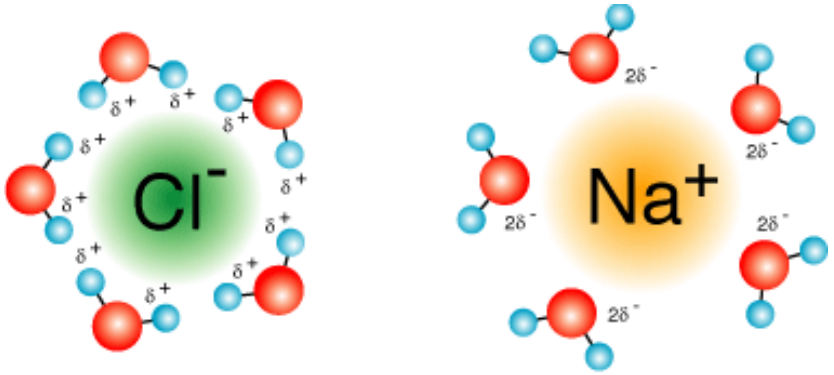
Sublimation and food processes

- Freeze dried coffee
- Freezed dried vegtables
- Freeze dried fruits

Water as Solvent

Because of its polarity, water can interact with and dissolve other polar compounds and compounds that ionize (electrolytes). Substances that readily dissolve in water are said to be **hydrophilic**, or water loving.

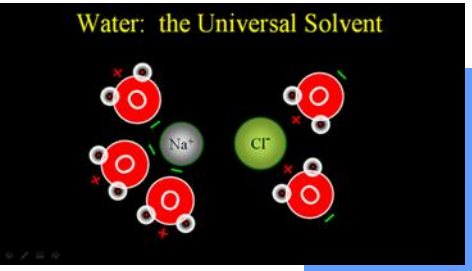
Water molecules align themselves around electrolytes so that the negative oxygen atoms of the water molecules are oriented toward the cations (the positive ions) of the electrolytes and the positive hydrogen atoms are oriented toward the anions (the negative ions).

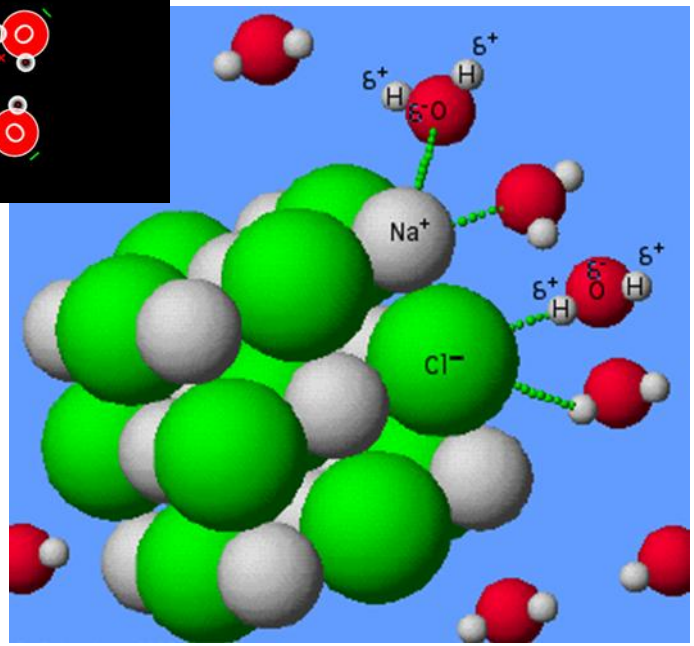


Slightly positive hydrogen are attracted to chlorine anions

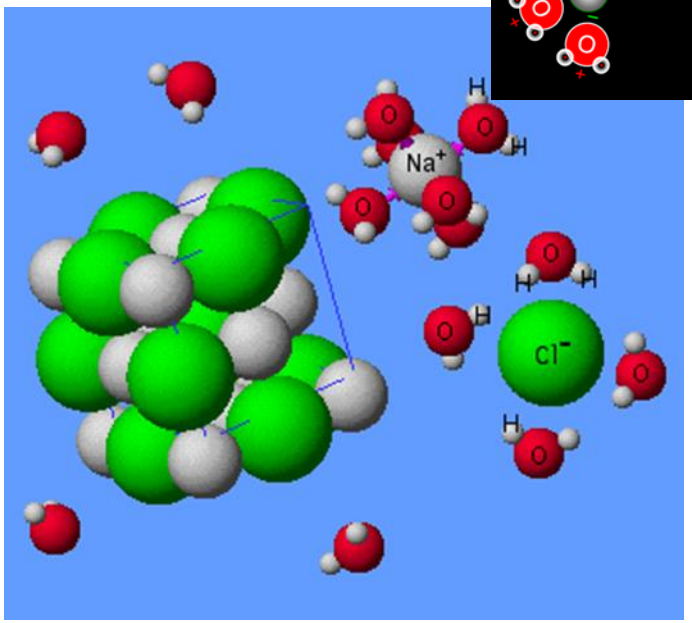
Slightly negative oxygen are attracted to sodium cations

Consider the dissolution of the crystalline electrolyte sodium chloride (NaCl). **The polar water molecules are attracted to the charged ions in the crystal. The attractions result in sodium and chloride ions on the surface of the crystal dissociating from one another**, and the crystal begins to dissolve.

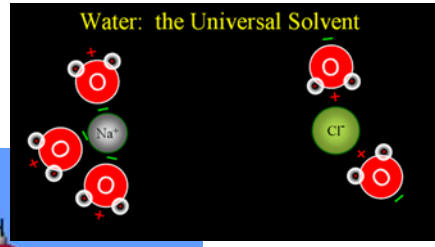




Salt crystal dissolving



Salt after dissolving



Interactions of Water with Food Components

The interactions of water with food components are at the root of many problems/solutions with the properties of food systems.

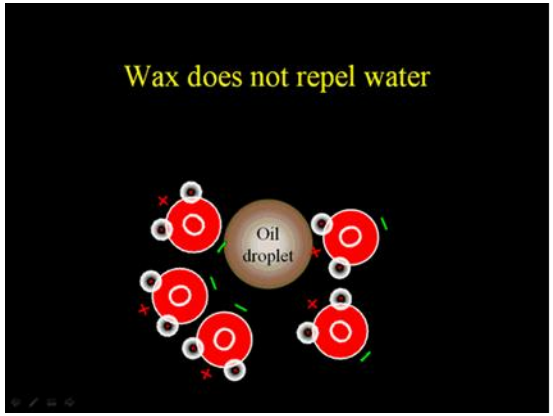
Interactions of water with **carbohydrates**:

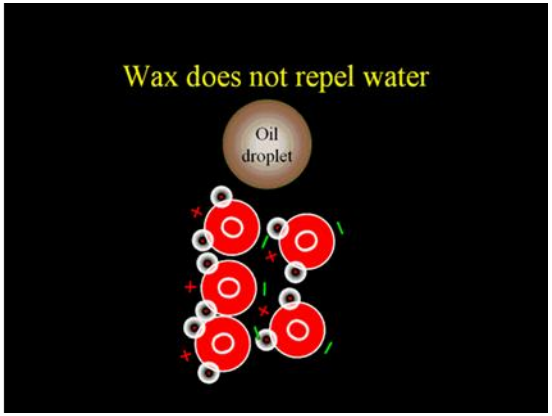
The binding of water to sugars and polysaccharides is an important contributor to the properties of many foodstuffs.

- retarding the formation of ice crystals (with liquid water- i.e. frozen desserts)
- formation of gel structure with high amount of water (binding high amount of water- i.e. agar)

Interactions of water with nonpolar (**oil**) molecules:
Water and oil do not mix…. WHY?

The answer:
The collective strength of hydrogen bonds of water.





Interactions of water with **proteins**:

Water is important for proteins because of influence of water on the structure and behaviour of proteins.

A protein molecule presents three kinds of surface groups to its aqueous environment, **depending on the nature of the amino acid side chain**

Polar charged groups
- Glutamic acid ($-CH_2CH_2COO^-$)
- Lysine ($-(CH_2)_4NH_3^+$)

Polar neutral groups
- Glutamic acid at low pH ($-CH_2CH_2COOH$)
- Serine ($-CH_2OH$)

Non-polar groups
- Valine ($-CH(CH_3)_2$)
- Methionine ($-CH_2CH_2-S-CH_3$)

Non polar side chains are usually found **buried in the interior** of the protein and **will not concern us**.

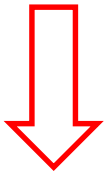
The pH value will obviously be a major influence on the properties of **ionisable side chains**.

As a general rule only small proportion of the **polar groups of a native protein will be unable to bind water**, **because of being buried in the largely hydrophobic interior** of the molecule.

Interactions of Water with Food Materials

We should consider food as a whole and leave the components behind.

The state of water in a food is described between the moisture content of the product and the relative humidity of air surrounding it.



What is Water Activity?

What is Water Activity?

Water activity or the equilibrium relative humidity of a system is defined as:

$$a_w = \frac{P}{P_0}$$

$$a_w = \frac{\%\ ERH}{100}$$

where

a_w = Water activity

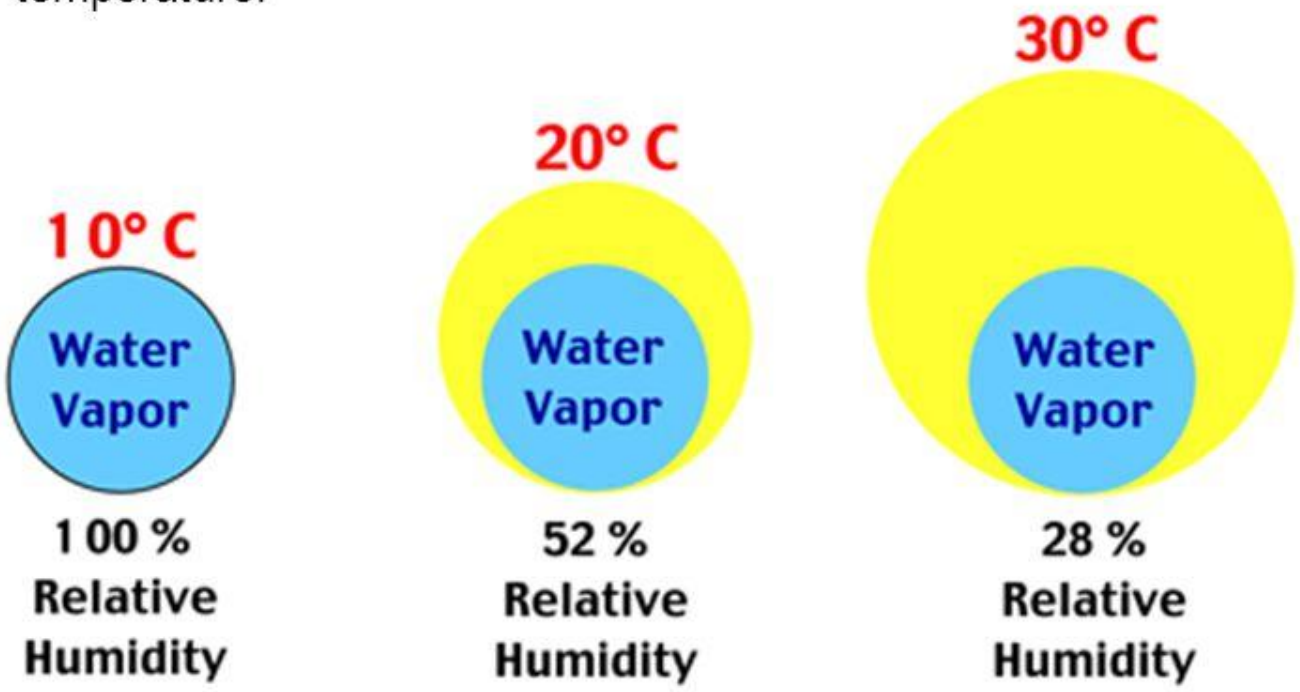
p = vapor pressure of water in food

P_o = vapor pressure of pure water (at the same temperature)

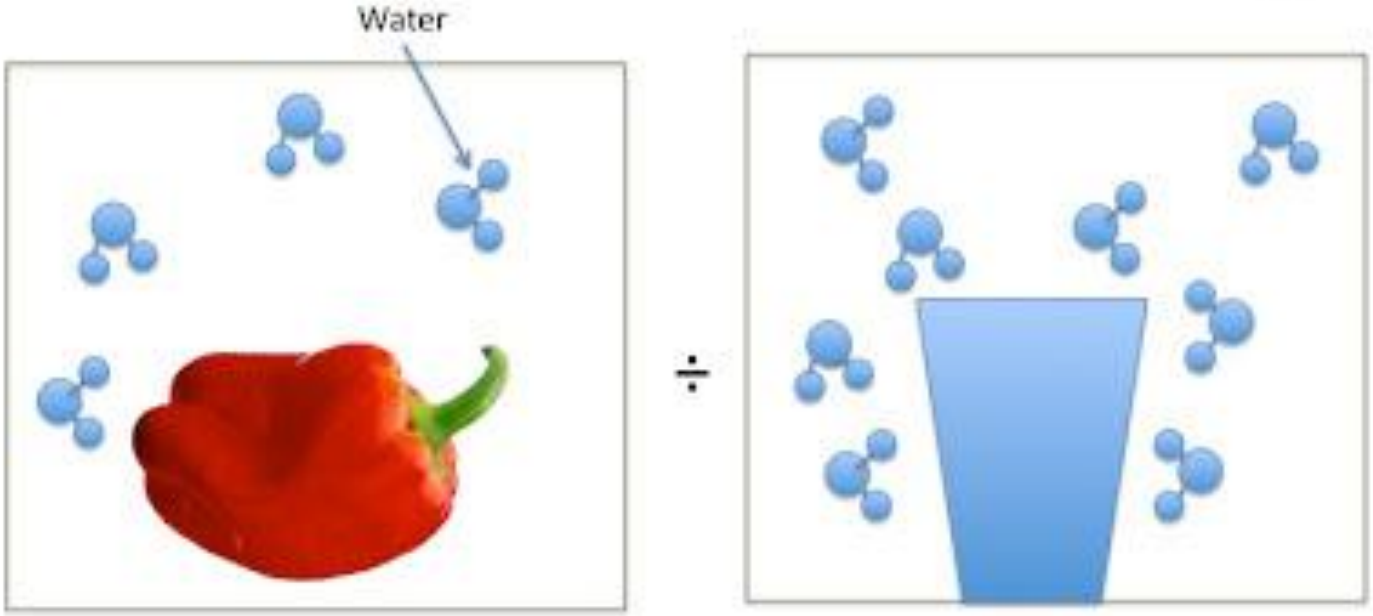
ERH = Equilibrium relative humidity

Relative Humidity

The most commonly used measure of humidity is **relative humidity**. Relative humidity can be simply defined as the amount of water in the air relative to the saturation amount the air can hold at a given temperature multiplied by 100. Air with a relative humidity of 50% contains a half of the water vapour it could hold at a particular temperature.



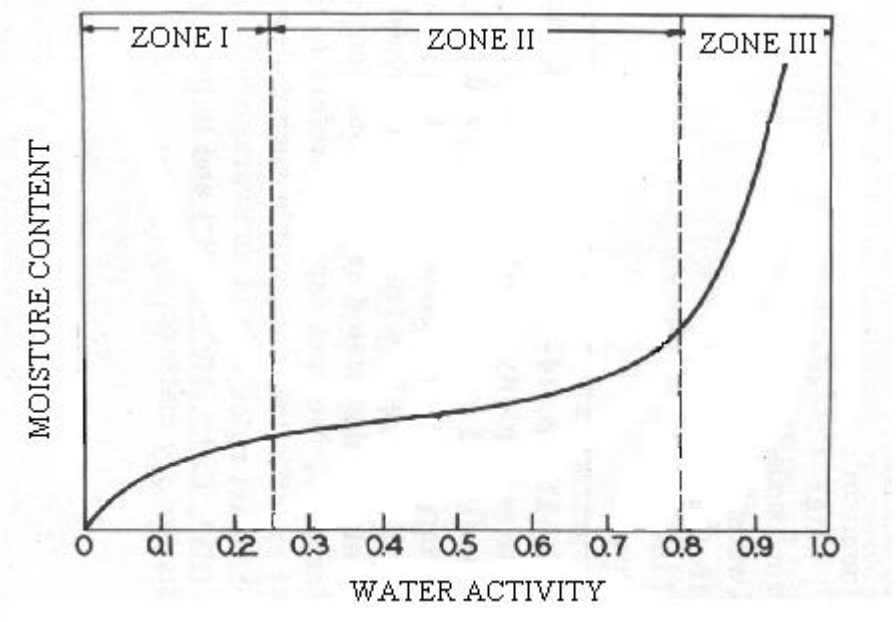
A Pictorial Definition of Water Activity



Vapor pressure of water from a food

Vapor pressure of pure water

The relationship between moisture content and relative humidity is represented by the **SORPTION ISOTHERMS**.



Types of Water?

It is convenient to divide the water into three types

Zone 1 Monolayer (tightly bound) water

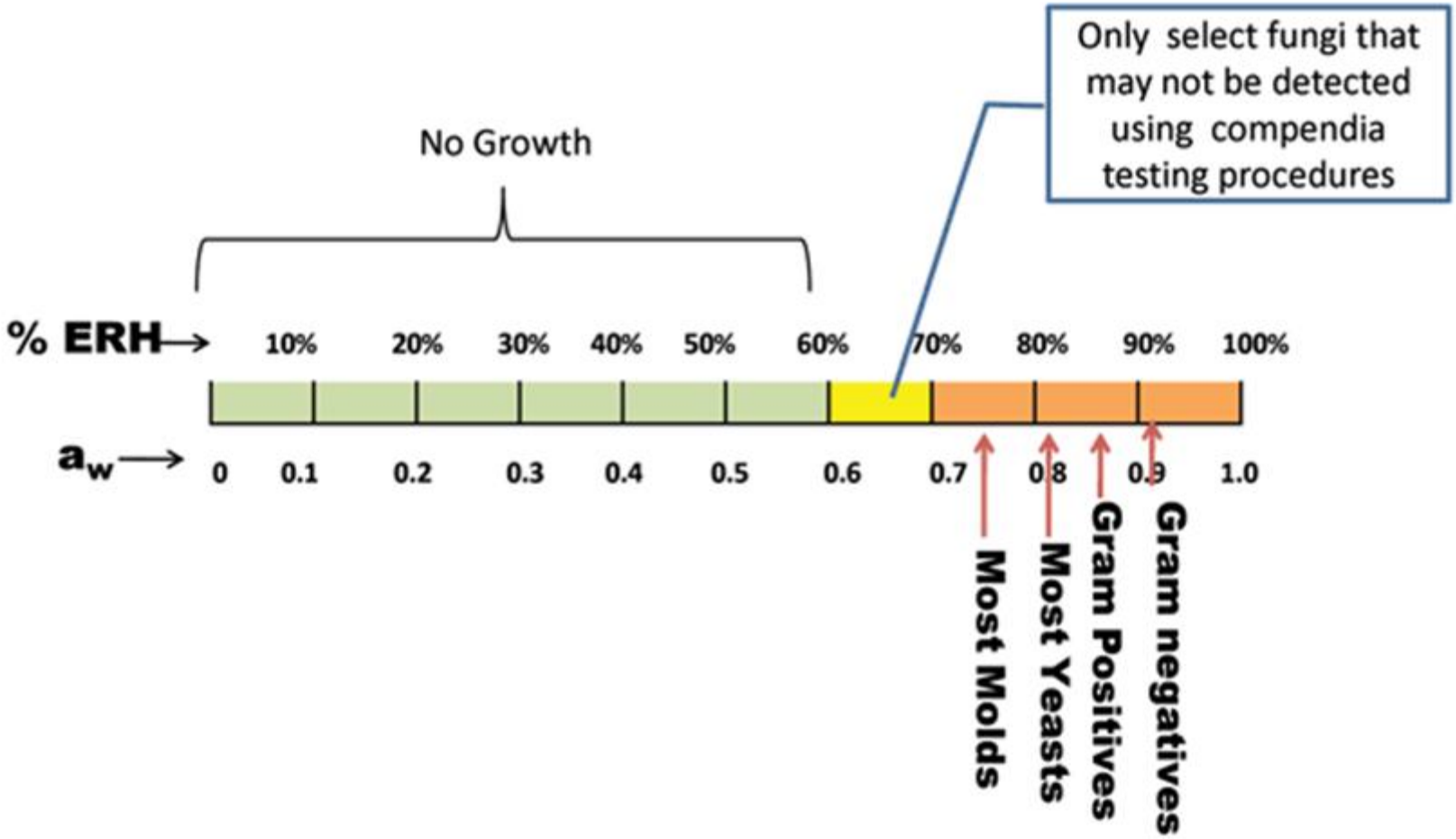
Zone 2 Additional (loosely bound) water

Zone 3 Free (capillary) water

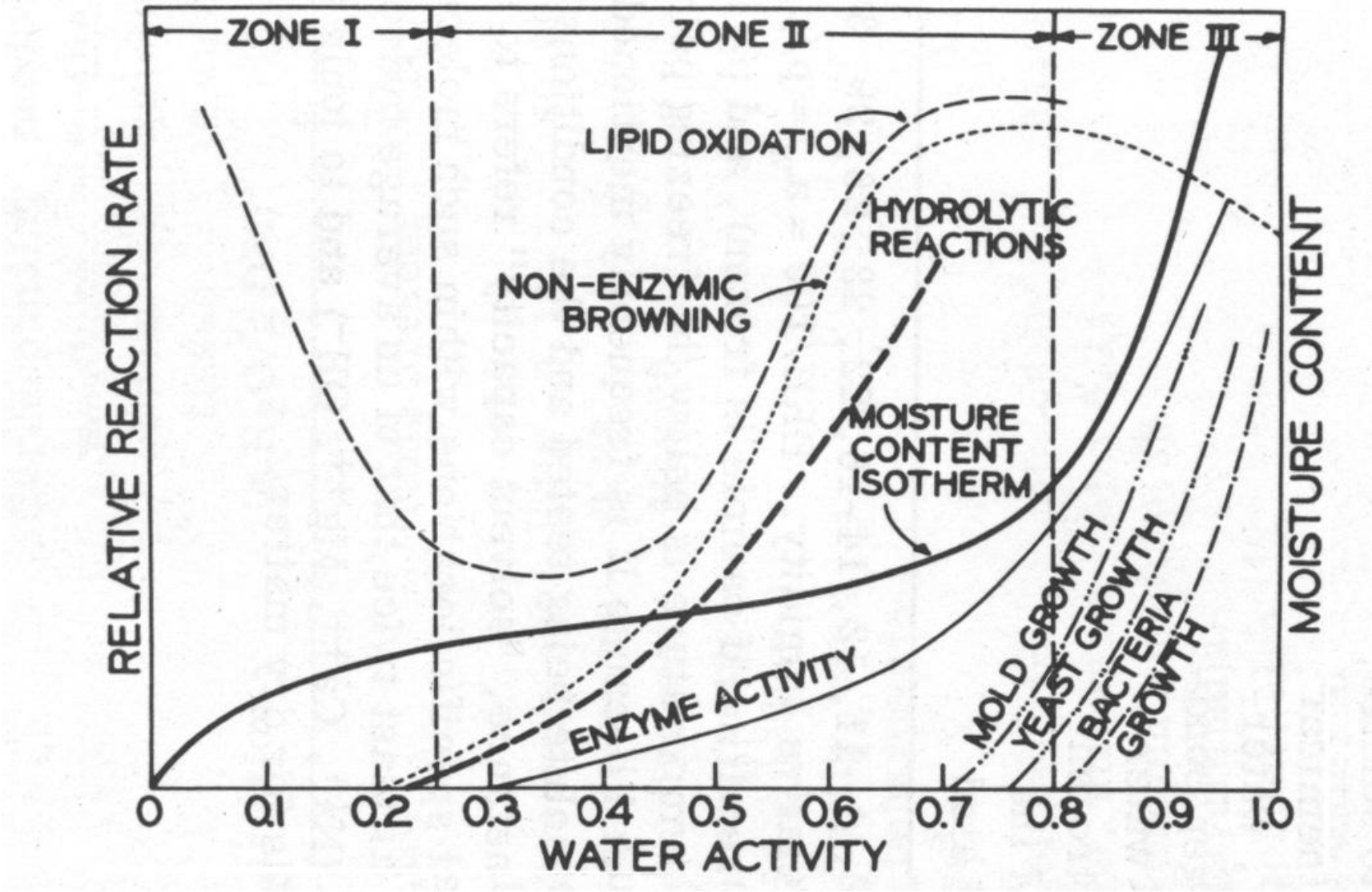
Dehydrated foods are preserved because **water activity is at a level where no microbiological activity can occur and where deteriorative chemical and biochemical reaction rates are reduced to a minimum.**

Food	Water activity
Fresh fish and meat	0.99
Bread	0.95
Fresh fruits and vegetables	<0.90
Jams and jellies	0.80
Dried fruits	0.60
Biscuits	0.30
Instant coffee	0.20

Reducing water activity below **0.7** prevents microbiological spoilage. However, although microbial spoilage does not occur at **aw=0.7**, prevention of other deteriorative reactions needed to preserve a food product succesfully by dehydration requires reduction of water activity to **0.3.**


Only select fungi that may not be detected using compendia testing procedures
No Growth
% ERH
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
a_w
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Most Molds
Most Yeasts
Gram Positives
Gram negatives

The relationship between **water activity** and **the rate of deteriorative reactions** in food



QUESTION 1

The water activity of 50 g sand in 100g water and
The water activity of 50 g sucrose in 100 g water

Are they the same or different?
If they are different, why?
If they are the same, why?

QUESTION 2

In water activity equation

p is ……..
ERH refers to ……

QUESTION 3

The change in state from a **solid** to **gas** **is called**?

The change in state from a **gas** to **liquid** **is called**?

QUESTION 4

Why there is no interactions between water and oil molecules?

ANSWER 1

The water activity of sand and water compared to sucrose and water is **different**

Because **sucrose is soluble in water and leads to hydrogen bonding**.

ANSWER 2

p = vapor pressure of water in food

ERH = Equilibrium relative humidity

ANSWER 3

The change in state from a **solid** to **gas** **is called SUBLIMATION.**

The change in state from a **gas** to **liquid** **is called CONDENSATION.**

ANSWER 4

The interaction is not allowed due to strength of hydrogen bonds between the water molecules.