<u>Summary of lecture # 1</u>

Introduction to G. Science & System of Measurement

What is it that allows us to term Biology, Chemistry and Physics as sciences whereas literature, languages, history and art are not termed as sciences? The answer to this question is the reproducibility of the results is the basic difference between science and humanity. Science is something which deals with experimentation, has certain methods and procedures. We can better understand about reproducibility as whatever a person is saying another scientist or researcher in another laboratory can reproduce those results…for example we take a small piece of equipment, measure its length and reported that its length is 10 cm. Another person who has the same equipment can do this and confirm the result. In other words, we can say that under similar condition and circumstances will lead to the similar results.

Science is basically means to look, observe and discover something.

Scientific method is a method of procedure consisting in systematic observation, measurement, and experiment and the formulation, testing and modification of hypothesis. It is a just roadmap for the study of science itself. It is through this process of experimentation and refinement by which new scientific knowledge is generated. It is a process through which we explore, observe and experiment. Scientists use this to search the cause and effect relationship in nature as something is happen by something which is causing it. **Hypothesis** is nothing just a statement conveying that we observe something. Then we test that statement through experiment and get a set of results. Here we can reach at three conclusions:

i. Hypothesis is correct and reported.
ii. Hypothesis is partially correct and reported
iii. Hypothesis is incorrect

If we reach at result 2 or 3 then we again observe the facts, consult with actual results and keep testing until reach the actual result.

All sciences obey two philosophical principals: 1. Principal of logic and 2. Search fort he truth.

Physics is known as fundamental science as other sciences use the laws and principals of Physics.

Physics deals with the study of properties of matter, energy and mutual relationship between them.

The System International Units is system of units which is used for measurement of different thing internationally.

Measurement system develops over centuries. The first measurement which is recorded is cubit. It is a measurement of length. It comes from ancient Egypt. It is the length of the tip of the finger to the bottom of the arm of a Firon.

In SI Units, there are seven base units:

Base Quantity	**Unit**
Length	Meter
Mass	Kilogram
Time	Second
Current	Ampere
Temperature	Kelvin
Quantity of a substance	Mole
Luminosity	Candela

Besides the base unit we have two supplementary units:

Plane angle	radian
Solid Angle	Steradian

Whenever two same units are added or subtracted, the final unit remains the same. But when two or more same units or different units are multiplied or divided, we have a new unit which is known as derived unit. For example

area = length x breadth

m^2 = m x m

Or

Speed = distance travelled / time taken

$ms^{-1} = m/s$

Scientific notation is a method to write very small and very large umbers in powers of ten, e.g. $100,000,000 = 1 \times 10^8$ or $0.00002315 = 2.315 \times 10^{-5}$.

All the quantities in Physics need three things to be defined and four if we add the direction:

a) A number telling us how much
b) A unit telling us what the quantity is
c) A prefix if the required quantity is very large or very small like megawatt or nanometer
d) Direction

Commom Prefixes

1. nano = $1x10^{-9}$
2. micro = $1x10^{-6}$
3. milli = $1x10^{-3}$
4. centi = $1x10^{-2}$
5. Kilo = $1x10^{3}$
6. Mega= $1x10^{6}$
7. Giga = $1x10^{12}$

Physics is divided into two main branches: Classical Physics and Modern Physics

Classical Physics deals with mechanics, waves and light, heat and electricity and magnetism.

Modern Physics deals with Quantum Mechanics and Atomic and Nuclear Physics.

Mceanics is a branch of science which deals with the study of motion of objects. Mechanics is divided into two:

Kinematics: It is a branch of Physics which deals with the study of motion of bodies without the influence of force.

Dynamics: It is a branch of Physics which deals with the study of motion of bodies under the action of force.

State of rest: A body is said to be in state of rest if it does not change its position with respect to its surroundings. e.g. a book on the table is at rest.

State of Motion: A body is in motion if it changes its position with respect to its surroundings over time.

Motion is of three types:

1. **Translatory Motion**: Such type of motion in which every particle of a body has exactly the same motion. Translatory motion is further divided into three types of motion:
    a) **Linear Motion:** Motion in straight line is called linear motion for example the motion of freely falling body
    b) **Circular Motion:** Motion in circle is called circular motion for example a stone attached at one end of a thread, when whirled, it will move along a circular Path.
    c) **Ando Motion:** If a body moves in an irregular manner is called Random Motion for example Motion of Football player on the ground, flight of a butterfly, motion of gas molecules
2. **Rotatoryy Motion:** The motion of an object around its axis or when each point of a body moves around a fixed point or axis e.g. motion of a fan, the wheel of moving vehicle, the hands of a clock.
3. **Vibratory Motion:** To and fro motion of an object is called vibratory motion. e.g. motion of pendulum, A Swinging Cradle, Opening and Closing the door of a refrigerator

Are motion and rest absolute or relative? No these terms rest and motion are relative. For example, a person inside a car, carrying a ball in his hand will see the ball is at rest. While for another person, outside the car will see the ball is also moving.

How can a state of motion of a body depend upon the observer? Consider two observers – one in train and the other on plate form. The person in the train has a book at his side, for the passenger the book is at rest with respect to him. For the observer on the platform the book would move at a high-speed as the train hurtles past. Thus the position of the observer would determine the state of motion of a body.

LECTURE # 02

Kinematics- I

1. **Physical Quantities:** A Physical Quantity is that which can be described or measured in terms of fundamental, derived or supplementary units. Mass or length or temperature of any quantity can be measured, that quantity is known as physical quantity. The measurements remain the same (within the accuracy of the measuring system) irrespective of who makes those measurements Some examples of Physical Quantities are length, area, volume, time, frequency, speed, volume, mass, force, electric and magnetic parameters, strength of materials etc.

2. **Non-Physical Quantities:** Quantities which do not have the same value for all observers, but are dependant upon who is making the measurement i.e. are subjective, are non physical quantities. Examples are emotive or ecstatic measurements like love, hate, beauty, happiness etc.

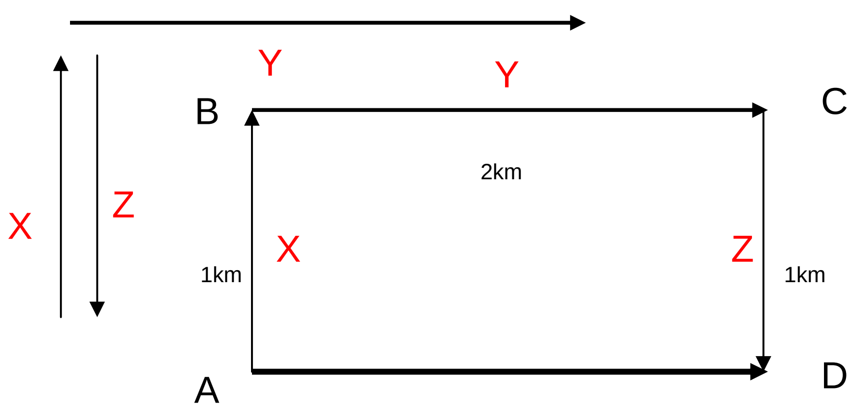
3. Physical Quantities can be sub-divided into two different components:

   a) **Vector:** the quantity which requires a direction along with magnitude and unit for its representation. Examples velocity, displacement, acceleration, force, momentum

   b) **Scalar:** the quantity which requires only magnitude and direction for its description. Examples distance, speed, mass, time, work, pressure etc.

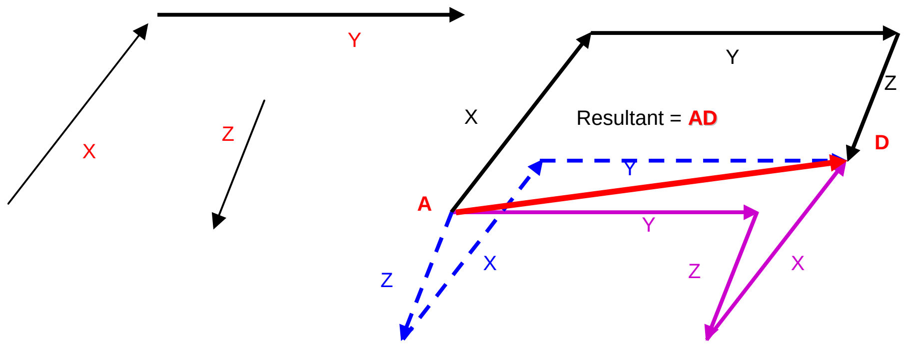
4. **Adding scalar quantities:** We add them just like everyday arithmetic i.e. 5 litres of milk and 7 litres of milk added give 12 litres of milk.

5. **Head to tail Rule:** This rule is use for addition and subtraction of vectors.



Resultant = 2km

Vectors are not added with simple arithmetic rules. Join the head of first vector with the tail of second vector. To get the resultant vector join the tail of first vector with the head of second vector. This is known as head to tail rule. If we have only two vectors then we add them by two different ways but the resultant is same in every case. A+ B = C = B + A. if we have three vector, add them in 6 different ways but the resultant is same. XYZ, YZX, ZXY, XZY, YXZ and ZYX.



6. Scalars are physical quantities which do not need a direction to be defined like a mass of 4 kg or 11 litres of milk etc. While vectors are physical quantities which are incomplete unless direction is specified, like a force of 200N acting upwards. It is pertinent to mention that Physical quantities already defined as vectors (weight, acceleration, velocity etc.) normally do not require mention of direction in a problem unless it changes during the course of the solution.

7. **Distance:** Moving between two points (from point A to point B), covers distance. **Displacement:** Distance between two points in particular direction is called

displacement. The SI unit of both distance and displacement is meter. Meter is the base unit. Some units are smaller than meter and some are lager.

Smaller units (smaller than a meter)

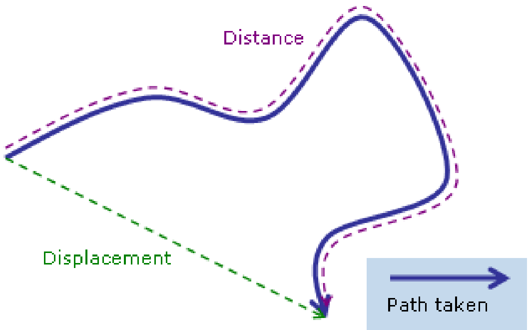
Centimetre (cm)	1/100 of a meter
Millimetre (mm)	1/1000 of a meter
Micrometre (μm)	1/1000 000 of a meter

Larger units (larger than a meter)

kilometre (km)	1,000 meters
Mega-metre (Mm)	1,000,000 meter (rarely used)
Astronomical unit (AU)	150,000,000,000 meters or 1.5x1011m
Light Year (LY)	9,400,000,000,000,000 m or 9.4x1021m

8. **Differences between distance and displacement:**

- Distance is scalar quantity while displacement is a vector quantity
- Displacement needs direction while distance not.
- Distance is the length of the actual path traversed by an object during motion in a given interval of time while displacement is the shortest distance between the two positions of the object in a particular direction during a given interval of time.
- The value of distance can never be negative or zero while the value of displacement can be negative or zero (if final and initial position coincide).
- The actual distance traveled by an object in a given interval of time can be equal to or greater than the magnitude of Displacement while the Displacement of an object between two points tells about the shortest distance between two points. It can be less than the distance.



Difference between distance and displacement

9. **Speed:** the distance covered in specific period of time. It is a scalar quantity. Its unit is ms^{-1}. Its formula is $\text{speed (v)} = \dfrac{\text{distance moved}}{\text{time taken}}$

Velocity: the displacement covered in specific period of time. It is a vector quantity. Its unit is ms^{-1}. Its formula is $\text{velocity } (\vec{v}) = \dfrac{\text{displacement}}{\text{time taken}}$.

(We do not normally indicate direction with speed or velocity, but their names differentiate between vector and scalar quantities – velocity being a vector and speed a scalar quantity – direction is only mentioned if it changes/or required in the solution of the problem)

10. For solution of problems, we have divided velocities in different types. **Initial Velocity** is the velocity which is at the start of the problem. Its symbol is V_i. **Final Velocity** which is asking at the end of the problem. Its symbol is V_f. **Average Velocity**: total displacement covered in total interval of time. Instantaneous velocity, Constant velocity and Variable velocity all have the same symbolic representation which is V. All velocities have the same units i.e. m/s or ms^{-1}. the formulas for finding the average and instantaneous velocities:

$$v_{av} = \frac{displacement}{time} = \frac{s}{t}$$

or

$$v_{av} = \frac{v_f + v_i}{2}$$

$$v_{inst} = \lim_{\Delta t \to 0} \frac{\Delta s}{\Delta t}$$

11. **Relative Velocity:** Relative velocity is always a velocity when there are two or more bodies moving with respect to each other. Relative velocity has two relationships:

a) Bodies moving in the same direction. $V_{relative} = V_2 - V_1$

b) Bodies moving in opposite directions $V_{relative} = V_2 + V_1$

12. **Acceleration:** the time rate of change of velocity. SI unit of acceleration is m/s^2 or ms^{-2} meters per second squared. It is a vector quantity.

$$\text{acceleration} = \frac{\text{change in velocity}}{\text{time taken}}$$

$$\text{change in velocity} = v_f - v_i$$

$$\bar{a} = \frac{v_f - v_i}{t}$$

13. **Acceleration and deceleration:** both have similarities and differences. Similarities are: both are vector quantities and have same unit. Difference is: acceleration is increase in velocity over the time interval. Deceleration is the decrease I velocity over the time interval.

14. A runner on a race track runs 400m in 42.8 seconds. What is his average speed?

<u>Data:</u>

Distance covered   s = 400 m

Time taken   t = 42.8 s

<u>Information required:</u> Average Speed?

<u>Relationship (formula)</u>

$$\text{speed} = \frac{\text{distance}}{\text{time}} = \frac{s}{t}$$

$$\text{speed}_{av} = \frac{400\text{m}}{42.8\text{s}} = 9.35\ \frac{\text{m}}{\text{s}}\ \text{or ms}^{-1}$$

Summary of Lecture # 3

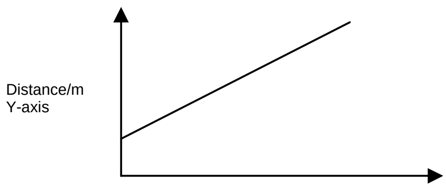
Kinematics- II

GRAPHS

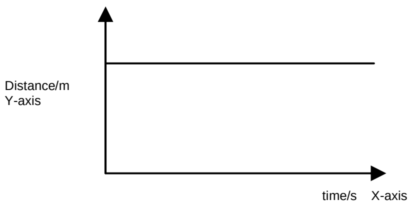
1. Graph: A graph is a mathematical tool or technique to show visually the relationship between two or more quantities. The quantities are always express along Horizontal Axis or X-Axis and Vertical axis or Y-Axis. Theses two relationships show how X-axis changes Y-axis is the visual representation which tell us the information which is conveyed. In Physics we look at trends therefore graphs are the best fit curve (or line) of the data points and therefore a continuous curve. In Biology on the other hand we are looking at living specimens therefore the line is plotted data point to data point.

2. Shapes of Graphs:

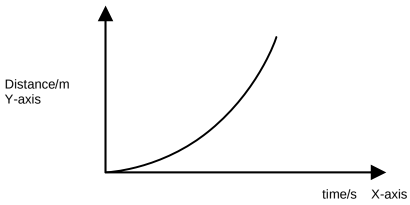
- A proportional quantity increasing with respect to (w.r.t.) another will give a straight line e.g. a body moving with constant speed time w.r.t. time.



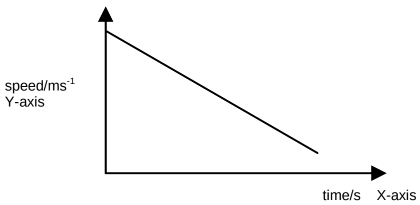
- A quantity constant with time will also give a straight line, but one which is parallel to the x-axis e.g. position of a book at rest w.r.t. time



- A quantity which increase with time but not at a constant rate will give a curve e.g. distance covered by a falling object w.r.t. time



- A quantity which decreases with time at a constant rate will give a straight line e.g. speed of a motorcycle once brakes are applied w.r.t. time



3. Steps required to plot a graph:

   i. Choice of variables along x-axis and y-axis means which quantity is to be represented along x-axis and y-axis alongwith its unit.

   ii. Selection of suitable scale: scale means a certain distance along the graph. Scale should be chosen so that the extreme data points occupy **2/3rd** of the graph area. This allows us to extrapolate what the relationship would be beyond the data points, i.e. predict what if.

   Acceptable scales divisions are magnitudes of 1, 2, 4, and 5 per box. Not acceptable scale divisions are magnitudes of 3, 6, 7, 8, and 9 per box as these are difficult to plot or read

   iii. Plot the points**:** Points are plotted to represent the data available. Join the points to indicate trend by making a best fit curve or straight line.

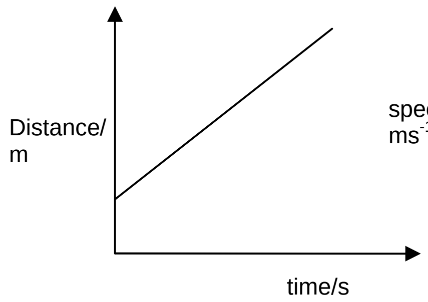
4. Presentation of the Graph

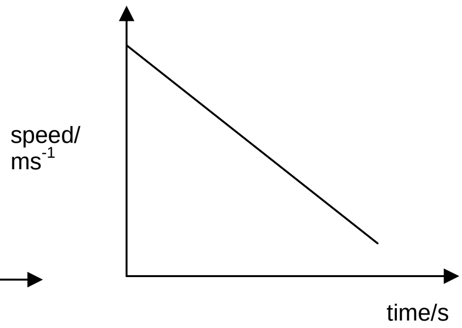
   - Give a suitable title means what is plotting against what i.e. Distance – Time Graph or a Velocity – Time Graph
   - Mention the scale: e.g. 1small box along y-axis represents 1 cm and 1small box along x-axis represents 2 s
   - Physical Quantity and units: Mention the physical quantity and scale along each axis e.g. distance/m.

- Plot the points to get a curve or a straight line.

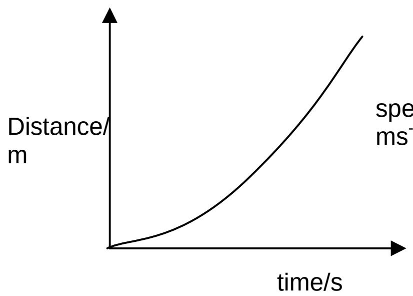
5. Relation or proportion

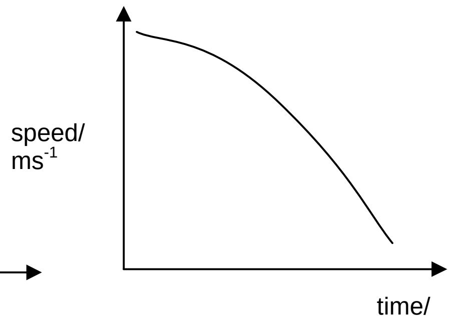
- Direct or increasing proportion means that an object starts from rest when its distance and time is zero and after some time its velocity is increasing with the increase in distance and time then there would be a straight line which shows a Direct or increasing proportion.
- Inverse or decreasing proportion means that an object is moving with constant velocity and suddenly breaks are applied then the velocity is decreasing as the distance and time increasing which shows a Inverse or decreasing proportion



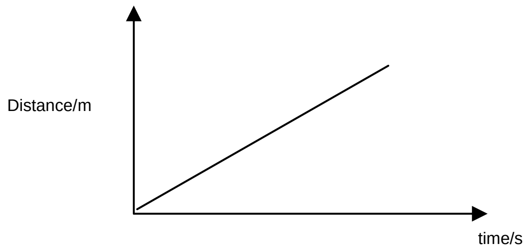


Sometimes acceleration might have not constant with time, so we have curves upward is increasing proportion or curve downward showing decreasing proportion.

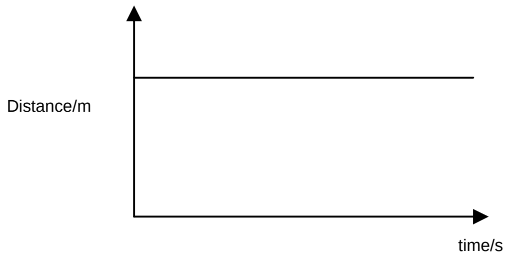




6. Distance – Time Graph: if distance is increasing with respect to time then we have a straight line as shown below



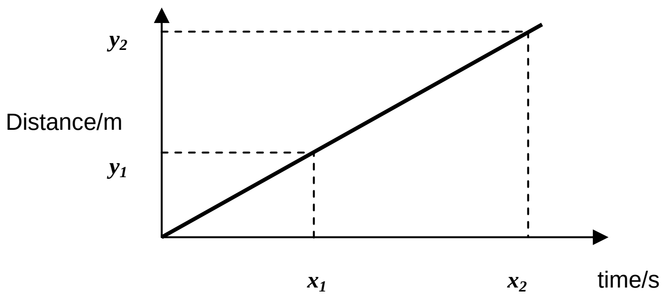
If the object is moving with constant speed then we have the graph show below



7. Rate of change, or slope of a graph:

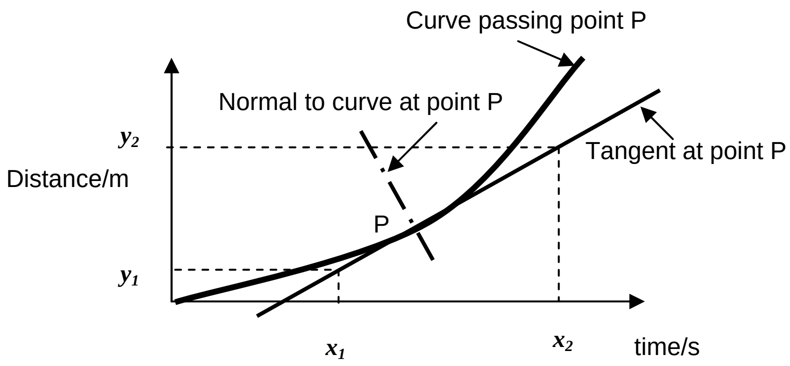
Finding the Rate of change or slope of a graph. Here we define the slop: change in the value of Y-axis with respect to X-axis.

Formula: $\text{Slope} = \frac{y_2 - y_1}{x_2 - x_1}$

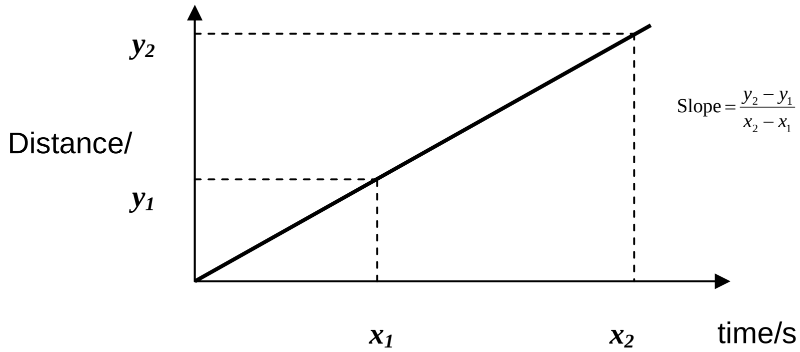


Finding the Rate of change or slope of a graph at a point P of a curve at that point.

Formula: $$\text{Slope} = \frac{y_2 - y_1}{x_2 - x_1}$$

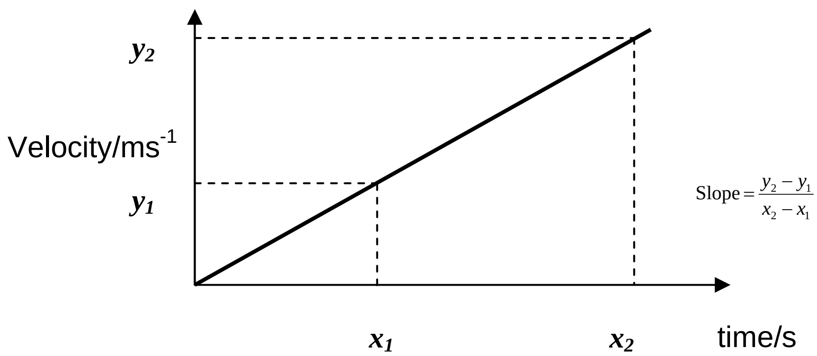


Graphs allows us to derive empirical relationships between the quantities represented on the axis



$$\text{Slope} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{\text{Distance } (y_2 - y_1)}{\text{time } (x_2 - x_1)} = \frac{\text{Distance}}{\text{time}}$$

As we know that distance divided by time is speed so slope of a distance time graph is speed.

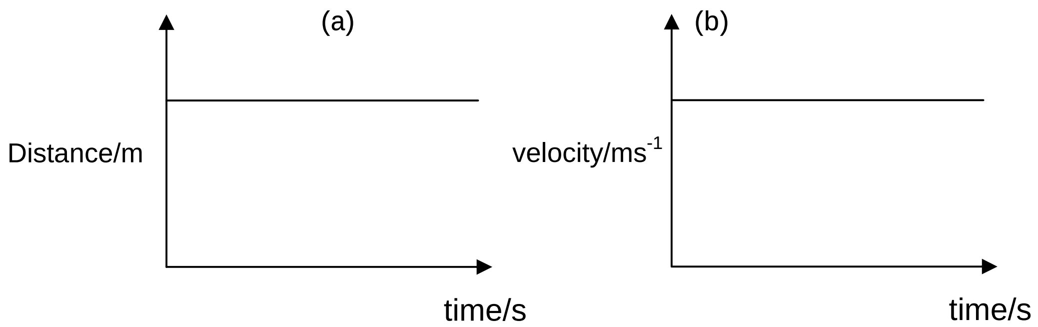


$$\text{Slope} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{\text{velocity } (y_2\text{-}y_1)}{\text{time } (x_2 - x_1)} = \frac{\text{change in velocity}}{\text{time}}$$

As we know that change in velocity divided by time is acceleration so slope of a distance time graph is acceleration.

8. Questions

What states of a body's motion are shown by the following figures?



(a) The distance is not changing with time – the object is in a state of rest

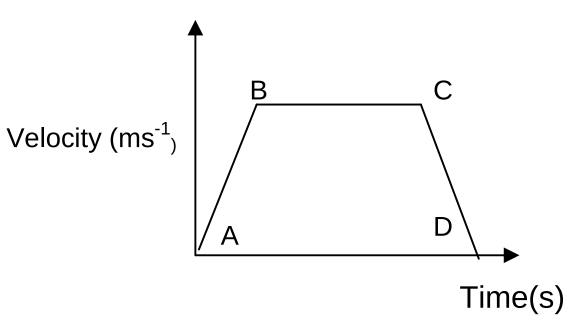
(b) The figure depicts the state of motion of a body starting from a particular point. Its velocity is not changing with time i.e. it is moving at a constant velocity

The figure depicts the state of motion of a body starting from rest. Discuss its acceleration in the sections. Discuss its acceleration in the sections

(a) A to B,

(b) B to C and

(c) C to D



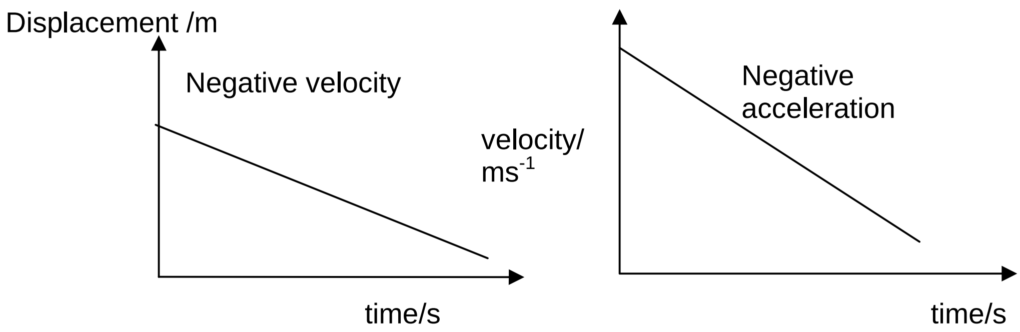
(a) part A to B: Velocity goes from zero to a certain value – velocity is increasing with time – body is acceleratin

(b) part B to C: Velocity is not changing w.r.t. time so the body is in a state of motion at a constant speed in a fixed direction i.e. velocity is constant. Acceleration is zero

(c) part C to D: Velocity in goes from a certain value to zero – velocity is decreasing with time – body is decelerating.

9. What is meant by negative acceleration and negative velocity. Represent these changes graphically.

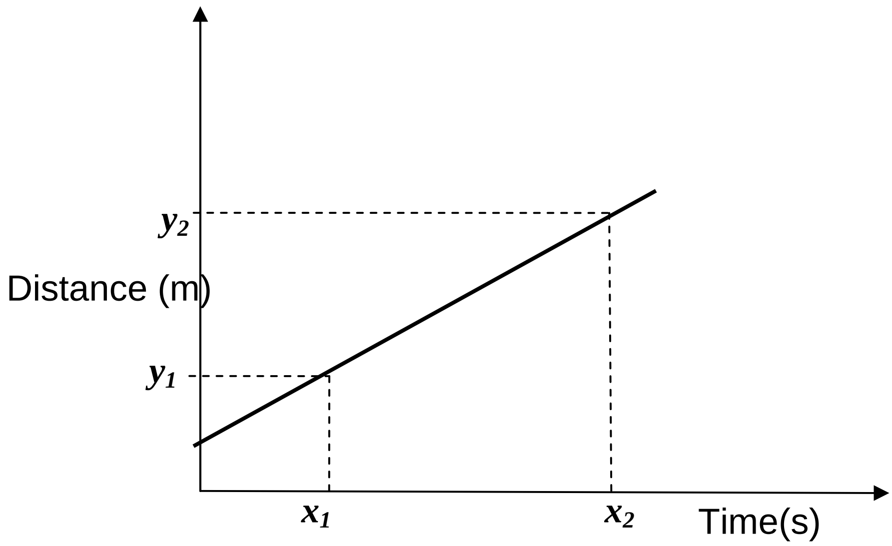
Negative velocity indicates that the displacement is decreasing with time (body is coming closer). Because acceleration is a vector a negative acceleration shall have a direction always opposite to the direction of the positive initial velocity. Negative acceleration normally means that the velocity is decreasing thus the slope of a velocity time graph should be negative. It is also called **retardation**. Because acceleration is a vector a negative acceleration shall have a direction always opposite to the direction of the positive initial velocity.



10. What is indicated if the straight line (or curve) of the graph does not pass through the origin.

When a straight line or curve does not pass through the origin it indicates that there is a residual value at that point. In a distance time graph it would indicate that there is a small displacement (distance) when the timer was started. Example: a handicap of five meters given to a weaker runner in a race i.e. when the race started he already have 5 meters covered.

11.



SUMMARY OF LECTURE # 04

Kinematic Equations

1. The equation of motions tells us that how a body behaves when it is moving or accelerating. There are three equations of motion also known as fundamental equations of motion.

2. Symbols Used:

   V_i = initial velocity
   V_f = final velocity
   a = acceleration
   t = time
   S = displacement

   By taking any four of these quantities, we can find one or the other quantity.

3. There are certain conditions when we do equations of motion:

   - Motion will always be taken along a straight line
   - Acceleration will be constant
   - Only the magnitude of velocity and acceleration will be considered
   - Initial velocity v_i will be positive; any quantity in the direction of v_i will be positive
   - any quantity in the opposite direction will be taken as negative

4. Relationship between velocity and time

   - A constant velocity means that the speed or the velocity is changing at a constant rate or Constant acceleration implies a uniform rate of change of velocity
   - The longer the acceleration, the greater the change in velocity
   - When a = constant, $v \propto t$

5. First Equation of Motion: Derivation

Suppose that a car is moving with initial velocity v_i. After time *t*, the velocity becomes v_f. The acceleration *a* is the average acceleration because the car is moving with uniform acceleration.

$$a = \frac{\text{change in velocity}}{\text{change in time}} = \frac{\Delta \text{ velocity}}{\Delta \text{ time}} = \frac{\Delta v}{\Delta t}$$

$$\Delta v = \Delta \text{ velocity} = v_f - v_i$$

Δt = t (starting from zero time)

Where Δ is change

$$a = \frac{\Delta v}{t}$$

$$a = \frac{v_f - v_i}{t}$$

Rearranging we get

$$v_f = v_i + at$$

Where V_i = initial velocity, V_f = final velocity, a = acceleration, t = time

6. Suppose that a ball is travelling at 10 ms^{-1} in a direction that we decide to call positive and that 6 s later, it is moving in the opposite direction at 20 ms^{-1}. What is the average acceleration of the ball?

Data available

v_i = 10 ms^{-1} (+)

v_f = 20 ms^{-1} (-) = - 20 ms^{-1} (+)

t = 6 s

a = ?

Relationship/formula

$V_f = V_i + at$

Substitution

$v_f = v_i + at$

$- 20 = 10 + a*(6)$

$- 20 - 10 = 6 a$

$- 30 = 6 a$

$a = - 5 ms^{-2}$

Minus sign indicates acceleration is directed opposite to direction of initial velocity.

7. A ball is thrown into the air with an initial upward velocity of 19.6 ms^{-1}. What is the velocity of the ball after 2s? What is the velocity of the ball at 4s.

Data available

$v_i = 19.6\ ms^{-1}$ (upwards)

$t = 2$ s

$a = 9.8\ ms^{-2}$ (downwards)

$v_f = ?$

Relationship/formula

$V_f = V_i + at$

Substitution at t = 2 s

$v_f = v_i + at$

$v_f = 19.6 +(-9.8)(2)$

$v_f = 19.6 – 19.6$

$v_f = 0\ ms^{-1}$

At rest i.e. at max height

Substitution at t = 4 s

$v_f = v_i + at$

$v_f = 19.6 +(-9.8)(4)$

$v_f = 19.6 – 39.2$

$v_f = -19.6\ ms^{-1}$

Same as v_i but in opposite direction.

8. Second Equation of Motion

A body is moving with initial velocity v_i, After time *t*, its velocity becomes v_f. We find the total distance, *s*, covered in time *t by* the formula

Distance = Time x Average Velocity

$$s = v_{av}t \qquad \rightarrow 1.1$$

Average Velocity is given by

$$v_{av} = \frac{v_i + v_f}{2} \qquad \rightarrow 1.2$$

Substituting eq.1 in eq.2 $s = \frac{(v_i + v_f)}{2}t$

$$\rightarrow 1.3$$

First Equation of Motion:

$$v_f = v_i + at$$

Substituting the first equation of motion in 1.3

$$s = \frac{(v_i + v_i + at)}{2}t = \frac{2v_i}{2}t + \frac{at}{2}t$$

$$\rightarrow 1.\ 4$$

Second Equation of Motion: $s = v_i t + \frac{1}{2}at^2$

9. Relationship between Displacement and Time

$s = v_i t + ½at^2$

Displacement of a moving object is proportional to its average velocity and time as

$s = v_{av}$ x t (directly if v is constant; a=0)

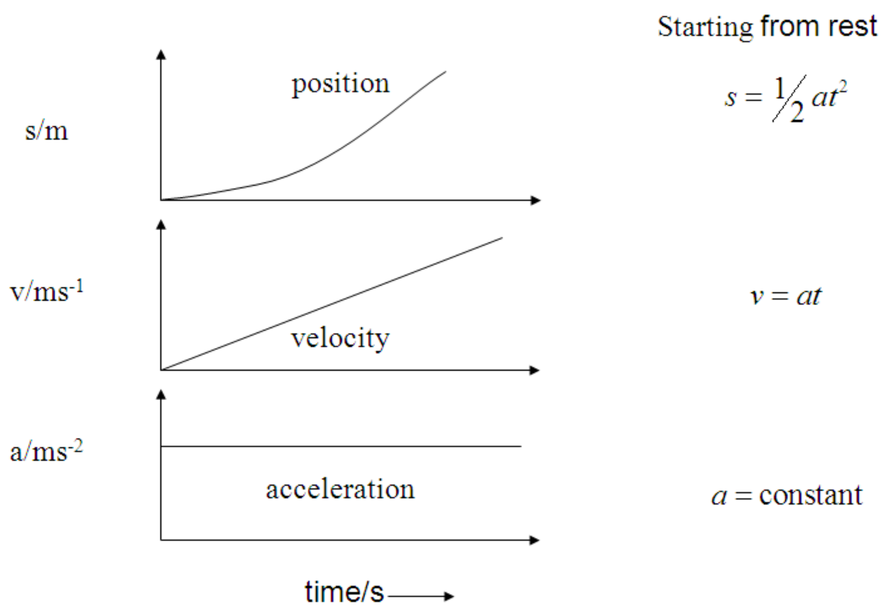
Generally $s \propto t^2$ (accelerated motion)

Velocity is proportional to time as well

v = a x t (directly if a is constant)

10. Constant Acceleration Motion:

The first graph is indicating that how the position is changing with time. On the right hand side, second equation of motion is given with the first part missing shows that the object starts its motion from rest. It is sloping upward indicating that how distance or displacement is changing with time. In the second graph, we have a straight line which shows constant acceleration motion because on the right hand side we have first equation of motion with zero initial velocity. In the third graph, acceleration is constant with respect to time.



11. A brick is dropped from a height of 78.4 m. How long will it take the brick to reach the ground? What will its velocity be before touching the ground? Aacceleration due to gravity is 9.8 ms^{-2} downwards.

Data available

a =g= 9.8 ms^{-1} (downwards)

v_i = 0 ms^{-1} (rest)

s = 78.4 m

t = (?); v_f = (?)

Relationship/formula

$s = v_i t + \frac{1}{2} at^2$

$v_f = v_i + at$

Substitution for t=?

$s = v_i t + \frac{1}{2} at^2$

$78.4 = 0 \times (t) + \frac{1}{2} \times 9.8 \times t^2$

$78.4 = 4.9\, t^2$

$16 = t^2$

t = 4.0 s

Substitution at t = 4 s

$v_f = v_i + at$

$v_f = 0 + 9.8 \times (4)$

$v_f = 39.2\ ms^{-1}$

12. Third Equation of Motion: Derivation

From first equation of motion

$$v_f = v_i + at \Rightarrow t = \frac{v_f - v_i}{a}$$

We define velocity as rate of change of displacement.

$$v_{av} = \frac{s}{t} \qquad \Rightarrow \qquad s = v_{av} \times t$$

Where

$$v_{av} = \frac{v_f + v_i}{2}$$

Using value of average velocity and time in equation

$$s = v_{av} \times t = \frac{v_f + v_i}{2} \times \frac{v_f - v_i}{a} = \frac{v_f^2 - v_i^2}{2a}$$

$2as = v_f^2 - v_i^2$

This equation shows the relationship between initial velocity, final velocity, acceleration and distance and is the required the equation of motion.

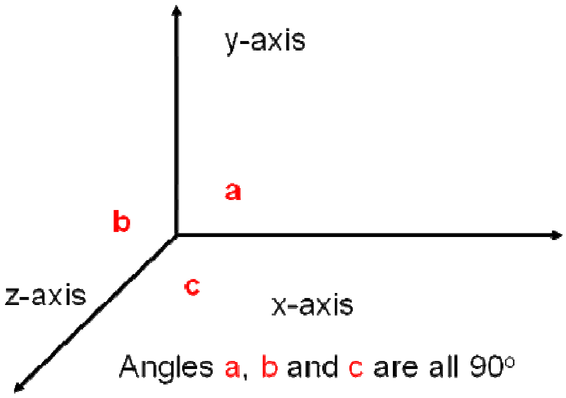
SUMMARY OF LECTURE # 5

Newton’s laws of motion

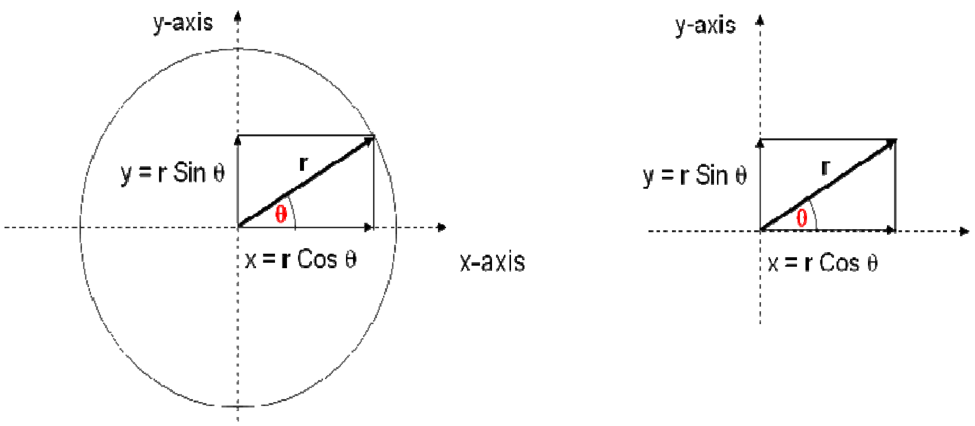
1. As we studied earlier that mechanics is divided into two branches, kinematic and dynamics. Now we discussed dynamics here. Dynamics is the branch of Physics which deals with motion under the influence of force.
2. Aristotle first gives the concept of force as something that caused motion. He stated that when force acting is stopped, motion ceased.
3. 2000 years later Galileo, who was reputed to challenge Aristotle's teachings, regarded Aristotle explanation as incomplete because it did not explain why a tossed ball flew in air after the force on it (our hand) had ceased to act.
4. Sir Isaac Newton was the person who explained this phenomenon in terms we now consider to be correct. Something that can cause, or try to cause a change in the physical state of a body.
5. Force can do a lot of things:
   a) A force can cause a body to move or cause a moving body to speed up/stop or change direction
   b) A force can compress or stretch a body without causing motion
6. Force: The agent or agency that changes of tends to change the state of a body is called force. In simple words we can say that an agency causing a pull or a push is a force. The standard international unit of force magnitude is the *Newton* (N), which is the equivalent of a kilogram-meter per second squared (kg m s^{-2}).
7. Types of force: a). Contact Forces b) Non-contact or Action at a distance Forces. Elastic push–pull force and Frictional or drag force are contact forces while gravitational force (between two masses like Earth and Moon) and magnetic force (force between two pieces of magnet) are non-contact forces.
8. Newton's First law: Everybody continues in a state of rest or of uniform motion, in a straight line, unless an external unbalanced force acts upon it. This is also known as the Law of Inertia. If an object is at rest, it will remain at rest unless some external force is

acting on it to change its states and if an object is moving with uniform speed, it will continue its motion unless some external force is acting on it.

9. Basic Trigonometry: Cartesian coordinate system contains three mutually perpendicular directions x, y and z and is a three dimensional system also known as the real life system of coordinates.



Why we use coordinate system? The coordinate system combines with the trigonometry gives us important relationship for the solving the problems. In physics, we are dealing with two dimensional space.



Trigonometric ratios

$$Sin\theta = \frac{y}{r}$$

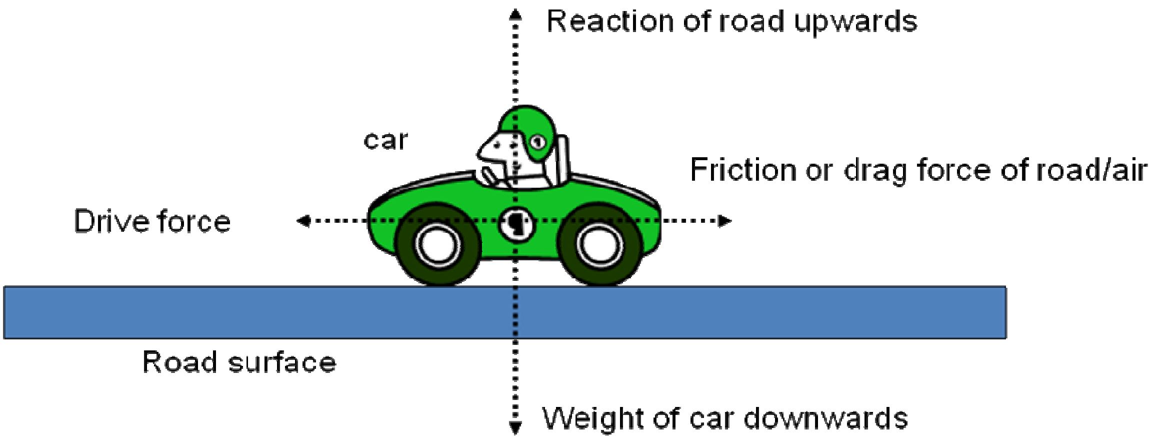
$$Cos\theta = \frac{x}{r}$$

$$Tan\theta = \frac{Sin\theta}{Cos\theta} = \frac{y}{x}$$

$$x^2 + y^2 = r^2$$

10. Force: Free body diagrams: A free body diagram represents all forces on a body, so we can understand what action is performed by what force.

Example: a car on the road, four forces act on the car. Size of the arrows would be indicative of magnitude of the Forces on the car.



11. Mass: quantity of matter in an object or the ability of matter to resist against the action of force. The SI unit of mass is a kilogram (kg) and as we have already studied it is a scalar quantity (i.e. has magnitude but no direction)

12. Newton's second law of motion: Acceleration produced in a body is directly proportional to the applied force and inversely proportional to the mass of the body

$$a \propto F$$

$$a \propto \frac{1}{m}$$

Combining we get,

$$a \propto \frac{F}{m}$$

$F = \text{constant} \times \text{ma}$

In the SI measurement system the unit of force is a Newton [N] and is defined such that a 1 N force causes an acceleration of 1 ms^{-2} in a mass of 1 kg
N = kg m s^{-2}

$$1\ \text{N} = \text{constant} \times 1\ \text{kg} \times 1\ \text{ms}^{-2}$$
$$1 = \text{constant}$$

Therefore in the SI measurement system F = ma

SUMMARY OF LECTURE # 06

LINEAR MOMENTUM & TENSION IN A STRING

1. Mass: The quantity of matter in a body is called mass. It is a scalar quantity and its unit is the kilogram [kg].

Matter: Anything that can occupy space and has mass is called matter. Examples: table, television, water, cold drink, gas, air etc.

Non-matter: Things that do not occupy space or do not has mass are called non-matter e.g. data stored in hard disk of computer, feelings, thoughts, vacuum etc.

2. States of Matter: matter exits in four different states.

   a) Solid → Solids
   b) Liquid
   c) Gas → Fluids
   d) Plasma

3. Mass and weight in relation to force: F= ma Mass is the characteristic of a body which determines the magnitude of acceleration when a force is applied to it. W = mg weight is the force with which the Earth attracts a body towards its centre and we call it as the gravitational field strength or acceleration due to gravity. Weight is a force so a vector quantity. $W = mg$

$$g = \frac{W}{m} = \frac{F_E}{m}$$

4. Difference between mass and weight:

Mass	Weight
Mass is the characteristic of a body which determines the magnitude of acceleration when a force is applied to it	Weight is force with which he earth attracts a mass towards its centre
Mass is a scalar quantity	Weight is a vector quantity directed towards the centre of the earth
Mass remains same everywhere	Weight varies as g varies
Mass of a body cannot be equal to	The weight of the body can be equal to

zero	zero (at the centre or beyond the gravitational pull of earth)
The unit of mass is kilogram	The unit of weight is newton
Mass can be measured by physical or electronic balance	Weight can be measured by spring balance
Mass is a base or fundamental quantity	Weight is a derived quantity
Mass is independent of the position of the body	Weight depends on the position of the body from the centre of the earth
Mass can be calculated by the formula $F = ma$,	The value of weight can be calculated by the formula $W = mg$

5. Question: The mass of an astronaut is 65 kg.

(i) What will be his weight on the surface of the earth?

(ii) What will be his weight on the surface of moon where value of $g = 1.6\ ms^{-2}$?

Data :

Mass of astronaut = m = 65 kg

Value of g, on earth surface = $g = 9.8\ m\ s^{-2}$

Weight of astronaut on earth = W = ?

Formula used

$W = mg$

$W = 65\ kg \times 9.8\ m\ s^{-2}$

$W = 637\ kg\ m\ m\ s^{-2}$

Weight = 637 N

Mass of astronaut on the surface of moon

Data :

mass of astronaut m = 65 kg

Value of g, on moon surface $g = 1.6\ m\ s^{-2}$

Weight of astronaut on moon W =?

Formula used

W = mg

W = 65 kg x 1.6 m s^{-2}

W = 637 kg m m s^{-2}

Weight = 104 N

6. Newton's third law of motion: For every action there is an equal but opposite reaction. However, action and reaction are on different bodies. Examples Weight of a book is downwards while push of table is upwards. A bullet leaving a gun moves forward while the gun recoils backwards.

7. Newton (or third law) pair of forces are always

- Equal in magnitude
- Opposite in direction
- On different bodies
- Acting on same line of action

8. Tension in a string due to gravity:

Tension: The Force exerted along a string due to load on one or both of the ends of the string.

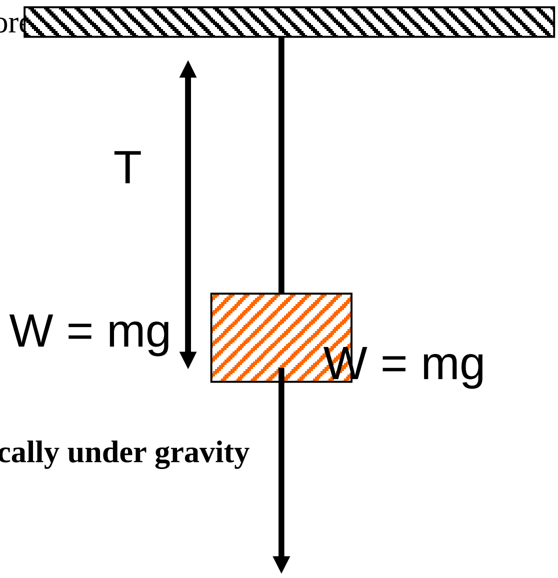
As tension is a force so its SI unit Newton

<u>Case I a:</u> Bodies at rest, under tension vertically under gravity

T and W are third law pair of forces therefore

T = W = mg (magnitude)

Directions are opposite



<u>Case I b:</u> Bodies in motion, under tension vertically under gravity

$(T - W_1) = -F_1 = -m_1 a$

$m_1 g - T = m_1 a$

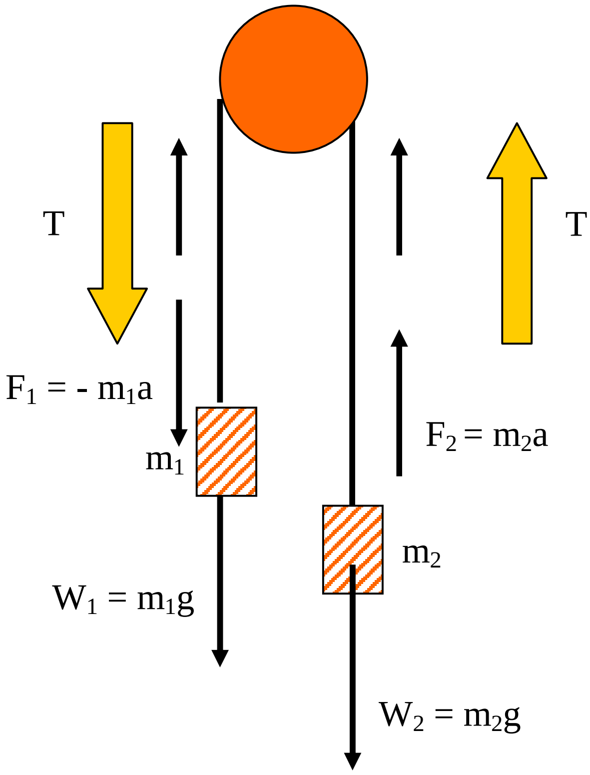
$T = m_1 g - m_1 a$

$(T - W_2) = F_2 = m_2 a$

$T - m_2 g = m_2 a$

$T = m_2 a + m_2 g$

$$T = m_1 g - m_1 a$$
$$T = m_2 a + m_2 g$$
$$m_1 g - m_1 a = m_2 a + m_2 g$$
$$m_1 g - m_2 g = m_2 a + m_1 a$$
$$(m_1 - m_2) g = (m_2 + m_1) a$$
$$(m_2 + m_1) a = (m_1 - m_2) g$$
$$a = \frac{(m_1 - m_2)}{(m_2 + m_1)} g$$



Here, *a* is the acceleration of the system as well as the individual bodies (which because they are connected behave as a system)

$$T = m_2 a + m_2 g$$
$$a = \frac{(m_1 - m_2)}{(m_2 + m_1)} g$$
$$T = m_2 \frac{(m_1 - m_2)}{(m_2 + m_1)} g + m_2 g$$
$$T = \left[\frac{(m_1 - m_2)}{(m_2 + m_1)} + 1\right] m_2 g$$
$$T = \left[\frac{(m_1 - m_2) + (m_2 + m_1)}{(m_2 + m_1)}\right] m_2 g$$
$$T = \left[\frac{2m_1}{(m_2 + m_1)}\right] m_2 g = \frac{2m_1 m_2}{(m_2 + m_1)} g$$

9. Problem: Two bodies of masses 1 kg and 2 kg respectively are tied to a string which moves over a frictionless pulley. Find the acceleration of the bodies and the tension in the string

Data :

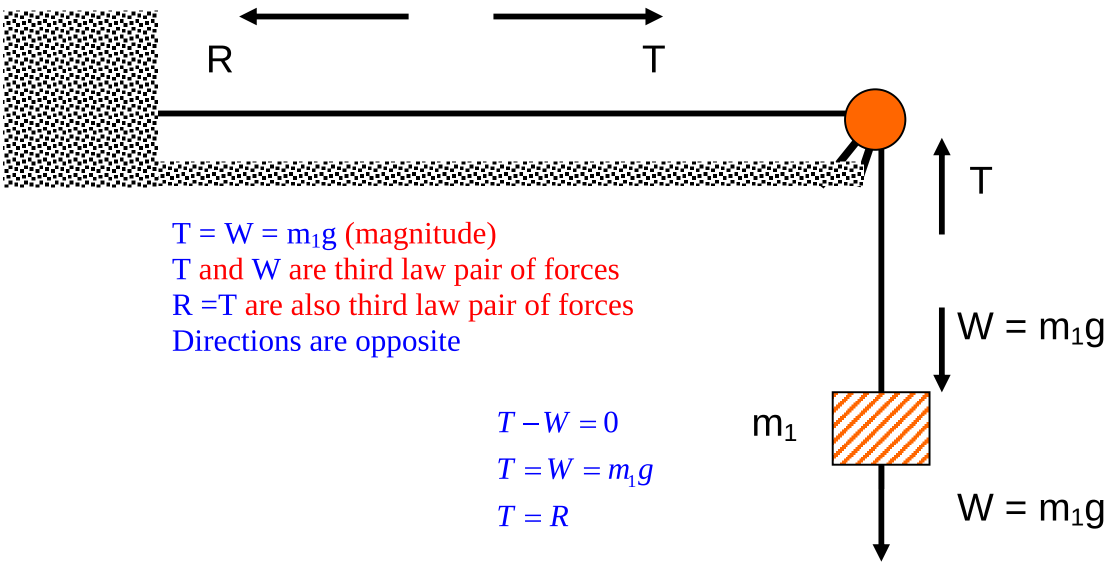
mass m_1= 1.0 kg, mass m_2 = 2.0 kg, g = 9.8 **m s-2**

Solution

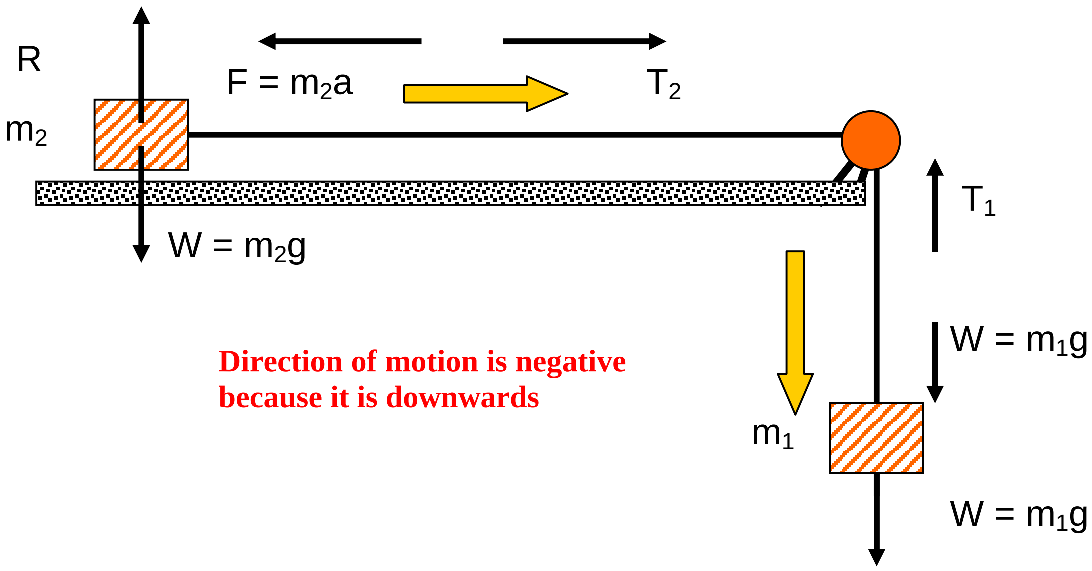
$$a = \frac{(m_1 - m_2)}{(m_2 + m_1)} g$$
$$a = \frac{(2 - 1)}{(2 + 1)} \times 9.8$$
$$a = \frac{1}{3} \times 9.8 = 3.27 ms^{-2}$$

$$T = \frac{2m_1 m_2}{(m_2 + m_1)} g$$
$$T = \frac{2 \times 2 \times 1}{(2 + 1)} \times 9.8$$
$$T = \frac{4}{3} \times 9.8 = 13.07 N$$

10. Case II(a): string under tension, held stationary horizontally and the body hanging vertically under force of gravity,



Case II(b): Bodies under tension during motion, one body moving vertically under force of gravity, the other moving horizontally under the force of tension:



$T = T_1 = T_2$

$T = W = m_1g$

$R = m_2g$

$T = F = m_2a$

$-T = -m_2a$

$T = m_2a$

$(T - W) = -m_1a$

$T = m_1g - m_1a$

$m_1g - m_1a = m_2a$

$m_1g - m_1a = m_2a$

$m_1g = m_2a + m_1a$

$m_1g = (m_2 + m_1)a$

$$a = \frac{m_1}{(m_2 + m_1)}g$$

$T = m_2a$

$$T = m_2\frac{m_1}{(m_2 + m_1)}g$$

$$T = \frac{m_1m_2}{(m_2 + m_1)}g$$

11. Problem: A block of mass 6 kg is placed on a smooth horizontal surface. It is connected to another mass of 4 kg by means of a string passing over a smooth frictionless pulley, assuming no friction between the surface and the block find the tension in the string and the acceleration of the system of blocks.

<u>Data :</u>

mass $m_1 = 4.0$ kg mass $m_2 = 6.0$ kg $g = 9.8$ **m s**$^{-2}$

Solution:

$$a = \frac{(m_1)}{(m_2 + m_1)}g$$

$$a = \frac{(6)}{(4+6)} \times 9.8$$

$$a = \frac{6}{10} \times 9.8 = 5.88ms^{-2}$$

$$T = \frac{m_1m_2}{(m_2 + m_1)}g$$

$$T = \frac{4 \times 6}{(4+6)} \times 9.8$$

$$T = \frac{24}{10} \times 9.8 = 23.52N$$

12. Momentum: The product of mass and velocity is called Momentum. It is a vector quantity. Unit of Momentum = (mass x velocity) i.e. [kg ms-1] or N s

Momentum = mass x velocity

M = mv

The rate of change of momentum is equal to the force and takes place in the direction of the applied force.

$$F = ma = \frac{m\Delta v}{t} = \frac{\Delta M}{t}$$

This is another statement of Newton's Second Law.

13. Law of conservation of momentum: When two (or more) bodies collide there is no net change in momentum, provided no external force acts. Thus if there is no change then the momentum of bodies before collision has to be equal to the momentum of the same bodies after collision.

Momentum of bodies before collision = $m_1u_1 + m_2u_2$

Momentum of the same bodies after collision = $m_1v_1 + m_2v_2$

OR

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

Explanation: When we fire a gun the bullet goes forward and the gun recoils

Momentum of gun and bullet before firing	Momentum of gun and bullet after firing
$m_1u_1 + m_2u_2 = 0$	$m_1v_1 + m_2v_2$

Both at rest

$$0 = m_1v_1 + m_2v_2$$

$$m_1v_1 = -m_2v_2$$

$$v_1 = -\frac{m_2}{m_1}v_2$$

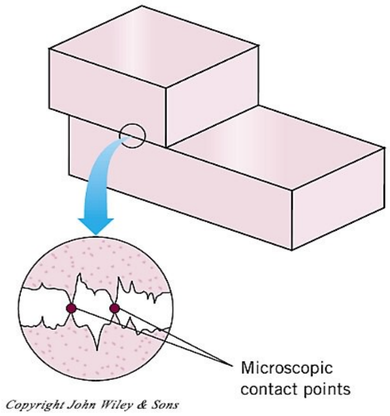
$$0 = m_1v_1 + m_2v_2$$

$$m_1v_1 = -m_2v_2$$

$$v_2 = -\frac{m_1}{m_2}v_1$$

14. How does a car stop? Why is it easier to drive on a dry road? The answer to these question lies in the inherent property of matter i.e. friction. It is a force acting in opposite direction to movement. Whenever two surfaces slide over each other the force which does not allow the motion to take place is known as friction. When

two surfaces meet, there are some contact points between them. These are microscopic contact points.



15. Advantages of Friction

- Vehicles can move
- Vehicles can stop (apply brakes)
- Machines can work
- We can walk
- We can do work
- A pencil can be held
- A nail can be fixed in the wall

16. Disadvantages of Friction

- Energy is lost (wasted)
- Wear and tear of machines, instruments
- More fuel is consumed
- Parts and machinery need replacement
- Lubrication is required
- Etc.

17. Types of Friction:

- Static Friction: when body is at rest the force of friction is known as static friction.
- Kinetic friction: whenever two objects moving, there is a frictional force known as Kinetic friction. Kinetic friction is less than static friction.
- Rolling Friction: when an object rolling down the ground, the friction is rolling friction. As the contact points between the object and ground are very very small, so rolling friction is minimal. Rolling friction has a vide application in Ball Barings.

- Sliding Friction: sling friction is present when an object is sliding with other object.
- Limiting Friction: when force is applied to overcome the friction, a slight more increase in force is going to cause motion is known as limiting friction. limiting friction is very essential in solving problems

18. How to calculate friction: friction depends upon the weight. The larger the weight of the object, the larger the friction would be. Friction is directly proportional to weight. Weight and the reaction of the surfaces are identical so friction is directly proportional to reaction:

$$f \propto R$$

$$f = \mu R$$

$$W = mg$$

$$R = W = mg$$

$$f_k = \mu_k R$$

$$f_s = \mu_s R$$

μ is known as coefficient of friction

19. Methods to reduce Friction

- Polish surfaces
- Apply lubricant
- Use rolling objects wherever possible (ball bearings)
- Streamline the objects (ships aeroplanes etc)

SUMMARY OF LECTURE # 07
WORK, ENERGY AND POWER- I

1. When we say an object does work, what does this means? For example an object is lying on table. Is it doing any work? No, it is not doing any work because it is lying on the table. In physics work is defined as the work which is useful. The work is defined as the product of force and displacement.

   Work = Force x Displacement

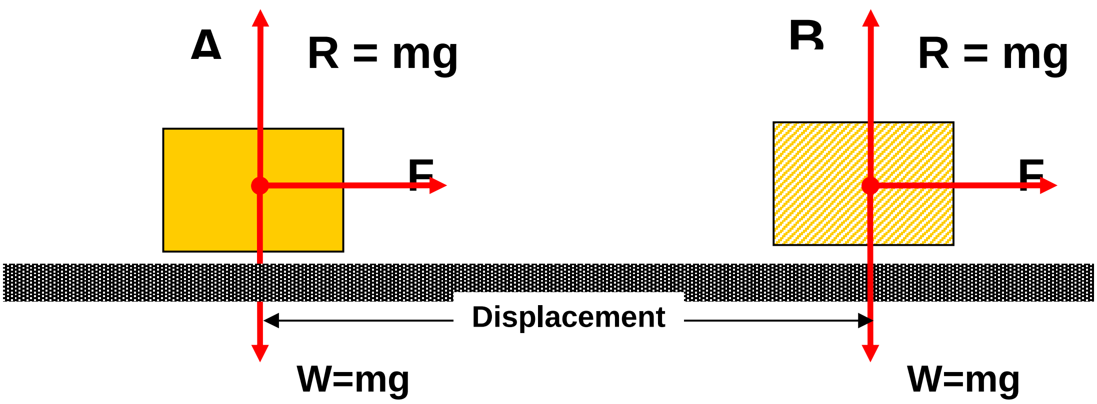
   = Force x Distance (covered in the direction of force)

   $$W = \vec{F}\,\vec{s}$$

   The force should acting on a body should be a net unbalanced force and the body should cover some distance under the action of this force

   Work is a scalar quantity and its units are N m or Joule (J)

2. What about action reaction forces?



   From the figure, weight of the object acts in downward direction and reaction of the surface is in upward direction, so equal and opposite cancel out each others effect and does not allowing the object to move in the vertical direction. So the object is moved from point A to point B and covers displacement X in the direction of force. This is the force F which is causing the work.

3. conditions for the work to be done:

   (a) Force (F) must be acting on the body

   (b) The body should cover distance (s) in direction of force

Case 1 ***F= 0***

$F = 0$

$s \neq 0$

$W = \vec{F}s = 0$

Case 2 s = 0

$F \neq 0$

$s = 0$

$W = \vec{F}s = 0$

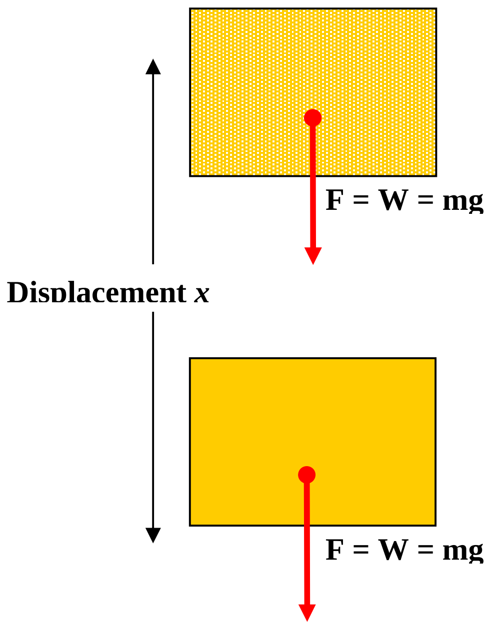
4. **Work against gravity:**

$$F = mg$$

$$s = x$$

$$W = mgx$$

Work done in falling and rising has to be same therefore we say that work against gravity has also to be equal to *mgx*



5. Sometimes force is applied at an angle. Then we use trigonometric relations to find out the work. The factors upon which **work done depend:**

   a) Force acting (F)
   b) Distance covered in direction of force (s)
   c) Angle at which the force acts.

$$W = \vec{F}s$$

$$W = F Cos\theta\, s$$

$$W = F s Cos\theta$$

Angle at which the force acts.

Case 1

$\theta = 0^o$

$W = Fs[Cos0]$

$W = Fs[1]$

$W = Fs$

Case 2

$\theta = 90^o$

$W = Fs[Cos90]$

$W = Fs[0]$

$W = 0$

Case 3

$\theta = 180^o$

$W = Fs[Cos180]$

$W = Fs[-1]$

$W = -Fs$

For all other angles the net work will always be less than *Fs*

6. Unit of Work:

Unit of work done = Unit of force x Unit of Displacement

Work is a scalar quantity and its units are N m or Joule (J)

Joule: Work done will be one joule when a 1 Newton force acts on a body and it covers a distance on 1 meter in the direction of force.

Larger Unit: kJ = 1,000 J = 10^3 J

MJ = 1,000,000 J = 10^6 J

7. Problem: A Labourer pusher a heavy crate through a distance of 20m, if the force of the labourer is 250 N, what is quantity of the work done.

<u>Data :</u>

Force applied = F = 250N

Distance moved = s = 20 m

Work done = W =?

<u>Solution:</u>

$$W = \vec{F}\,\vec{s}$$

$$W = 250 \times 20$$

$$W = 5,000\ J$$

8. Power: Rate of doing work is power i.e. Work done per unit time is power

$$P = \frac{W}{t} = \frac{\text{Work done}}{\text{Time taken}}$$

Power is a scalar quantity and its unit is the Watt. If 1 Joule of work is done in one second then the power is 1 W

Larger Unit: kW = 1,000 W = 10^3 W

MW = 1,000,000 W = 10^6 W

9. Problem: A motor pumps 2,000 kg of water in one hour from a well to an overhead tank through a distance of 50 m. Find the power of the motor.

<u>Data :</u>

Mass = m = 2,000 kg
Force applied = F = 19,600 N
Distance moved = s = 50 m
Time taken = t = 3,600s
Power P=?

$$F = mg = 2000 \times 9.8$$

$$F = 19,600 N$$

$$W = mgx = 2000 \times 9.8 \times 20$$

$$W = 392,000\ J$$

$$P = \frac{W}{t} = \frac{392,000}{3,600} = 108.88W$$

10. Energy: "It is the ability of a body to do work." Energy is needed to do any type of work. Energy is a scalar quantity and its SI unit is that of Work i.e. Joule

    Unit of work done = Unit of force x Unit of Displacement

    1 J = 1 N x 1 m

Larger Unit:	kJ = 1,000 J	= 10^3 J
	MJ = 1,000,000 J	= 10^6 J

SUMMARY OF LECTURE # 08

WORK, ENERGY AND POWER- II

1. Energy: "It is the ability of a body to do work." Energy is needed to do any type of work. Energy is a scalar quantity and its SI unit is that of Work i.e. Joule
   Unit of work done = Unit of force x Unit of Displacement
   1 J = 1 N x 1 m
   Larger Unit: kJ = 1,000 J = 10^3 J
   MJ = 1,000,000 J = 10^6 J

2. Types of Energy:
   - Kinetic Energy
   - Potential Energy (a) Gravitational (b) Elastic PE
   - Chemical
   - Heat Energy,
   - Nuclear Energy,
   - Solar Energy etc.
   - Light Energy
   - Sound Energy
   - Electrical Energy
3. Conversion of Energy: Energy can be converted from one form to another for of energy
4. Conservation of Energy: from the law of conservation of energy, Energy can neither be created nor destroyed; it can only be converted from one form to the other.
5. Mechanical Energy: Kinetic energy and potential energy collectively called mechanical energy.

   a) Kinetic Energy: Energy (or ability to do work) a body possesses due to its state of motion
      Kinetic Energy (KE) = mass of body x (velocity) ^{2} = $KE = \frac{1}{2}mv^2$
   b) Potential Energy: Energy (or ability to do work) a body possesses due to its position or state. PE is further divided into two:
      i. Gravitational potential Energy is due to height of the object which it is possesses
      ii. Elastic Potential Energy: the energy stored in a spring is EPE.
6. Kinetic Energy (derivation): Assuming a body starts from rest and attains a final velocity v,

$$v_f^2 - v_i^2 = 2as$$

$$a = \frac{F}{m}$$

$$v_f^2 - v_i^2 = 2\left(\frac{F}{m}\right)s$$

$$F \times s = \frac{1}{2}m\left(v_f^2 - v_i^2\right)$$

$$KE = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$$

Substituting values of $v_i = 0$ and $v_f = v$

$$KE = \frac{1}{2}m(v)^2 - \frac{1}{2}m(0)^2$$

$$KE = \frac{1}{2}m(v)^2$$

7. Problem: A fast bowler bowls a cricket ball of mass 0.25 kg at 20 ms-1. What is the kinetic energy of the ball?
   If a slow bowler bowls at half this speed what is the work done by the slow bowler.
   Data :
   m = 0.25 kg
   v = 20 ms-1
   v = 10 ms-1
   KE (fast) = ?
   KE (slow) = ?
   Solution:

$$KE(fast) = \frac{1}{2}m(v)^2 \qquad KE(slow) = \frac{1}{2}m(v)^2$$

$$KE(fast) = \frac{1}{2}\times 0.25 \times (20)^2 \qquad KE(slow) = \frac{1}{2}\times 0.25 \times (10)^2$$

$$KE = 50J \qquad KE = 12.5J$$

8. G. Potential Energy (derivation): Assuming a body moves a distance h under gravity

$$W = Fs$$

$$W = mg\ \ s$$

$$W = mgh$$

9. Other Energies:
   - Chemical Energy: It is the energy produced as a result of Chemical Reaction. E.g: Energy in Cell Battery, burning of wood coal etc.

- Elastic P.E: Energy produced in compressed or stretched elastic object. E.g: Energy in a compressed spring.
- Gravitational P.E: Energy due to the position of a body above the earth surface. For a body of Mass "m" at height "h" above the earth's surface. Gravitational P.E = Wt x h=mg h
- Internal Energy: It is the energy possessed by the constituent molecules of a substance. i.e. due to the temperature of the body
- Electric Energy: It is the energy produced by the coils of a generator when run by a turbine or a turning mechanical force in a magnetic field
- Sound Energy: It is the energy produced by a vibrating body.
- Magnetic Energy: Energy due to forces of attraction/repulsion between two magnets
- Electric Potential Energy: Energy due to forces of attraction/repulsion between two charges
- Solar Energy: It is the energy produced by the Sun.
- Tidal: Energy due to forces rising and falling of ocean tides
- Geothermal: Energy present inside the earth (hot molten core)

10. Question: Show that the unit for work and energy are the same –

$$KE = \frac{1}{2}mv^2 \qquad PE = mgh \qquad W = Fs = mas$$

$$KE = [\times][kg]\left(\frac{m}{s}\right)^2 \qquad PE = [kg]\left(\frac{m}{s^2}\right)[m] \qquad W = kg\left(\frac{m}{s^2}\right)[m]$$

$$KE = kgm^2s^{-2} \qquad KE = kgm^2s^{-2} \qquad W = kgm^2s^{-2}$$

kg m s-2 is same as J (joule) – so units of KE, PE and Work are same

11. Is any work done when we lift a load from the surface of the earth to a height h? As there is a difference of Energy (PE) therefore Work has to be done to raise the mass from surface to height h. $PE = mg(h)$
12. Difference between transfer modes – heating and working: Both heating and working transfers energy from one form to another – one uses a temperature difference the other uses a force. eg of use of a temperature difference (heating) a kettle and use of a force (working); a pendulum

13. Reversible and Irreversible conversions: Reversible conversions are interchanges of Energy that can be inter-converted or recovered, whereas in the case of an irreversible conversion the energy transformation is not recoverable or that it cannot be used again e.g. Reversible: Mechanical (spring stretching/compression) Electric energy in rechargeable batteries and Irreversible: Loss due to friction, Burning of fuel, e.g. - Energy from coal
14. Matter is also a form of energy. Or Matter can be converted into energy.

    $E = mc^2$,

    c = speed of light, m = mass, E = energy
15. Renewable and non-renewable sources of energies: Renewable sources are those which are refilled over a finite period of time and can be used again e.g. Solar, Hydal, Tidal, Waves, Rechargeable batteries etc. sources which become depleted when used e.g. oil, gas, coal and wood etc.
16. Inter-conversion of mechanical energy: Assuming a body of mass m falls a distance h under gravity from points A to C through B

    At point A

$$KE = \frac{1}{2}mv^2 \quad = 0$$

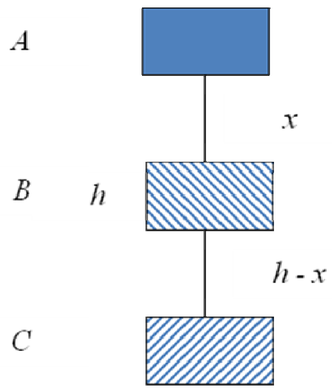
$$PE = mgh$$

$$W = mgh$$

$$TE = PE + KE$$

$$TE = mgh + \frac{1}{2}mv^2$$

$$TE = mgh$$



At point B

$$KE = \frac{1}{2}mv^2$$

$$v_f^2 - v_i^2 = 2gx$$

$$v_f^2 = 2gx$$

$$KE = \frac{1}{2}m(2gx)$$

$$KE = mgx$$

$$PE = mg(h - x)$$

$$PE = mgh - mgx$$

$$TE = PE + KE$$

$$TE = (mgh - mgx) + mgx$$

$$TE = mgh$$

At point C

$$KE = \frac{1}{2}mv^2$$

$$v_f^{\,2} - v_i^2 = 2gh$$

$$v_f^{\,2} = 2gh$$

$$KE = \frac{1}{2}m(2gh)$$

$$KE = mgh$$

$$PE = mg(h)$$

$$PE = 0$$

$$TE = PE + KE$$

$$TE = 0 + (mgh)$$

$$TE = mgh$$

Total Energy remains constant

$TE_A = TE_B = TE_C = TE$

However, PE at A is converted to KE at C.

17. Biological system also have energy converting systems:
    - You stand up your seat causes an increase in your gravitational P.E.
    - As PE has increased then as per the law of conservation of energy, energy must be converted from some other type of energy so that you increase your gravitational P.E. (the obvious answer is the chemical energy in what you eat i.e food. The internal energy of food is converted into Chemical Energy that is stored in muscles. Muscles contract and relax and convert this energy into kinetic or gravitational P.E. For example: 100g of ice cream give us 1.05 MJ or 1.05 x 10^6 J of energy.

18. Questions: What type of energy is stored in.
    a) Compressed spring: Elastic potential energy
    b) Moving body: Kinetic Energy
    c) Falling water in a hydroelectric reservoir or Dam: Gravitational P. E.
    d) Hot cup of coffee: Thermal or heat Energy

e) Tides of ocean: Tidal Energy (can be kinetic, potential or both)

f) Air moving west: Wind Energy

g) Current carrying wire: Electrical Energy

Q: 2. Can we create or destroy energy? Energy can neither be created nor destroyed it can only be converted into another form of energy

Q: 3. Is there any work done during conversion of energy? If the energy conversion involves Force then work is done, if it is a thermal exchange without change of volume then work is not done as no force is involved.

19. Energy and power: power can be defined as rate of change of energy.

$$Power = \frac{\text{Energy transfered}}{\text{time taken}} = \frac{E}{t}$$

$$Power = \frac{\text{work done}}{\text{time taken}} = \frac{Fs}{t} = F\frac{s}{t} = Fv$$

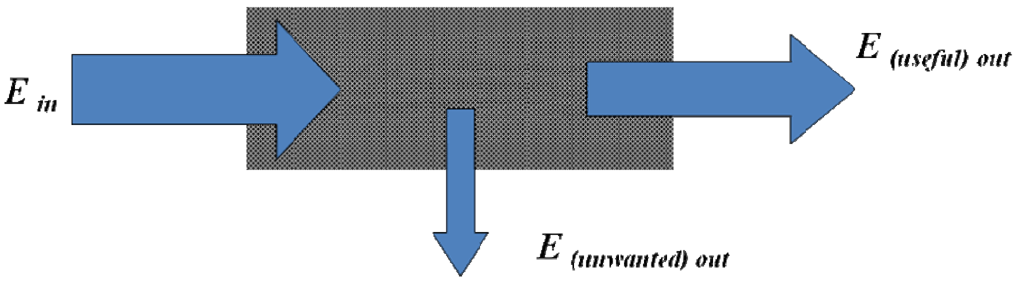
$$Power = Fv = \text{Force applied} \times \text{velocity}$$

Unit of Power is Joules per second or Watt

1 Watt = 1 J s^{-1}

20. Efficiency: useful energy output to the input is called efficiency. Or Fraction of energy of a system, performing useful work, is the efficiency of that system.

$$efficiency\% = \frac{E_{(useful)out}}{E_{in}} \times 100$$



If we multiply and divide the above relation with time then we can define efficiency as the useful power output to the input.

$$efficiency = \frac{E_{(useful)out}}{E_{in}}$$

$$efficiency = \frac{E_{(useful)out}/time}{E_{in}/time}$$

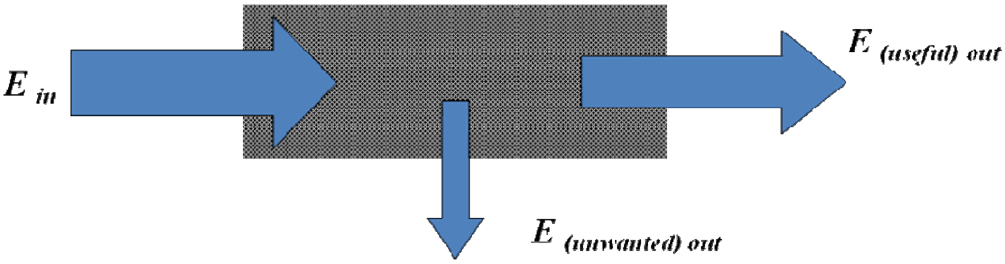
$$efficiency = \frac{Power_{(useful)out}}{Power_{in}}$$

$$efficiency\% = \frac{Power_{(useful)out}}{Power_{in}} \times 100$$

SUMMARY OF LECTURE # 09
ENERGY Power & HEAT

1. Efficiency: useful energy output to the input is called efficiency. Or Fraction of energy of a system, performing useful work, is the efficiency of that system.

$$efficiency\% = \frac{E_{(useful)out}}{E_{in}} \times 100$$



If we multiply and divide the above relation with time then we can define efficiency as the useful power output to the input.

$$efficiency = \frac{E_{(useful)out}}{E_{in}}$$

$$efficiency = \frac{E_{(useful)out}/time}{E_{in}/time}$$

$$efficiency = \frac{Power_{(useful)out}}{Power_{in}}$$

$$efficiency\% = \frac{Power_{(useful)out}}{Power_{in}} \times 100$$

2. Problem: A central heating system provides 250 kJ of energy in shape of hot water circulating in the system. If the amount of gas consumed releases 400 kJ of energy, calculate the efficiency of the system.

Data:

$E_{(in)}$ = 400 kJ

$E_{useful\ (out)}$ = 250 kJ

$$efficiency = \frac{E_{(useful)out}}{E_{in}} \times 100\ \%$$

$$efficiency = \frac{E_{(useful)out}}{E_{in}}$$

$$efficiency = \frac{250,000}{400,000} \times 100$$

$$efficiency = 62.5\%$$

What is the power of a boiler which provides 288 kJ of energy in four minutes? The boiler is run on an electric power input of 2000 Watts - what is its efficiency.

Data:

$P_{(in)} = 2000$ W

$E_{useful\ (out)} = 280{,}000$ J

Time $t = 240$ s

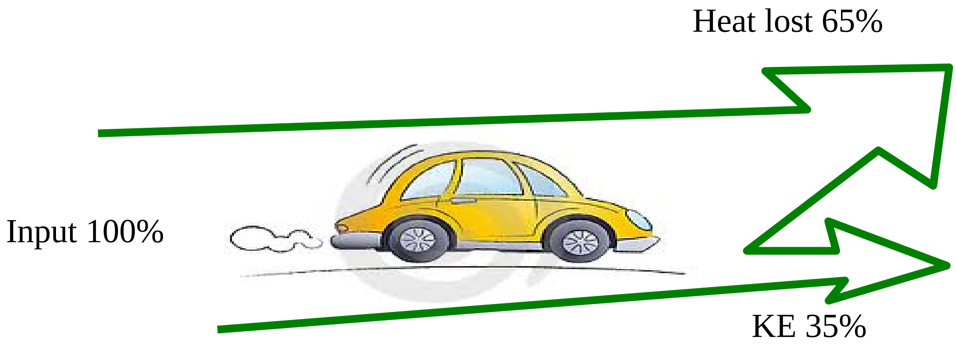
$$P = \frac{E}{t} = \frac{288,000}{240} = 1200W$$

$$efficiency = \frac{p_{(useful)out}}{p_{in}}$$

$$efficiency = \frac{1200}{2000} \times 100$$

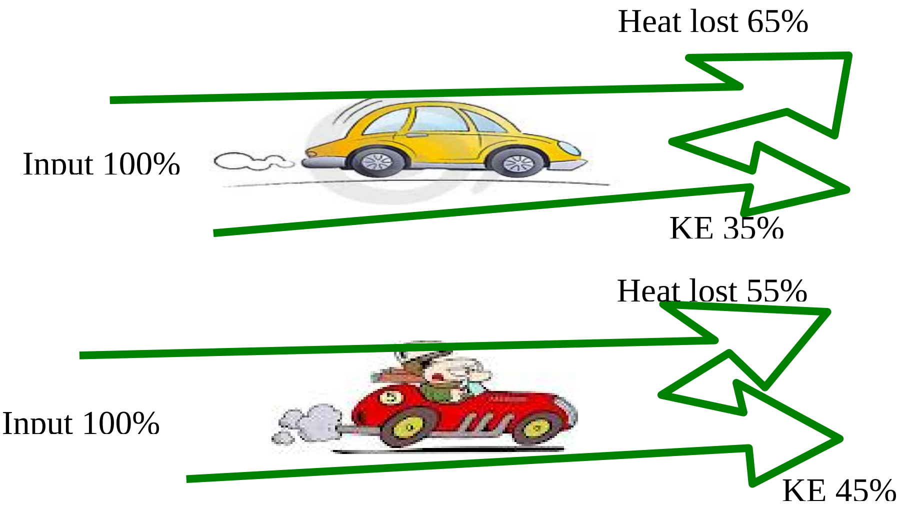
$$efficiency = 60.0\%$$

3. In a car fuel is burnt and a lot of energy is waste in the surroundings in the form of exhaust heat and friction to the ground. A small potion is given to the KE in which we are interesting. Normally a car uses only 35% of its fuel energy to attain the KE whereas 65% is lost as heat to the surroundings – clearly an inefficient use.



Car is a useful vehicle because it takes people and luggage's from one place to another place, therefore, we accept this usages. We accept this wastage because as a consequence we move from one point to another point very effectively.

4. Why do we need to increase efficiency? From the figure car A uses only 35% of its energy as KE and 65 % as wastage while ca B uses 45% energy as KE and 55% as Wastage so it has a higher speed. Sometimes we have to speed up the car, we require the efficiency. However it does compromise on other things for example racing cars are highly efficient because they have to compete with each other and weight and fuel of the car is limited. The more efficient is the car, the faster it will travel. A small fraction of the energy efficiency will result an increase in the speed.

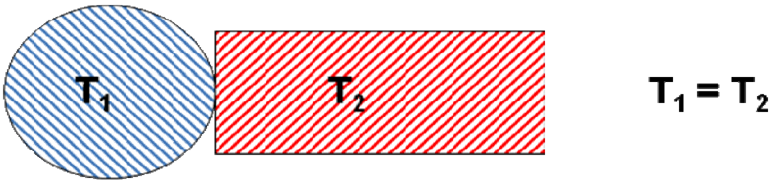


5. Heat: Heat is a form of energy that transfers (flows) from one body (at a higher temp) to the other body (at a lower temp). A body consists of particles in different state of motion and bonding – because of which the body can possesses all types of energies, translational, rotational, vibrational or random energies. Sum of these energies is manifest as ‘Internal energy’ or HEAT of that body.

   Unit of Heat: As heat is a form of energy therefore, its unit is also same as that of energy i.e. In the S.I system the unit of Heat is “Joule” or ‘Newton meter.
6. Difference: Temperature of a body refers to its degree of hotness or coldness and Heat of a body refers to the amount of thermal energy that flows from that body.
7. We determine if an object is hot or cold from the amount of heat that it gives out (or draws away), however, as hotness is a relative term we need to define a system which tells us which object is hotter.
8. Law of Heat Exchange: Two body at different temperatures interact with each other in such a way that one body loses and other gains heat. Heat like any energy flows from a higher (hotter) to a lower (colder) levels. Net heat exchange, in a system, is zero as is required by the law of conservation of energy. Two bodies which are in thermal equilibrium cannot have a net heat exchange between them.
9. When heat is added to a system it, what happens to the system:
   a) Gains energy.

b) Increases its internal energy (Rotational, translational, vibration and random energies)
c) Appears as work done on system
d) Usually result in expansion of matter.

10. When heat is taken out of a system it, what happens to the system:
    a) Loses energy.
    b) Decreases its internal energy (Rotational, translational, vibration and random energies)
    c) Appears as work done by the system.
    d) Usually result in contraction of matter.
11. Thermometry: The branch of Physics which deals with the measurement of temperature. Thermometer: A device used for the measurement of temperature. SI Unit of Temperature is "Kelvin". It is a fundamental or base quantity and the symbol is K.
12. Principle: Most practical thermometers (e.g. laboratory, clinical) are based on the physical property of most solids/liquids that they expand (e.g. metals, alcohol, mercury) on heating. A Thermometer is used for the measurement of temperature of objects it is in thermal equilibrium with. Thermal equilibrium means, it is the state when two bodies, in contact, attain the same temperature.



A contact type thermometer can only measure the temperature of an object it is in thermal equilibrium with.

13. A thermometer is a device which uses a physical property that changes linearly with temperature, to determine the temperature of a body. There are different physical properties which can be used to create a thermometer. It does not necessarily to have be linear but it has to be unique. In other words one temperature should give one value of that particular property.

Physical property that changes with temperature	Thermometer Type
Volume of a fixed mass of liquid	Liquid–in-glass

Pressure of a fixed mass of gas	Constant volume gas
Resistance of a metal	Resistance
Voltage (e.m.f)	Thermocouple
Length of a metal	Spiral metallic gauge
Wavelength of Light	Pyrometer

14. Temperature Scales: in order to thermometer work, what required is:
    a) a substance which has a physical property that changes continuously with temperature
    b) two fixed points and a scale between them.

Reference scales which agree at certain fixed points or positions are used to measure temperature. There are three temperature scales: the Celsius or centigrade scale, the Fahrenheit scale, the Kelvin scale. Reference or Fixed points are physical states, the temperature of which is fixed by definition

   i. steam point i.e. boiling point of water at standard pressure
   ii. ice point i.e. freezing point of water at standard pressure

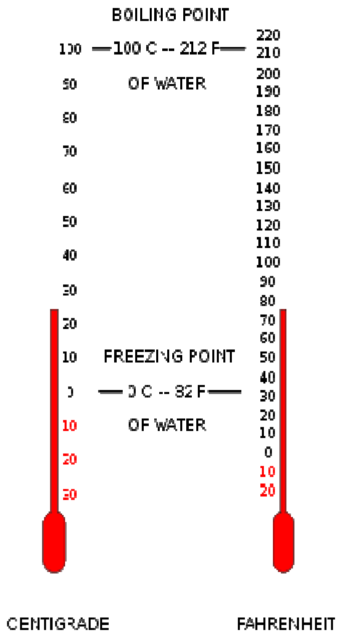
Thermometers which are calibrated to known fixed points (e.g. 0 and 100°C) will be accurate (i.e. will give a true reading) at those points.

The precision or resolution of a thermometer is simply to what fraction of a degree it is possible to make a reading.

For high temperature work it may only be possible to measure to the nearest 10°C or more.

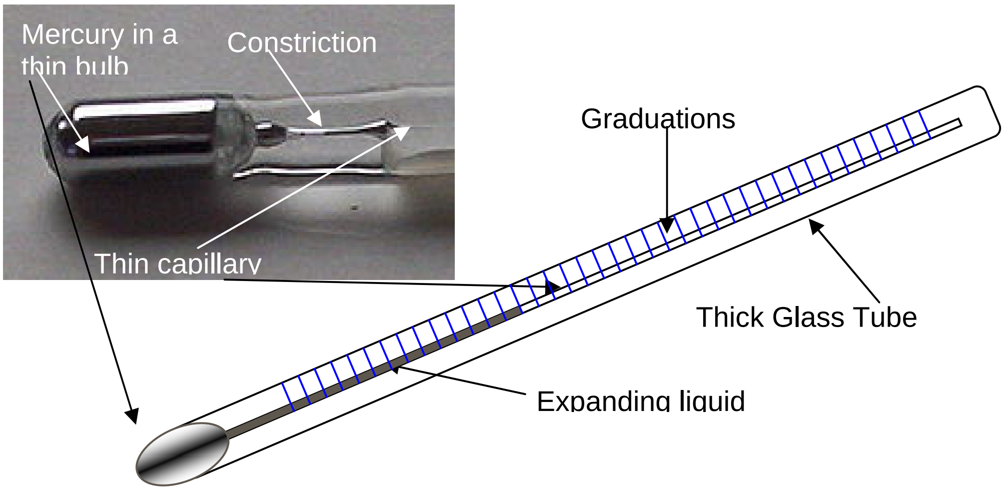
Laboratory liquid-in-glass, clinical thermometers and many electronic thermometers are usually readable to 0.1°C.

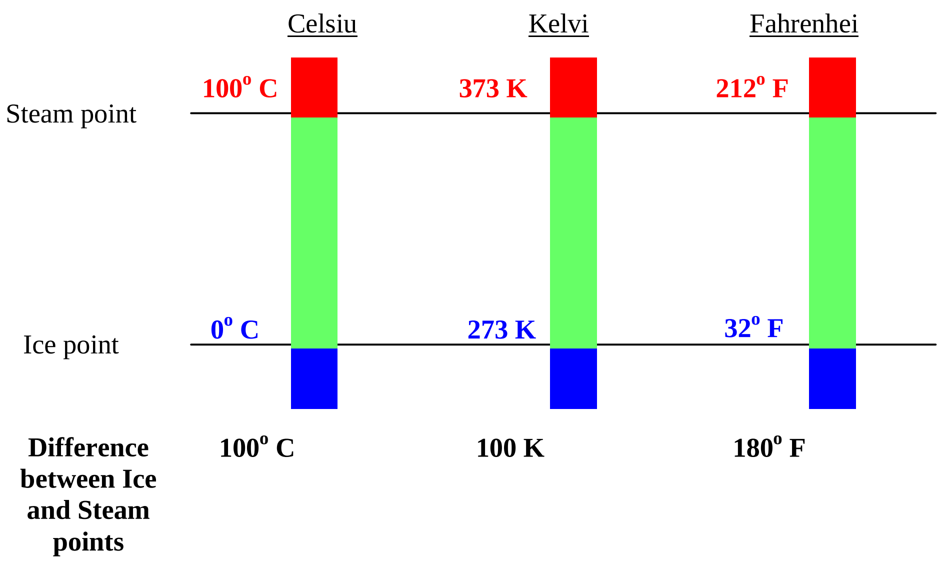
Special instruments can give readings to one thousandth of a degree. However, this precision does not mean the reading is true or accurate.



15. For many purposes reproducibility is important. That is, does the same thermometer give the same reading for the same temperature (or do replacements or multiple thermometers give the same reading)? Reproducible temperature measurement means that comparisons are valid in scientific experiments and industrial processes are consistent

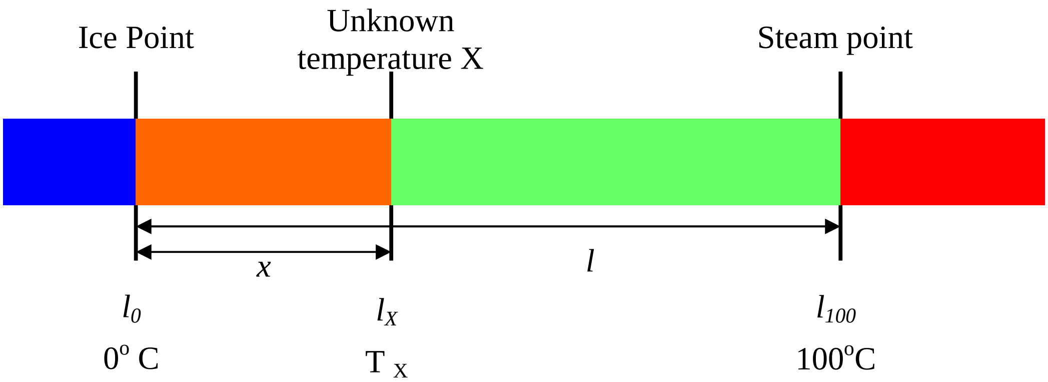
16. Working of Liquid in Glass thermometer: mercury is filled in a bulb of a very thin glass tube. Glass is an insulator and therefore heat has to be passed through the glass bulb into the mercury which is going to then expand. Here is a small thin construction which restricts the mercury from flowing into the capillary unless it expands or it is forced to going back. Capillary is enclosed in a thick glass tube because we do not want that the liquid loses heat and give us false reading.





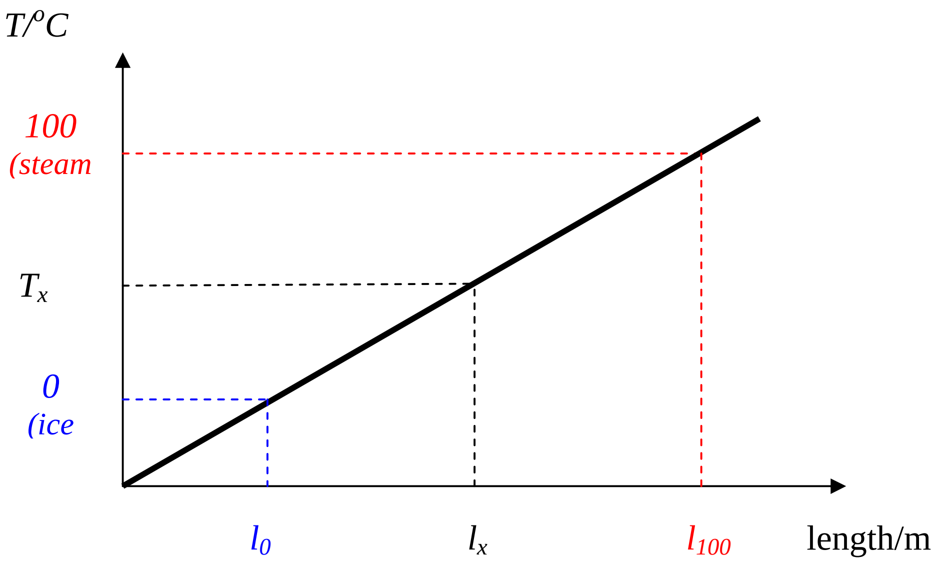
These scales were developed in different times due to different requirements. First, Fahrenheit scale was developed then Celsius scale which is more practical and more commonly because it breaks up into 100 divisions easily. it is more manageable and more understandable.

Ice point and steam point on Celsius scale is 0^o C and 100^o C respectively. There is a difference of 100 Division. Ice point and steam point on Kelvin scale is 0 K and 100 K respectively. There is also a difference of 100 divisions. Achange in temperature of one degree Celsius is the same as a change of one Kelvin. Ice point and steam point on Fahrenheit scale is 32^o F and 212^o F respectively. There is difference of 180^o F between the ice point and steam point.



Basically this diagrams shows how does a thermometer work. There are two points shown in the figure which are ice and steam points represented by l_0 and l_{100} respectively. The unknown temperature might be at point X. A change of property is length corresponds to 1 degree changes in Celsius or One hundredth of the change in property (length) between the Ice point and the steam point corresponds to one degree Celsius. If we plotting this on a graph, we are assuming that the property is changing continuously between the ice and steam points. So we would have a straight line on the graph between the ice and steam points or between l_0 and l_{100} . l_X basically the unknown temperature which is to be measured.

$$T_x / ^o C = \frac{l_{(x)} - l_{(0)}}{l_{(100)} - l_{(0)}} \times 100$$



17. Problem: In an unmarked thermometer it was found the length at the ice point was 5 cm and at the steam point it was 25 cm. Find unknown temperatures when the length was (i) 14 cm and (ii) 3 cm.

Data

l_0 = 5 cm

l_{100} = 25 cm

l_{x1} = 14 cm

l_{x2} = 3 cm

$$Tx_1 /^o C = \frac{l_{(x)} - l_{(0)}}{l_{(100)} - l_{(0)}} \times 100$$

$$Tx_1 /^o C = \frac{14-5}{25-5} \times 100$$

$$Tx_1 /^o C = 45^o C$$

$$Tx_2 /^o C = \frac{l_{(x)} - l_{(0)}}{l_{(100)} - l_{(0)}} \times 100$$

$$Tx_2 /^o C = \frac{3-5}{25-5} \times 100$$

$$Tx_2 /^o C = -10^o C$$

18. Inter conversion from one scale to other:

$$\frac{(\text{Temp on scale A}) - (\text{ice point on scale A})}{\text{number of divisions on scale A}} = \frac{(\text{Temp on scale B}) - (\text{ice point on scale B})}{\text{number of divisions on scale B}}$$

Inter conversion from Fahrenheit scale to Celsius scale

$$\frac{T_C - 0}{100} = \frac{T_F - 32}{180}$$

$$T_C = \frac{100}{180} \times (T_F - 32)$$

$$T_C = \frac{5}{9} \times (T_F - 32) \qquad \text{OR} \qquad T_F = \frac{9}{5} \times T_C + 32$$

Inter conversion from Kelvin scale to Fahrenheit scale

$$\frac{T_K - 273}{100} = \frac{T_F - 32}{180}$$

$$T_K = \frac{100}{180} \times (T_F - 32) + 273$$

$$T_K = \frac{5}{9} \times (T_F - 32) + 273 \quad \text{or} \quad T_F = \frac{9}{5} \times (T_K - 273) + 32$$

Inter conversion from Kelvin scale to Celsius scale

$$\frac{T_K - 273}{100} = \frac{T_C - 0}{100}$$

$$T_K = \frac{100}{100} \times (T_C - 0) + 273$$

$$T_K = T_C + 273 \quad \text{or} \quad T_C = T_K - 273$$

SUMMARY OF LECTURE # 10
HEAT-II

1. Before we begin – we shall do a couple of numerical to reinforce the methodology of changing temperature scales

Problem 1. The hottest place on Earth as of 2005 is in the Lut Desert in Iran at 70.7 degrees Celsius. This inviting region is abiotic – meaning without life; not even bacteria have been found. The coldest natural temperature ever recorded on Earth was −89.2 °C at the Russian Vostok Station in Antarctica on 21 July 1983. Convert these temperatures to their Fahrenheit and Kelvin equivalent

Data:

T Hot = 70.7^o C

T Cold = -89.2^o C

Celsius to Fahrenheit

$$T_C = \frac{5}{9}\times(T_F - 32) \qquad T_{F(Hot)} = \frac{9}{5}\times 70.7 + 32 = 159.3^o F$$

$$T_F = \frac{9}{5}\times T_C + 32 \qquad T_{F(Cold)} = \frac{9}{5}\times(-89.2) + 32 = -128.6^o F$$

Celsius to Kelvin

$$T_C = (T_K - 273) \qquad T_{K(Hot)} = 70.7 + 273 = 343.7K$$

$$T_{K(Cold)} = (-89.2) + 273 = 183.8K$$

Problem 2. Find the temperature at which the Celsius and Fahrenheit scales have the same value

Data:

TC = TF =?

$$\frac{T_C - 0}{100} = \frac{T_F - 32}{180}$$

$$T_C = \frac{100}{180}\times(T_F - 32)$$

$$T_C = \frac{5}{9}\times(T_F - 32)$$

$$T_C = \frac{5}{9}\times(T_F - 32)$$

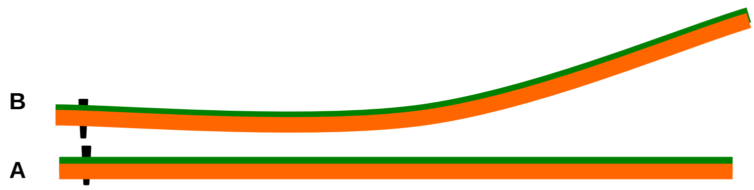
$$T_C = \frac{5}{9}\times(T_C - 32)$$

$$9T_C = 5T_C - 32\times 5$$

$$4T_C = -160$$

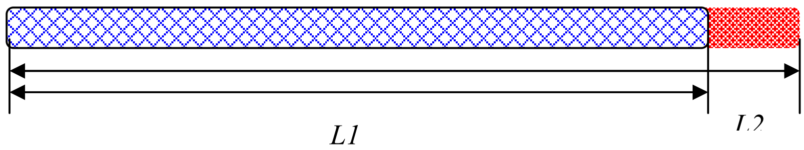
$$T_C = -40^o C = -40^o F = T_F$$

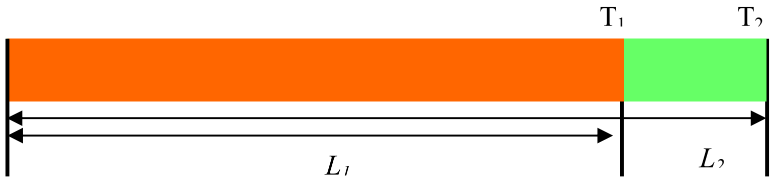
2. Thermal Expansion in Matter: Heat when added to matter, normally causes expansion in all states (Solid, Liquid, Gas). That is, all materials, when heated, normally undergo physical expansion, this expansion is termed as Thermal expansion. Different materials will expand by different amounts for the same rise in temperature. There are some materials which contract on heating – these are said to have anomalous behaviour – water near its freezing point has such behaviour. As a rule gases expand more than liquids and liquids expand more than solids. The fact that different materials expand by different amounts for the same rise in temperature is used in many applications. The most common being a thermostat.
3. Thermal Expansion in Solids: A Solid Thermostat. Two metal strips having different expansion rates are welded together and riveted at one end. On heating the larger expansion of one metal forces the system to bend – this is employed in many devices, like a thermostat, where the force of the bent strips is used to make or break an electrical contact.



Linear Expansion in Solids: The expansion in one dimension is known as linear expansion. Materials have three dimensions then how can we say material is expanding in one dimension only? Take a thin long rod (length 50 cm) of diameter 1 cm^2 and heating the rod. After heating its length increases by 1 cm and diameter increases 1/50 cm which is negligible as compared with length so this is constrained to expand in one direction only. This expansion will depend upon:

(a) original length of the thin rod
(b) Change in temperature
(c) Nature of the material of the rod





ΔL = Change in length = L_2 - L_1

L_2 = Length after Linear expansion.

L_1 = Original Length

α = Coefficient of linear expansion.

$$\Delta L = L_2 - L_1$$
$$\Delta T = T_2 - T_1$$

$$L_2 - L_1 \propto L_1$$
$$L_2 - L_1 \propto T_2 - T_1$$
$$(L_2 - L_1) \propto L_1 (T_2 - T_1)$$

$$(L_2 - L_1) = \alpha L_1 (T_2 - T_1)$$
$$L_2 = \alpha L_1 (T_2 - T_1) + L_1$$
$$L_2 = L_1 [1 + \alpha (T_2 - T_1)]$$
$$\alpha = \frac{(L_2 - L_1)}{L_1 (T_2 - T_1)}$$

$L_2 - L_1$ is very small value for 1 K change in temperature, so α is very small value. The unit of α is K^{-1}.

4. Volume Expansion in Solids: The expansion in three dimensions is known as volume expansion. This expansion will depend upon:

   (a) original volume

   (b) Change in temperature

   (c) Nature of the material.

ΔV = Change in volume = V_2 - V_1

V_2 = volume after expansion.

V_1 = Original volume

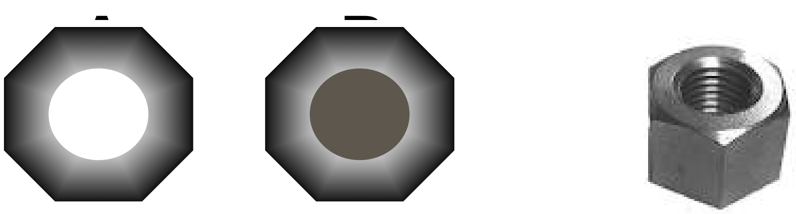
β = Co-efficient of volume expansion

$$\Delta V = V_2 - V_1$$
$$\Delta T = T_2 - T_1$$

$$V_1 \propto V_2 - V_1$$
$$V_2 - V_1 \propto T_2 - T_1$$

$$\left(V_2 - V_1\right) \propto V_1\left(T_2 - T_1\right)$$
$$\left(V_2 - V_1\right) = \beta V_1\left(T_2 - T_1\right)$$
$$V_2 = \beta V_1\left(T_2 - T_1\right) + V_1$$
$$V_2 = V_1\left[1 + \beta\left(T_2 - T_1\right)\right]$$
$$\beta = \frac{\left(V_2 - V_1\right)}{V_1\left(T_2 - T_1\right)}$$

5. The figure shows a metallic nut – a metal piece with a hole in it. When the nut is heated – it expands. What happens to the size of the hole?
   a) Does the hole expand,
   b) Does the hole contract, or
   c) Does the hole remains the same



The Hole has to expand as the spacing between atoms increases on heating and it will expand at the same rate as the nut.

This is illustrated by figure B, where the hole is replaced by a bolt of the same material, (or we can have a nut without a hole).

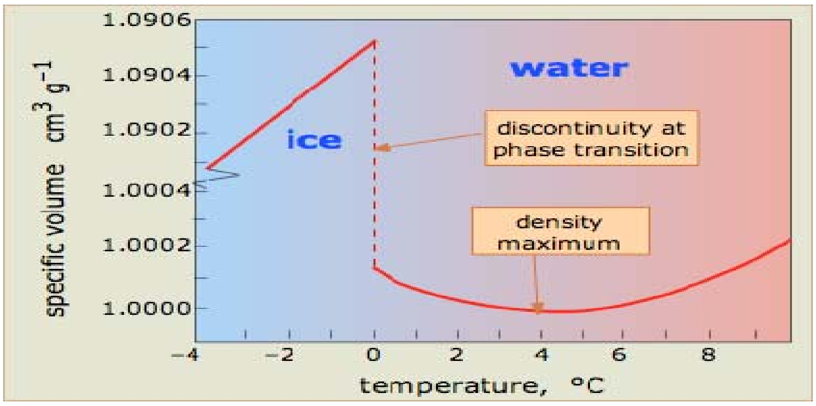
Now if the hole remained the same or contracted the bolt (or material where the hole is) would not have room to expand, which it should, as it is made of the same material as the nut.

6. Expansion of liquids: Unlike solids, liquids and gases require a container to give them shape therefore, whenever we are considering expansion of fluids we have to take into consideration the expansion of the container. We do know that liquids expand more than solids therefore, when a liquid in a container is heated from outside, like in a thermometer, the container expands first lowering the liquid level and only when the heat makes the liquid expand its level starts to rise. On the other hand, if heating is from within the liquid in the container, like in an electric kettle the level rises immediately, though its rate of increase falls as the container also starts to expand, though at a smaller rate.
7. There are two types of expansion in liquids. a) Real expansion is observed expansion after the container has expanded b) apparent expansion is the expansion of the Liquid.

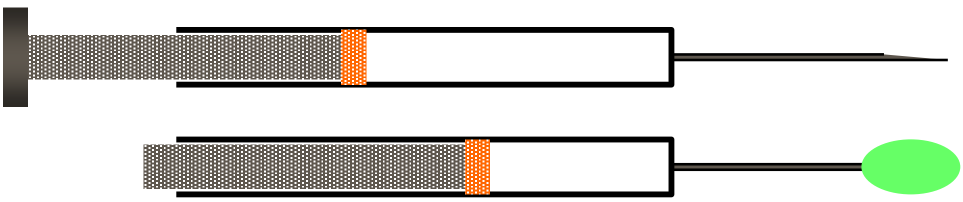
   Real Expansion = Apparent Expansion + Expansion in container

   $$\gamma_{\text{real}} = \gamma_{\text{container}} + \gamma_{\text{liquid}}$$

   However, we can make liquids expand linearly if they are forced to expand in a space which does not expand (or expands negligibly) as compared to the liquid for the same temperature range, e.g. mercury, and alcohol expand appreciably more than glass for the same range of temperature so we use this to our advantage in liquid-in-glass thermometers.
8. Anomalous Expansion of Water: there are some materials which do not expand on heating. These materials are given a special name anomalous material. In other words they behave different from what is normal. Water is one such a material. It is the unusual expansion of water. When water is heated, from 0ºC to 4ºC, it contracts instead of expanding. In other words its density increased as the temperature increases between that point which is very useful and nature has utilized this anomalous behaviour of water for its benefit. Unusual means when you cooling something it contract rather than expands but when water is cooled from 4ºC to 0ºC it expands. When water is heated from 0ºC to 4ºC, it contracts. Therefore, it is an anomalous behaviour. This is an unusual behaviour and so termed as anomalous i.e. unusual because on heating water contracts rather than normal expansion as would be expected and vice versa.



9. Effects of anomalous behaviour:
   a) Ice floats on water: Because material expands when it is cooled, its density is to be decreased as mass remains the same and it occupies a larger volume. So it become denser, therefore, rises. Once the water is concerted into ice it floats on the surface of the water due to the decrease in it density. Temp of water below ice is 4ºC because ice is an insulator. Aquatic or marine life survives in winter.
   b) Stones and even mountains crack due to expansion of water in crevices.
   c) Water pipes burst in winter.
10. Expansion in Gases: like liquids, gases also require a container to give them shape therefore, whatever has been said about liquids is also true for gases – both being considered as fluids (which flow). Gases however, can be restrained in containers which have no room for expansion and they can be compressed (their volume can be decreased). For example take a syringe and just push and pull the gas out. If we close the end of the syringe with some material and apply pressure. The plunger is going upto some extent and then it stops. We have to apply larger amount of force to make the plunger move further. Because we apply a lerger force, so we compress gases. The expansion in gases is not linear as in solids and liquids. for expansion of gases, we use different relationships.

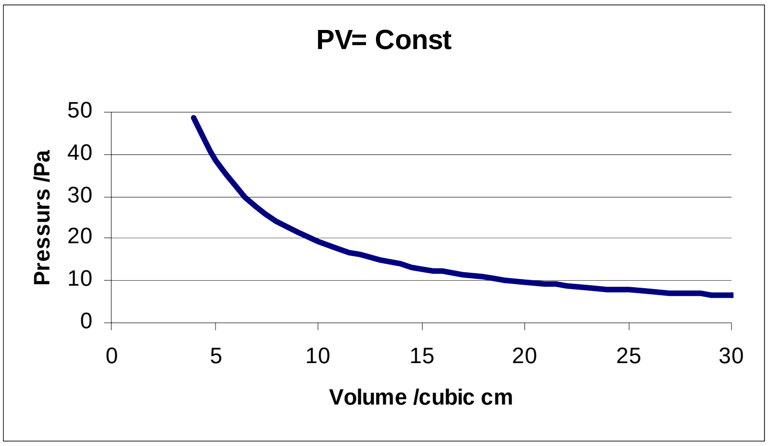


11. Boyles Law: for a given mass of a gas, volume V and pressure P are inversely proportional to each other provided the temperature does not change.

P = Pressure of Gas

V = Volume of gas

$$PV = \text{constant}$$
$$P_1V_1 = \text{constant}$$
$$P_2V_2 = \text{constant}$$
$$P_1V_1 = P_2V_2$$



Two conditions that mass of gas and temperature are kept constant. We say temperature does not change, means when a gas is compressed some heating effect takes place due to friction and compression of molecules. So we have to wait for certain period of time for that heat to be dissipated in order o satisfied the Boyles law.

12. Application of Boyle's law: A cylinder contains 1500 cm3 of a gas at a pressure of 1.5x105 Pa. If this gas is compressed to 250 cm3 find the new pressure assuming the temperature has not changed

Data

P1 = 1.5x105 Pa

V1 = 1500 cm3, V2 = 250 cm3

P2 = ?

$$P_1V_1 = P_2V_2$$
$$1.5\times10^5\times1500 = P_2\times250$$
$$P_2 = \frac{1.5\times10^5\times1500}{250}$$
$$P_2 = 9.0\times10^5\,Pa$$

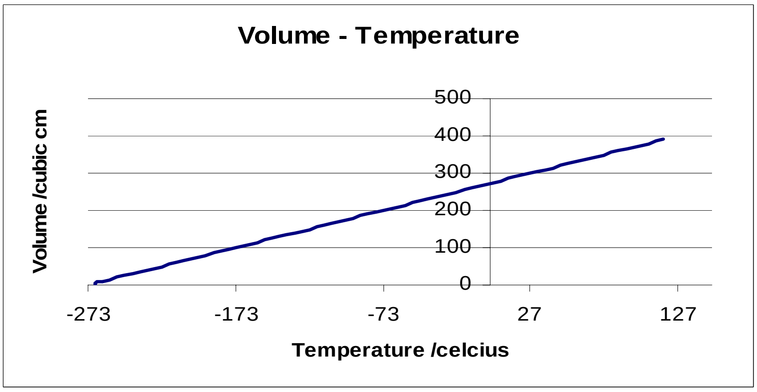
13. Charles's Law: Volume of a fixed mass of any gas and its temperature are directly proportional to each other provided the pressure is kept constant. The mass of gas (number of moles) and pressure are kept constant.

V = Volume of gas

T = Temperature of gas

$$\frac{V}{T} = \text{constant}$$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$



Charles' further added that if the line continuously expanding in the negative temperature range the line would meat the temperature axis at -273 ºC.

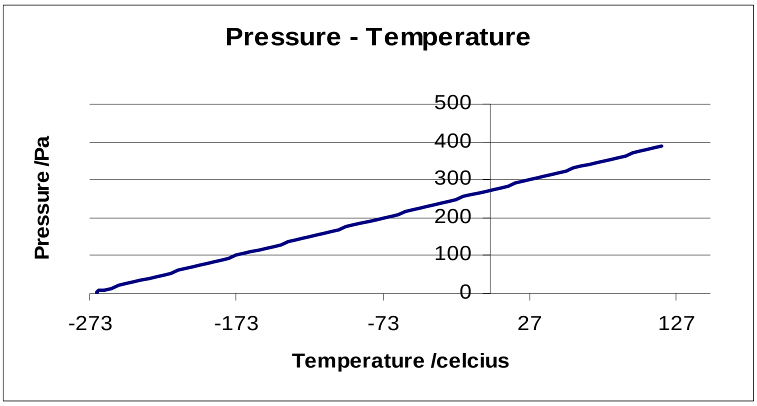
14. Concept of Absolute zero: Pressure law: Pressure of a fixed mass of any gas and its temperature are directly proportional to each other provided the pressure is kept constant. The mass of gas (number of moles) and volume are kept constant.

P = Pressure of gas

T = Temperature of gas

$$\frac{P}{T} = \text{constant}$$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$



Here the line also meets the temperature axis at -273 ºC which gives the concept of absolute zero. -273 ºC is a temperatures at which both Charles law and pressure law ultimately have either volume equal to zero or pressure become zero. That is why this temperature is given the name as absolute zero. There is no temperature below this because if we expand the line below this temperature then we either have the negative volume or pressure which is not possible.

15. Application of Charles's law: The volume of a gas in a container is 2.5 m3. What would be the volume this gas would occupy if its temperature is increased by a factor of three? Suggest a possible practical usage of this effect.

Data

T1 = T /K

T2 = 3T /K

V1 = 2.5 m3

V2 = ? m3

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\frac{2.5}{T} = \frac{V_2}{3T}$$

$$V_2 = \frac{2.5}{T} \times 3T$$

$$V_2 = 7.5\ m^3$$

16. Avogadro's Law: the three gas laws can be combined in Avogadro's law

$$\frac{PV}{T} = \text{constant}$$

The mass of gas (number of moles) is kept constant

V = Volume of gas
T = Temperature of gas
P = Pressure of gas

17. Ideal Gas Equation: From Avogadro's laws

$PV = nRT$

V = Volume of gas

T = Temperature of gas

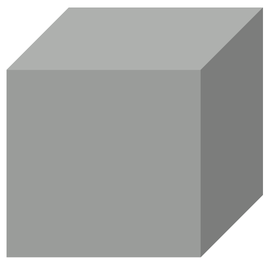
P = Pressure of gas

n = number of moles (mass)

R = *Rydberg* gas *constant*

In all gas laws temperature (T) is measured on the Absolute temperature scale i.e. in Kelvin. This equation is valid for ideal gases only. We use real gas and few gases are close but still not perfectly ideal gases. Noble gases like helium are the nearest approximation of ideal gases. Ideal gas is that which obeys gas laws.

18. Question 1. What is the relationship b/w linear and volumetric expansion? Linear expansion takes place in one direction only whereas volume expansion is in three directions. If we have a cube of material of length *l*, then



linear expansion would be $l + \Delta l$, Each side of the cube is going to increase by this factor Δl, Volume of new cube is: $(l + \Delta l)^3$

It is going to be a cubic relationship. However the coefficient relationship, α:β is approximately 1:3

19. Question 2. Why a little sag is left in the wires when used in summer? During winter wires will contract due to decrease in temperature and become taut – if sag is not left then the wires may snap due to this contraction.
20. Question 3. What do you mean by ideal real gas? Any real gas which follows the gas laws in the ideal form are ideal gases.

SUMMARY OF LECTURE # 11
HEAT-III

1. Heat capacity: it is the amount of heat absorbed or released by a mass of substance to rise or lower its temperature by one Kelvin.
2. Specific Heat Capacity: it is the amount of heat absorbed or released by a one Kg mass of substance to rise or lower its temperature by one Kelvin. The quantity of heat depends upon the mass and change in temperature.

   m = mass

   ΔT = Change in Temp

   c = Specific Heat capacity

   ΔQ = Heat Energy

   $$\Delta Q \propto m$$
   $$\Delta Q \propto \Delta T$$
   $$\Delta Q \propto m \Delta T$$
   $$\Delta Q = m c \Delta T$$
   $$c = \frac{\Delta Q}{m \Delta T}$$

   Unit of specific heat capacity is $J\,kg^{-1}K^{-1}$
3. Measuring of Specific heat capacity: mass can be measured by any ordinary lab balance or electronic balance. Change in temperature can be measured by thermometer. Heat energy can be measured by power meter or Joule meter and specific heat capacity can be calculated. For measuring the specific heat capacity, remember that liquids can not exist in free space, they requires a container. For measuring the specific heat capacity of liquid, when liquid is in container, it should also kept in mind that some energy will also absorb by the container and the temperature of the container will rise. Measuring the mass and change in temperature of the liquid which is in the container and the heat energy of the system. So measures the specific heat capacity of the liquid. In this case we should know the heat capacity of the container.

   Mass = $m_2 - m_1$ i.e. total mass (liquid + container) – mass of empty container

   $\Delta T = T_2 - T_1$ i.e. Temperature rise for a given time

4. Problem: 100 g of water at 15 ^oC is heated to a temperature of 65 ^oC. If 21,000 J of energy were provided, find the specific heat capacity of water.

   Data:

   m = 100g = 0.1 kg

   $\Delta T = 273+65 - (273+15) = 50$ K

   c = Specific Heat capacity

   ΔQ = Heat Energy = 21,000 J

$$c = \frac{\Delta Q}{m\Delta T}$$

$$c = \frac{21,000}{0.1 \times 50} = 4,200 \frac{J}{kgK}$$

5. Measuring of Specific heat capacity by Method of mixtures: Here we have to find the specific heat capacity of liquid by the method of mixture. This method involves two bodies the liquid which is cold and a hot solid body of known mass and known specific heat capacity.

Mass = m_1	mass of hot body
Mass = m_2	total mass (liquid + container) – mass of empty container
$\Delta T_{(fall)} = T_1 - T_x$	i.e. Temperature fall of the body
$\Delta T_{(rise)} = T_x - T_2$	i.e. Temperature rise of the liquid
ΔQ Energy supplied	$\Delta Q = m_1 \times c_1 \times \Delta T_{(fall)}$
	$\Delta Q = m_2 \times c_2 \times \Delta T_{(rise)}$

   According to the law of heat exchange:

   Amount of heat gained by cold body = Amount of heat lost by hot body

   Or

   Heat gained = Heat lost

   $m_2 \times c_2 \times \Delta T_{(rise)} = m_1 \times c_1 \times \Delta T_{(fall)}$

   However in case of liquids the heat energy required by container has also to be taken into account.

6. A calorimeter of mass 0.15 kg, having heat capacity of 400 $Jkg^{-1}K^{-1}$ contains 0.10 kg of water at 15 ^oC. A metal piece of mass 0.25 kg heated to 100 ^oC is transferred to the calorimeter. The final temperature is recorded at 40 ^oC. Calculate the specific heat capacity of the metal.

   mass of calorimeter m_1= 0.25 kg, mass of water m_2= 0.10 kg

   $T_1 = 15\ ^oC = 15+273 = 288$ K; $T_2 = 40\ ^oC = 40+273 = 313$ K

   $\Delta T = (313 - 288) = 25$ K

c_1 (calorimeter) = 400 $Jkg^{-1}K^{-1}$

c_2 (water) = 4,200 $Jkg^{-1}K^{-1}$

mass of metal m_3= 0.25 kg

T_3 = 100 ^oC = 100+273 = 373 K; T2 = 40 ^oC = 40+273 = 313 K

Δ T = (373 - 313) = 60 K

c_3 (metal) =? $Jkg^{-1}K^{-1}$

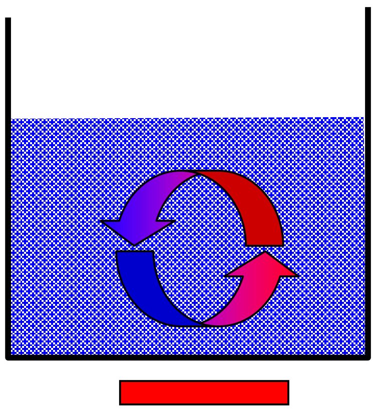
$$m_1c_1\Delta T + m_2c_2\Delta T = m_3c_3\Delta T$$
$$0.25\times 400\times 25 + 0.1\times 4200\times 25 = 0.25\times c_3\times 60$$
$$2,500 + 10,500 = 15c_3$$
$$13,000 = 15c_3$$
$$c_3 = 867\,Jkg^{-1}K^{-1}$$

7. Transmission of Heat: Heat (energy) transfer from one body to another only if there is a difference in temperature. There are three modes of heat transfer:

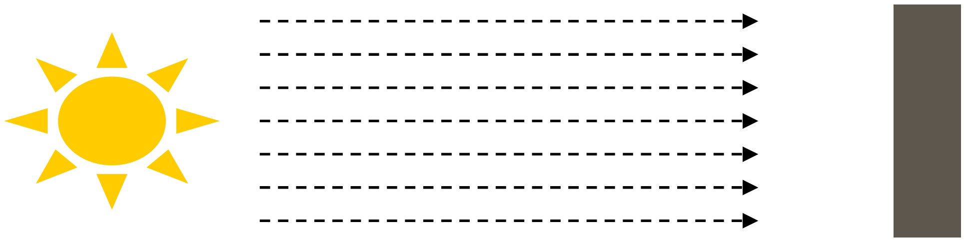
a) Conduction: heat transfer through contact. Two come in contact, because of difference in temperature hot body lose energy and cold body gain energy.

A medium is required to transfer heat from one body to another. Heat travels from hot end to cold end via the vibration of particles. The vibration is transferred from particle to particle until it reached to the cold end.

b) Convection: Transfer of heat through actual movement of particles. A medium is necessary. Convection is normally takes place in fluids. When a liquid is heated, it expands and its density decreases. It becomes lighter and it rises. Cold liquid at the top is denser so it sinks. It is a continuous process.



c) Radiation: Heat transfer through electromagnetic radiation. Electromagnetic radiations can travel through vacuum so medium is not necessary. For example ligt reaches us from sun.



8. Factors Effecting The Conductivity: conductivity depends on the following factors:

    a) Cross sectional area of the conductor
    b) Length of the conductor
    c) Material of the conductor.
    d) Temperature difference between the ends
    e) Time for which the conductor remains in contact

Cross sectional area	$\Delta Q \propto A$
Length	$\Delta Q \propto 1/L$ or L-1
Difference in Temperature	$\Delta Q \Delta \propto T$
Time	$\Delta Q \propto t$

$$\Delta Q \propto \frac{A \Delta T t}{L}$$

$$\Delta Q = \frac{kA(T_2 - T_1)t}{L}$$

$$k = \frac{\Delta Q L}{A(T_2 - T_1)t}$$

If L = 1 m, t = 1 s; ΔT=1 K and A= 1 m^2 then k = ΔQ.

k is coefficient of thermal conductivity of the material i.e. energy transferred per second through a cross section of one square meter of a conductor of length one meter and placed at a temperature difference of 1K

9. Problem: A glass window in the outer wall has a surface area of 4 m^2. The temperature outside the room is 7 ^oC, whereas the inside of the room is at 22 ^oC.

Calculate the amount of heat lost every second if the glass is 10 mm thick (k for glass is 0.8)

Data

A= $4m^2$

L= 10 mm = $1x10^{-2}$ m

ΔT= 22+273-(7+273) = 15K

k = 0.8 $Jm^{-1}K^{-1-1}$

ΔQ=?

$$\Delta Q = \frac{kA(T_2 - T_1)t}{L}$$

$$\Delta Q = \frac{0.8 \times 4 \times 15 \times 1}{10 \times 10^{-3}}$$

$$\Delta Q = 4,800\,J$$

10. Application of Conduction, Convection, Radiation:

a) Conduction

i. Conduction makes it possible to cook food

ii. Conduction property of substance make it possible to use them as a conductor or insulator (metals, air, fur, lagging etc)

b) Convection

i. Weather systems including blowing wind are a result of convection (sea and land breezes)

ii. Domestic hot water supply (Geysers) works using convection

iii. Room Ventilators use convection

c) Radiation

i. Heat and light of sun reaches us by radiation

ii. Body can be scanned by radiation

iii. X-Ray is application of radiation

iv. Radioactive elements emit radiation

11. Latent Heat: It is the amount of heat required to change the state of a substance of a 1 kg mass. The SI unit of latent heat is joule/ kg.

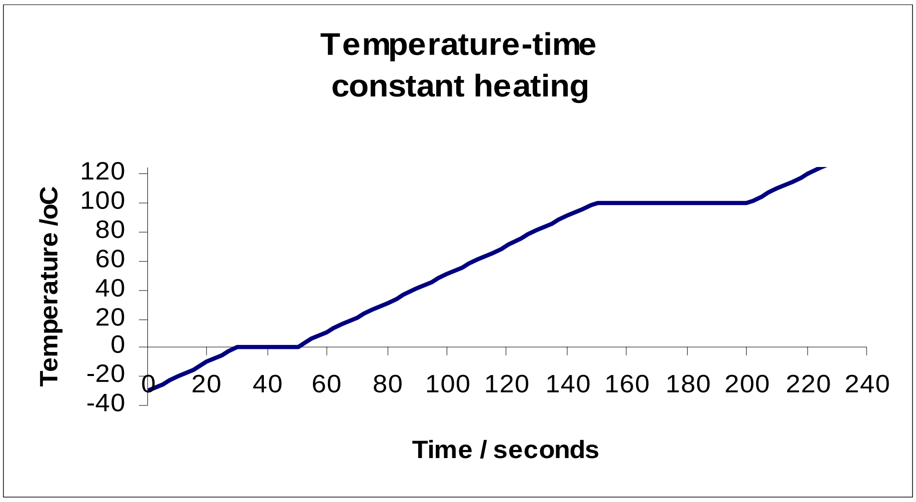
Latent Heat of Fusion: It is the quantity of heat needed to convert 1kg of solid state of a substance to the liquid state without any change in its temperature (at its melting point). The SI unit of latent heat is joule/ kg. Latent heat of fusion of ice = 336,000 or 3.36×10^5 Jkg^{-1}. It should be noted that the temperature of the solid will not rise (or remain same) until all the solid is melted or is converted into liquid state. Now, we are understood what a latent heat is.

Let us take ice and record its temperature; suppose it is -10ºC. It is placed in a beaker and heated at a constant rate. A thermometer inserted in the beaker indicates the temperature. We will observe that initially the temperature of the thermometer rises up to 0ºC and then although heat is constantly being added to the system there will be no increase in temperature for a certain passage of time. Where does the added heat go? The answer to this question is the amount of heat added to the ice is used to overcome the attractive forces between the molecules of ice. Those molecules which gain sufficient energy break their bonds within the solid and convert into a liquid state.

Continue heating at a constant rate. We will observe that the temperature of the thermometer starts to rise again (indicating that all ice has converted into water) and it rises up to 100ºC and again, although heat is constantly being added to the system, there will be no further increase in temperature for a certain passage of time. Again now where does the added heat go? The answer is the amount of heat added to the water at 100oC is used to overcome the attractive forces between the molecules of water. Those molecules which gain sufficient energy break their bonds within the liquid and convert into a gaseous state (or steam).

12. Latent Heat of Vaporization: It is the amount of heat energy required to convert one kg of a liquid into its gaseous state without changing its temperature. Its S.I Unit is Joule / Kilogram. (As in the case of Latent Heat of fusion the temperature during the conversion of the state remains unchanged). Latent Heat of Vaporization of water = 2,260,000 Jkg^{-1} or 2.26×10^6 Jkg^{-1}
13. Graphical Representation: In the example explained above all the ice converts into liquid. At this point the thermometer record temperature as 0ºC. Keep this thing in mind that heat is constantly being added to the water. After all the ice has melted the temperature starts increasing again and is recorded by the thermometer however, when it reaches 100ºC again there will be no increase in temperature beyond 100ºC for another long period although heat is constantly being added. The heat added will be used by the molecule to change their state. Solid – liquid – Gas. The graph shows that at 0^oC due to latent heat of fusion of ice the

temperature do not change. Temperature rise to 100ºc and then remains constant although heat is being added constantly.



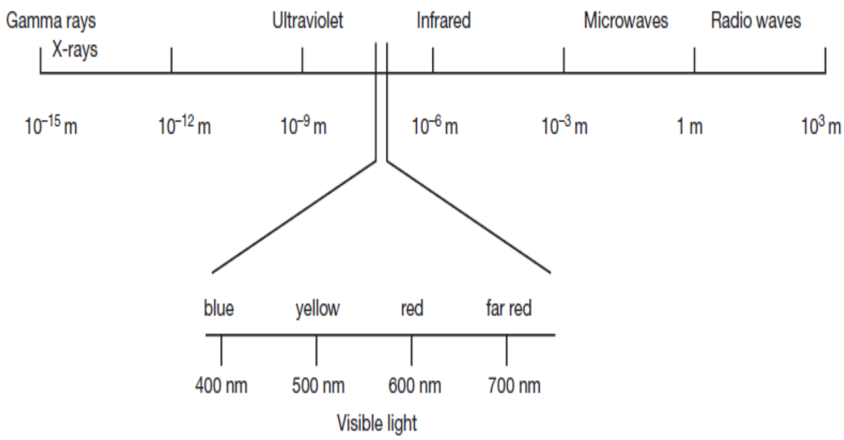
14. Vaporization: It is the process of conversion of liquids into vapors. Process of vaporization or evaporation takes place at all temperature, although its rate is different.
15. Factors Effecting Evaporation:
    a) Surface area of the liquid.
    b) Temperature
16. Sublimation: It is the process in which the solid convert directly into the gaseous state without passing through the liquid state.
17. Boiling: It is the temperature at which the rate of evaporation is such that the vapor pressure of the liquid equals the atmosphere. Strictly saying boiling is evaporation at a certain temperature. Liquid have fixed boiling Points. Boiling can not take place at all temperatures.
18. Why a hot cup of tea place on a table cools down and a cold glass of water warms up? Heat is transferred from a hotter body (higher energy) to a colder body (lower energy) – when we place a hot cup of tea it loses energy to the surroundings so it cools, where as a cold glass of water being at lower temperature has to gain heat from the surrounding so it heats up.

19. What is forced convection? Convection depends upon (i) difference in temperature (ii) surface area. However the surface area is dependant on the amount of fluid particles coming in contact with that surface area – increase the number of particles increases convection and hence larger exchange of energy (heat). In forced convention the flow of air or liquid over the surface will increase the rate of convection.
20. By which mode of heat transfer is heat lost by:
    a) The Engine of a car: Conduction to radiator and forced convection due to flow of air over the radiator
    b) A Hot rod of iron dropped in water: Conduction (iron to water) and convection in water
    c) Ventilated Room: Air convection

SUMMARY OF LECTURE # 12

LIGHT-I

1. We are looking another form of energy which is light. We shall discuss and try to explain behaviour of light in geometric optics. we are in this section concerned with the optical rather than the energy properties of light
2. Electromagnetic Spectrum contains large number of radiations. All radiations travel with same speed i.e. with speed of light. Gamma rays, X-rays, ultraviolet, visible light, infrared, microwave and radio waves are different parts of the electromagnetic spectrum. We are interesting only in visible light.

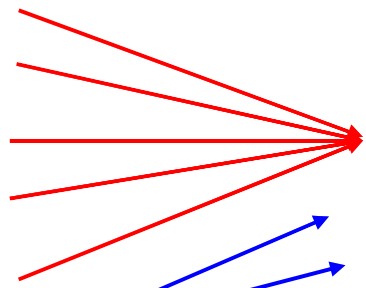


3. **Basic Definition:**
   a) Light: Light is a form of energy, that produces sensation in eyes, permitting the brain to formulate an image, we call as sight (allows us to see) – Visible light consists of all colours we can perceive.
   b) Ray of light: The direction in which light moves is represented by the help of a ray.

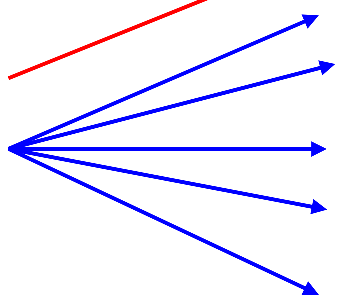
   c) Beam: Beam is a collection or bundle of rays.

   d) Parallel Beam: the rays which are align parallel to each other.

e) Converging Beam. The rays of light which are met on a point.



f) Diverging Beam: rays coming out of a point and spread in all directions.



g) Luminous Objects: Objects which emit light. Bulb, flame, sun, stars etc.

h) Non-Luminous Objects: Objects which do not emit light. Book, table etc.

i) Transparent object: Object through which light can pass. Glass, Water etc.

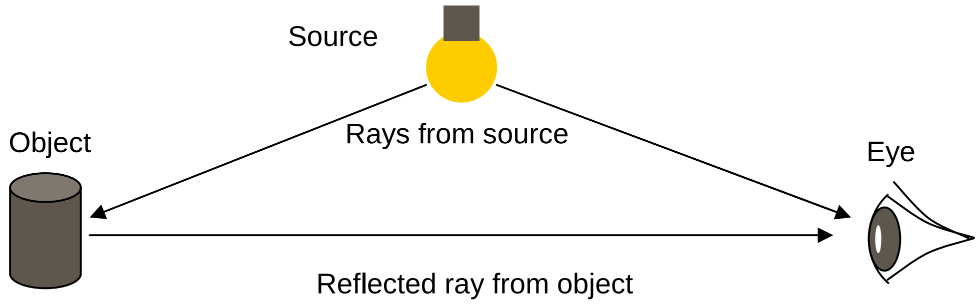
j) Opaque objects: Objects which block light. Book, desk etc.

k) Translucent object: Objects which partially transmit light. Plastic, oily sheets, thin paper etc.

l) Real image: An image which can be projected, Image on a screen, cinema film etc.

m) Virtual image: An image which can be seen but not projected on a screen. Image in a mirror etc.

4. Theory of Vision: Light falls on an object which reflects it, reflected light falling into our eye allows us to see.



5. Reflection of light: Bouncing back of light into the same medium.

6. Types of Reflection: there are two types of reflections.

a) Normal reflection: if the reflection from the plane surface is regular then this type of reflection is normal reflection.

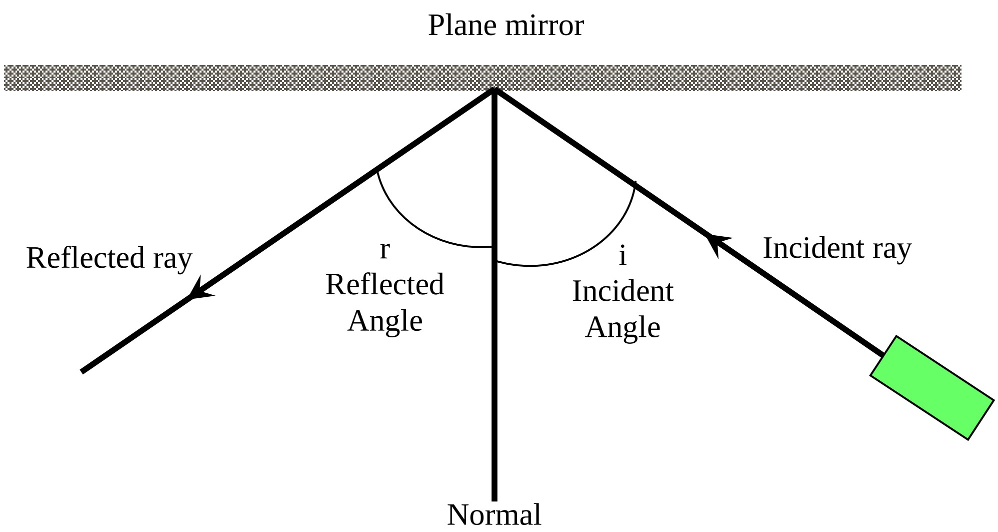
b) Diffused or Scattered Reflection: if the surface is rough, the light which comes can bounce off in different directions. Because of scattering of light, intensity of light falls.

7. Laws of Reflection: there are two laws of reflection

a) 1st Law: Incident ray, reflected ray and normal to the reflecting surface lie in the same plane.

b) 2nd Law: the Angle of incidence equals the Angle of reflection

The principle of *reversibility* states that *light* will follow exactly the same path if its direction of travel is reversed



8. Reflection from Mirrors: Mirrors are smooth polished surfaces, which reflect light like in normal reflection. There are different types of types of mirrors:

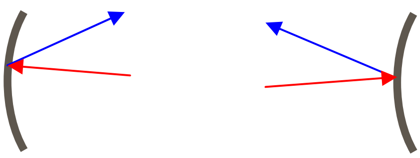
a) Plane Mirror: A mirror whose surface is plane or flat.

b) Spherical Mirror: A mirror whose surface is curved. There are two types of spherical mirrors.

i. Concave Mirror whose inner curve surface is reflecting.

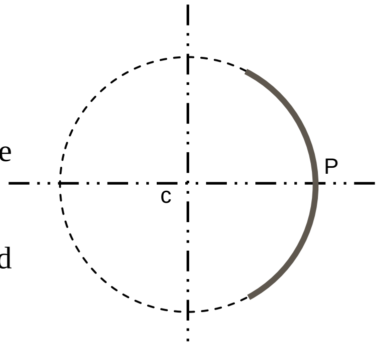
ii. Convex Mirror whose outer curve surface is reflecting.

Spherical Mirrors

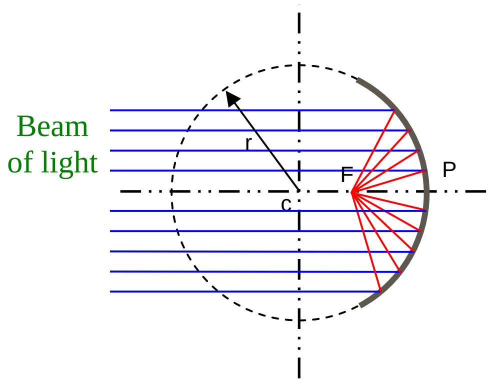


Concave Mirror Convex Mirror

9. Terms related to Spherical Mirrors:



a) Pole: (P) It is the centre of the mirror.
b) Centre of Curvature: (c) It is the centre of the sphere of which the spherical mirror is made.
c) Principle Axis: Is the line joining pole (p) and centre of curvature (c).
d) Principle Focus: (F) Is the point through which, light passes or appear to pass after reflection from a curved surface.
e) Focal Length: (f) Distance b/w the pole and principle focus.
f) Radius of curvature: (r) It is the radius of the sphere of which the spherical mirror is made.



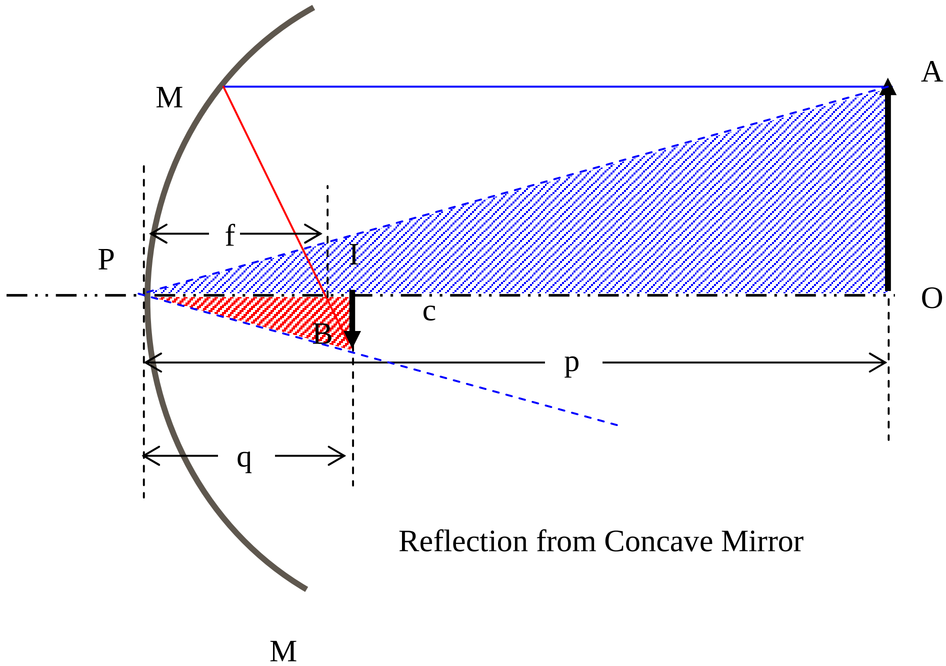
In plane mirrors the size of the image equals the size of the object whereas spherical mirrors are used to alter the size of the image

10. Rules For Drawing A Ray Diagram:

a) After reflection from a curved mirror the rays parallel to the principle axis will pass or appear to pass through the principle focus.
b) A ray striking the pole of mirror is reflected in such a way that
c) Angle of incidence (i) = Angle of reflection (r)
d) A ray passing through the principle focus, after reflection travels parallel to principle axis.
e) A ray passing through the centre of curvature on reflection passes through the centre of curvature (i.e. bounces back along the incident path)

f) Any of the two rays can be use for image formation. Point of intersection of rays gives us image.

11. Using ray diagrams for concave mirrors:



Reflection from Concave Mirror

In case of concave mirror the rays of light after reflection from the mirror actually pass through the principle focus of the mirror. Its image can be obtained on a screen. The image formed is real.

Focal length of Concave mirror	(f) is positive.
Object distance	(p) is positive.
Image distance	(q) is also positive.
Image Distance: (p)	Distance of image from mirror.
Object Distance: (q)	Distance of object from mirror

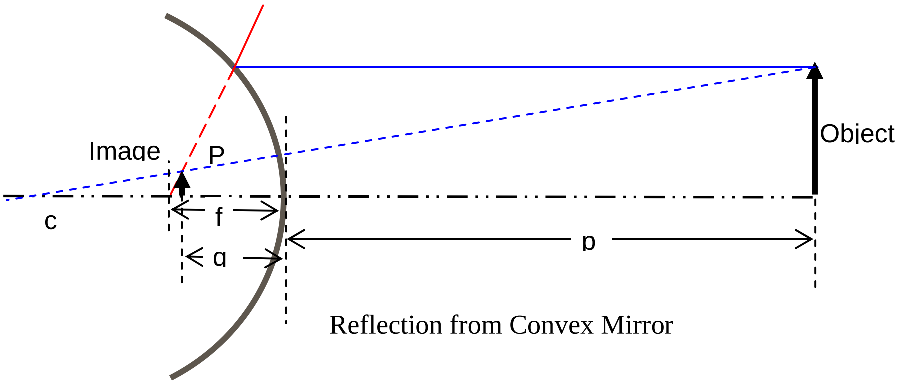
Focal length, object and image distance are positive because all these are on the right side of the pole.

12. Using ray diagrams for convex mirror

If rays of light are parallel to principle axis are reflected in such a way that the rays of light appear to come from principle focus. Its image can not be obtained on a screen. The image formed is called a Virtual image.

Its focal length is considered	(-) negative
Image distance is considered	(-) negative

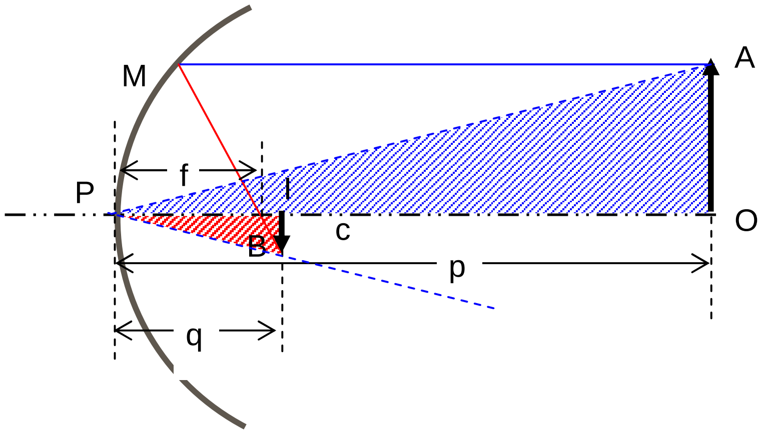
Object distance is considered (+) positive



Reflection from Convex Mirror

13. **The mirror equation**:

Consider an object OA placed in front of concave mirror its real image is formed at position B as shown in the figure.



$$\Delta AOP \rightleftarrows \Delta BIP$$

$$\frac{OA}{IB} = \frac{OP}{IP} \Rightarrow$$

$$\frac{MP}{IB} = \frac{PF}{IF}$$

$$\frac{PF}{IF} = \frac{OP}{IP}$$

$$\frac{f}{q - f} = \frac{p}{q}$$

$$\frac{f}{q - f} = \frac{p}{q}$$

$$qf = p(q - f)$$

$$qf + pf = pq$$

$$Dividing\ by\ pqf$$

$$\frac{qf}{pqf} + \frac{pf}{pqf} = \frac{pq}{pqf} \Rightarrow \frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

14. Problem: An object is placed on the axis of a concave Spherical Mirror at a distance of 20 cm from the mirror. If the focal length of the mirror is 15 cm, calculate the position of the image.

Data:

p = 20 cm = 0.20 m, f = 15 cm = 0.15 m

q = ?

$$\frac{1}{p}+\frac{1}{q}=\frac{1}{f}$$

$$\frac{1}{0.2}+\frac{1}{q}=\frac{1}{0.15}$$

$$\frac{1}{q}=\frac{1}{0.15}-\frac{1}{0.20}=\frac{0.20-0.15}{0.20\times0.15}=\frac{0.05}{0.03}$$

$$q=\frac{0.03}{0.05}=0.60m$$

15. Problem: An object is placed on the axis of a convex Spherical Mirror at a distance of 20 cm from the mirror. If the focal length of the mirror is 15 cm, calculate the position of the image.

Data:

p = 20 cm = 0.20 m, f = - 15 cm = - 0.15 m

q =?; f is negative as mirror is convex

$$\frac{1}{p}+\frac{1}{q}=\frac{1}{f}$$

$$\frac{1}{0.2}+\frac{1}{q}=-\frac{1}{0.15}$$

$$\frac{1}{q}=-\frac{1}{0.15}-\frac{1}{0.20}=-\frac{0.20+0.15}{0.20\times0.15}=-\frac{0.35}{0.03}$$

$$q=-\frac{0.03}{0.35}=-0.086m$$

16. Linear Magnification: A magnified image is the one whose size is greater than the object. Linear Magnification is the ration of size of image to the size of object. Size of image varies with the distance of object from mirror, so the ration of image distance to object distance gives magnification.

$$M=\frac{\text{size of image}}{\text{size of object}}=\frac{p}{q}$$

17. An image formed by a concave lens is three times its object size. If the focal length of the mirror is 15 cm, calculate the position of the image.

Data:

M=3, p = ?, f = 15 cm = 0.15 m, q = ?

$$M = \frac{p}{q}; \quad \frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

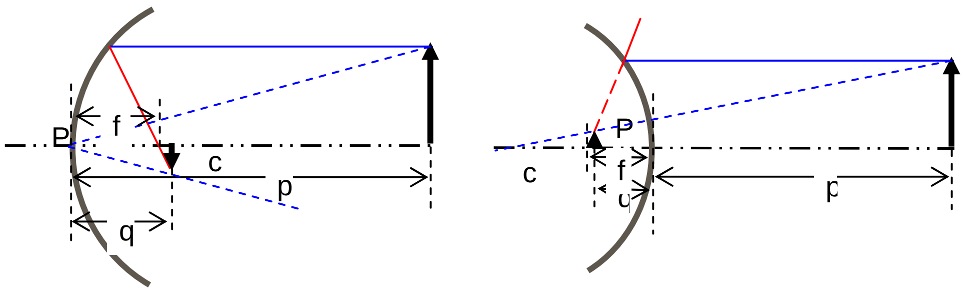
$$3 = \frac{p}{q} \Rightarrow p = 3q$$

$$\frac{1}{3q} + \frac{1}{q} = \frac{1}{0.15}$$

$$\frac{4}{3q} = \frac{1}{0.15} \Rightarrow \frac{1}{q} = \frac{3}{4 \times 0.15} = \frac{3}{0.60}$$

$$q = \frac{0.60}{3} = 0.20m$$

18. Uses of plane mirrors:
   a) Use to see our image
   b) Use in periscope to bend light in a particular path. Periscope is used in submarine.
19. Uses of spherical Mirrors:
   a) In wing (rearview) mirror of vehicles
   b) Used to reflect light from sources like car headlights, search light and spot light etc
   c) In optical instruments like astronomical telescopes
   d) Used by Doctor's to examine throat, ear, nose, and eyes.
20. Question: Why image distance and focal length of convex mirror is negative?



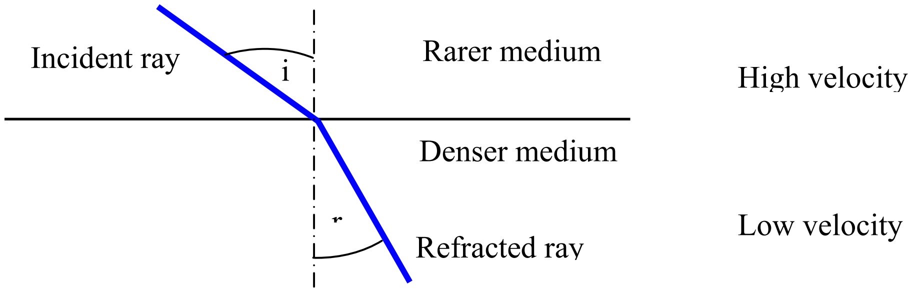
All distances are taken from the pole P, along the x-axis as shown. In case of concave f, p and q are all to the right of P so are positive. In case of convex p, is to the right of P so is positive but f and q are the left of P so are negative.

21. Distinguish between a convex and a convex mirror:

	Concave	Convex
Physical bulge	Inwards	Outwards
Reflecting surface	Inside	Outside
When parallel beam falls	converges	diverges
Focal length (f)	positive	negative
Image distance (p)	positive	positive
Object distance (q)	positive	negative

SUMMARY OF LECTURE # 13
LIGHT-II

1. Refraction: Change in the direction of light when it enters from medium to other. For refraction two mediums are required. One is rarer medium (air) and other is denser medium (water, glass). The incident ray is in air and moving towards the denser medium. Angles are always taken from the normal or perpendicular from the surface. The incident angle is angle between the normal and the incident ray. Angle between the normal and refracted ray is the angle of refraction.



2. Refractive Index: The extent of refraction of a ray of light is given by the refractive index. The ray of light bends due to the change in velocity of light when it enters from one medium to other

$$\eta \text{ or refractive Index} = \frac{\text{speed of light in air (vacuum)}}{\text{speed of light in medium}}$$

3. Speed of light in different materials:

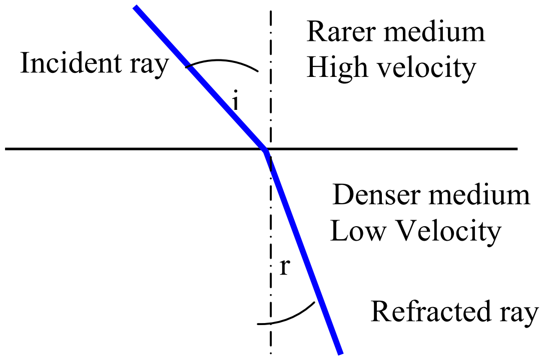
Material	speed m/s	RI = c/v
Vacuum (c)	3.00×10^8	0
Air	3.00×10^8	1.00
Water	2.26×10^8	1.33
Alcohol (ethanol)	2.20×10^8	1.36
Glass	2.00×10^8	1.50
Diamond	1.24×10^8	2.42

Refractive index of glass is 1.50 and that of water is 1.33

4. Laws of refraction:
   a) The incident ray, refracted ray and normal, at the point of incidence, lie in the same plane.
   b) Ratio between sin (i) and sin (r) is constant and equals the refractive index

Snell's Law

$$n = \frac{\text{velocity in air}}{\text{velocity in medium}} = \frac{c}{v} = \frac{Sin(i)}{Sin(r)}$$



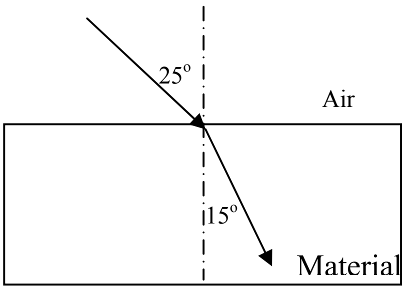
5. Difference b/w Reflection and refraction:

Reflection	Refraction
The medium through which the light travels does not change	The medium through which the light travels changes
angle (i) = angle (r)	angle (i) ≠ angle (r)
Speed of light remains same	Speed of light changes

6. Problem 1.The path of the ray is show in the figure. Calculate the refractive index of the material. Calculate the velocity of light in the material.

Data

Incident angle	(i) = 25^o
Refracted angle	(r) = 15^o
Velocity of light	c = $3.00 \times 10^8 ms^{-1}$



$$n = \frac{Sin(i)}{Sin(r)} = \frac{Sin(25)}{Sin(15)} = \frac{0.423}{0.259}$$

$n = 1.63$

$$n = \frac{c}{v} \Rightarrow v = \frac{c}{n}$$

$$v = \frac{3\times10^8}{1.63} = 1.84\times10^8 ms^{-1}$$

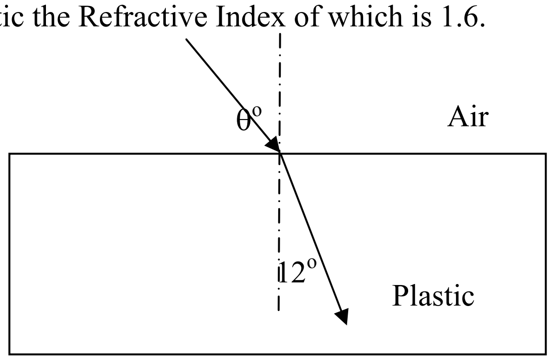
7. Problem 2. The path of the ray is show in the figure. Calculate the value of θ. Calculate the velocity of light in plastic the Refractive Index of which is 1.6.

Data:

Refracted angle (r) = 12^o,

RI of plastic η = 1.6

Velocity of light c = $3 \times 10^8 ms^{-1}$



Incident angle (i) = θ^o=?

$$n = \frac{Sin(i)}{Sin(r)} = \frac{Sin(\theta)}{Sin(12)}$$
$$n = 1.6 = \frac{Sin(\theta)}{0.208}$$
$$Sin(\theta) = 1.6 \times .208 = 0.333$$
$$\theta = Sin^{-1}(0.333) = 19.4^o$$

$$n = \frac{c}{v} \Rightarrow v = \frac{c}{n}$$
$$v = \frac{3\times10^8}{1.6} = 1.88\times10^8 ms^{-1}$$

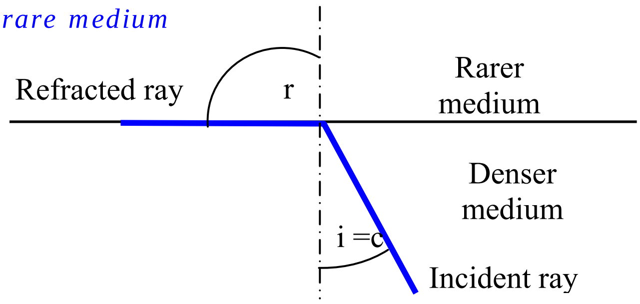
8. Critical Angle: Angle of incidence in denser for which the corresponding angle of refraction in rarer medium is 90º is called the critical angle. The Refractive index also depends on critical angle.

When light is entering from rare to densor medium

$$n = \frac{Sin(i)}{Sin(r)}$$

And When light is entering from densor to rare medium

$$n = \frac{Sin(r)}{Sin(i)}$$
$$= \frac{Sin(90)}{Sin(c)} = \frac{1}{Sin(c)}$$
$$n = \frac{1}{Sin(c)}$$



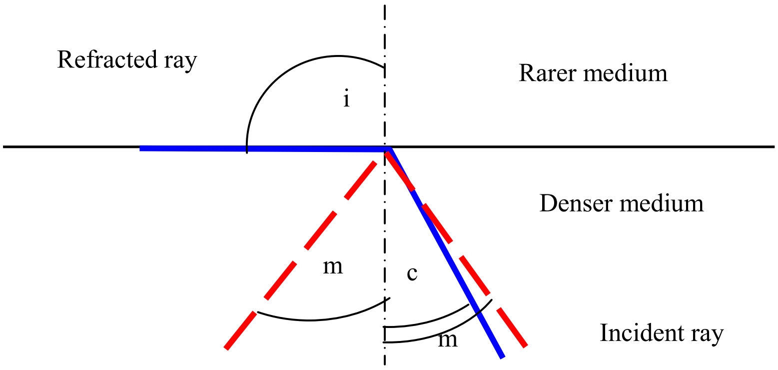
9. Problem3. Sapphire has a critical angle of 34.4°. What is its refractive index?

Data

Critical angle= 34.4 degrees. Refractive index =?

$$n = \frac{1}{Sin(c)} = \frac{1}{Sin(34.4)} = 1.77$$

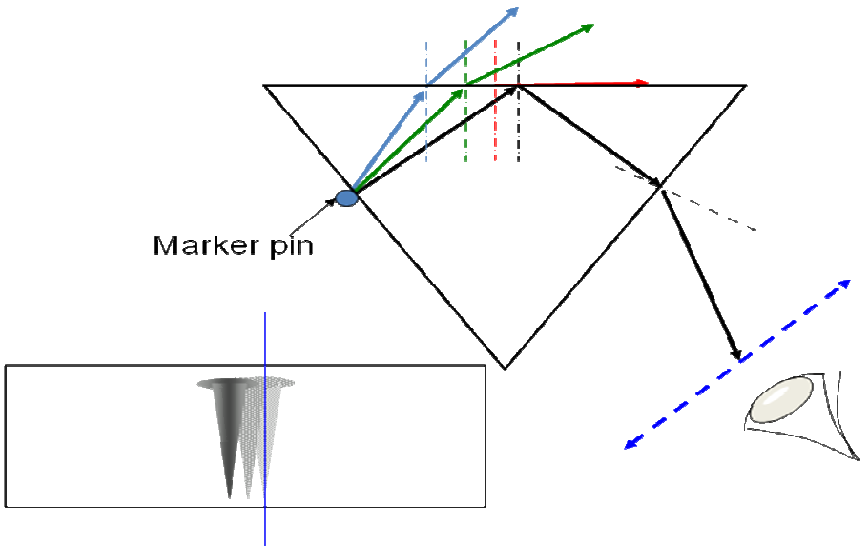
10. Total internal reflection: When a ray of light enters from denser to rarer medium in such a way that the angle of incidence is greater that critical angle, the ray of light cannot enter the other medium and is reflected back in the same medium. This phenomenon is called total internal reflection.



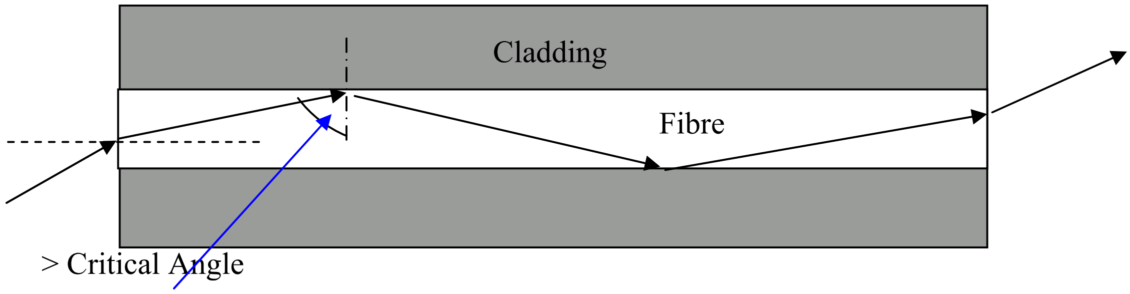
No light ray with m>c is refracted, and as the reflection takes place inside the medium, so it is called "Total Internal Refraction". As total internal reflection is a type of reflection, therefore, the laws of reflection are applicable

11. Conditions of Total Internal Reflection:
    a) The ray of light should enter from denser to rarer medium.
    b) Angle of incidence should be greater than critical angle of that medium.
    c) When angle of incidence is equal to the critical angle, the ray emerges at an angle i = 90º, the ray of light travels along the boundary of the prism.
    d) When angle of incidence is further increased no refraction takes place and the ray of light is reflected back (by the boundary) in such a way that Angle of incidence = angle of reflection. Total internal reflection has occurred at this point.
12. Multiple images in back coated mirrors: Mirrors are glass materials which might have certain thickness. Due to thickness, there are two ways of making a mirror. Coating the back side of the mirror then light has to travel through the mirror to the reflecting surface and bounce back. If front side of the mirror is coated, the light is just strike the top surface and bounces back. In this case, we have a perfect reflection. Front coated mirrors are used where high precisian work is to do. Normally we use mirrors everyday are back coated mirrors. In back coated mirrors the light enters the material. Some light is reflected from the top surface and some light is reflecting from the reflecting surface. In this case, some ghost images might be produced. Ghost images depend upon the type of materials and coating used and reduces the cost of the mirror.

13. Finding the critical angle using Total Internal Reflection: In a laboratory, right angle prism is used to find the critical angle. Place a pin on a sheet of a paper and then isosceles side of prism next to that. There are multiple rays coming out from that source. As the angle with which the rays striking the top surface of prism, the light can be refracted in different angles. The last ray is refracted just along the surface. If we increase the angle, we find that the ray is totally internally reflected and it going to be bounced back and can be viewed from the other side of the prism One side of the prism is acting as a reflector. Place an eye, move it forward and backward, see the images just disappearing. The moment when images are disappearing, back the eye to the position where the image is most bright next to the dimmest position and that is in fact the proper critical angle



14. Optical Fiber: Optical fibers are made up of very fine stands of glass, coated with another type of glass whose refractive index is less the inner glass so that the condition of total internal reflection is satisfied. It is also provided with protective coating to avoid damage. Different type of optical fibers are Single mode, Single mode step index fiber. Multimode step index fiber. Multimode graded index fiber.



15. Advantage of optical fiber: Optical fiber are:
    a) Light in weight
    b) Flexible
    c) Cheaper than copper cables
    d) No heating effect (minimum energy loss)
    e) Can carry huge information, capacity is thousands of times greater than electrical signals or radio waves
    f) Can carry telephone signals
    g) Minimum amount of energy is lost.
16. Uses of Optical Fiber:
    a) Used for transmission of computer data,
    b) telephonic signals and TV programmes,
    c) Widely use in medical field as endoscopes and related specific scopes
        i. Endoscope: Can view and photograph internal parts of human body.
        ii. Bronchoscope: Used to view sour throat.
        iii. Cysto scope: Used to examine liver working.
        iv. Gastro scope: Used to examine stomach.
17. Questions:
    a) Why minimum or no power is lost in optical fibers? Very little energy is absorbed when light moves in a transparent medium – so minimum power is lost in Optical Fibers.
    b) Can total internal reflection take place when light enters from air into water? No for Total Internal Reflection light has to come out of a more denser material. Water is denser than air so TIR is not possible as light enters water.

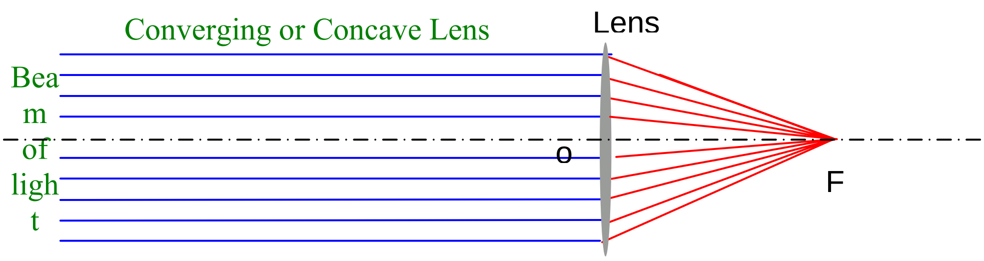
c) Can we take a photograph of the image obtained using optical fiber? Yes – Optical fibers create real images therefore they can be photographed.

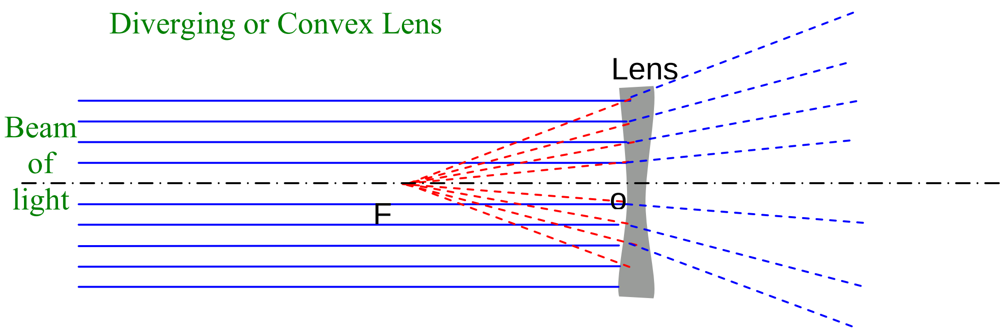
18. Lenses: Lenses are transparent object used to converge or diverge rays of light there are different type of lenses, two of them are:

a) Convex lens: The lens which is thinner at the edges and thicker at the middle is convex lens. It is also called converging lens because it converge all rays of light at one point.

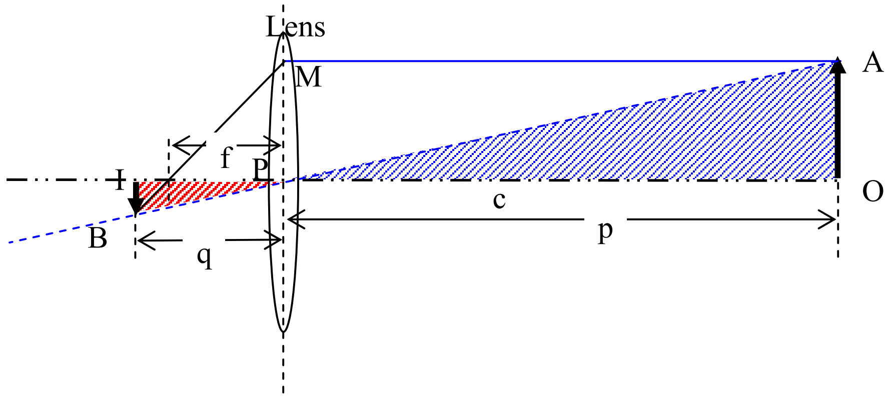
b) Concave lens: This lens is thicker at the edges and thinner at the centre and diverge the rays of light called diverging lens.

Convex Lens   Concave Lens





19. Using ray diagrams for convex lenses:



Principle focus (F):	Point where rays of light converge or appear to converge.
Principal axis:	line joining centre of curvature and optical centre
Optical centre:	Centre of the lens – a ray passing through this point is not refracted
Centre of curvature (c):	Centre of the sphere of which the lens is made.
Focal length (f):	Distance b/w principal focus and optical centre.
Object distance (p):	Distance of object from lens.
Image Distance (q):	Distance of image from lens.

20. Reflection for convex lenses: If rays of light parallel to principle axis are refracted in such a way that the rays of light appears to come from principle focus. Its image can be obtained on a screen. Image formed is real

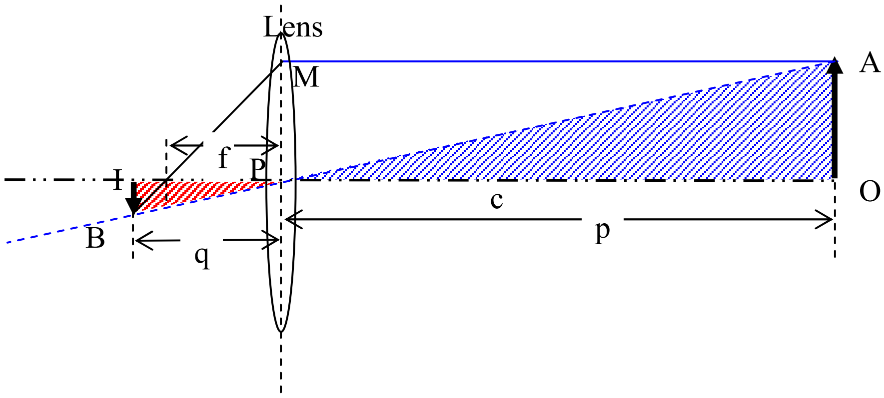
Its focal length is considered	(+) positive.
Image distance is considered	(-) negative
Object distance is considered	(+) positive.

21. Refraction from Convex lens: If rays of light parallel to principle axis are refracted the rays of light appears to converge at principle focus. Its image can be obtained on a screen. The image formed is real inverted and, depending upon its position diminished or magnified.

Its focal length is considered	(+) positive
Image distance is considered	(-) negative
Object distance is considered	(+) positive

22. The lens equation: The lens equation: consider an object OA, is placed in front of a convex lens. A ray of light starting from the point A and moving parallel to the

principal axis strikes the lens at point M. after refraction through the lens, it passes through the principal focus F. a second ray AP also starting from point A passes through the optical centre of the lens and moves straight and intersected the first ray at point B. Thus B is the real image of point A. if this process is repeated for other points of the object OA then real image IB of the object OA is obtained. Generally the distance of the object from the lens is represented by p and that of image by q.



$$\Delta AOP \rightleftarrows \Delta BIP$$

$$\frac{OA}{IB} = \frac{OP}{IP} \Rightarrow \frac{PF}{IF} = \frac{OP}{IP}$$

$$\frac{f}{q-f} = \frac{p}{q}$$

$$\frac{MP}{IB} = \frac{PF}{IF}$$

$$\frac{f}{q-f} = \frac{p}{q}$$

$$qf = p(q-f)$$

$$qf + pf = pq$$

$$\frac{qf}{pqf} + \frac{pf}{pqf} = \frac{pq}{pqf}$$

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

23. Questions: Distinguish between a convex and a convex mirror.

	Concave	Convex
Physical bulge	Inwards	Outwards
Reflecting surface	inside	Outside
When parallel beam falls	converges	diverges
Focal length (f)	positive	negative
Image distance (p)	positive	positive
Object distance (q)	positive	negative

24. Difference b/w concave and convex lens:

Sr. #	Concave	Convex
i.	Converge light	Diverge light
ii.	Focal length is positive	Focal length is negative
iii.	Image distance is negative.	Image distance is positive
iv.	Principal focus is real focus.	Principal focus is real focus.
v.	Image can be obtained a on screen.	Image cannot be obtained on screen.

25. Similarities between concave and convex lenses:

a) Both use principals of refraction.

b) Both are transparent.

c) Ray of light that pass through the optical centre of both lens suffers no refraction.

d) Both can be used to change the size of image as compared to the size of object.

e) Object distance is considered positive for both lenses.

26. Difference b/w lenses and spherical mirrors: The formula for both lens and mirror is the same $\frac{1}{p}+\frac{1}{q}=\frac{1}{f}$ both behave similarly, but there are some differences between them:

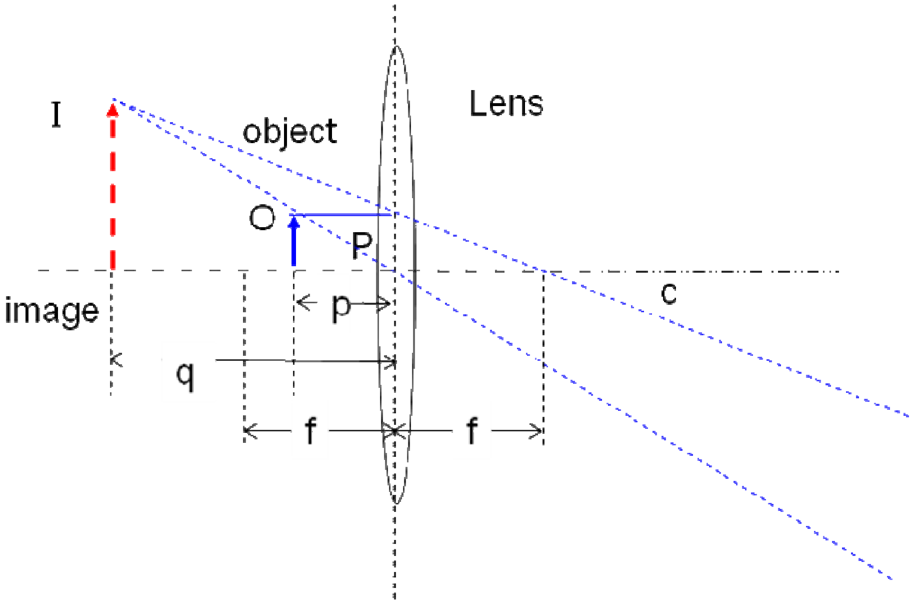
Lens	Spherical Mirrors
Image is formed on opposite side of the lens	Image is formed in front of the mirror
Follow laws of refraction	Follow laws of reflection
Transparent object	Opaque object

27. Uses of lens formula:

a) Lens formula is very useful in determining the focal length of a lens.
b) From the information of focal length of the length, it possible to use lenses for the construction of different instruments.
c) It also helps in determining the spectacles needed for a person unable to see clearly.

SUMMARY OF LECTURE # 14
LIGHT-III

1. What is a simple microscope? A microscope is a device to see very small objects. It usually consists of a number of lenses. However a simple microscope consists of only one lens. It is also commonly known as a magnifying glass. Object is placed between the focal point and the principal axis of the lens. Light coming from the object O, parallel to the principal axis passes through the focal point. The ray of light which passes through the optical center does not refract. When these two lines join, they meet at point I, which tells us the location of image. From the figure, we can see that it is vertical, magnified and virtual because it only can be seen through the lenses otherwise it does not exist.



2. Can we use lens to increase the intensity of light? If so, what type of lens will be used for this purpose? Yes as lenses have the property to converge light rays, therefore they can be used to increase the intensity of light at a point. A converging or convex lens has to be used.
3. You are unable to visually see the corner of a lens if they are thick or thin. How can you find, what type of lens is it? Even when we cannot visually see the edges, or if it is a thin lens and we cannot for sure say if it is convex or concave, we can always determine if it is converging or diverging and hence learn about it

   Convex lenses are converging and

   Concave lenses are diverging

4. Problem 1. An object 3.0 cm high is placed at a distance of 15.0 cm from convex lens of focal length 10.0 cm. Find (a) Position of image, (b) Nature of image, (c) size of image.

   Data

   P = 15.0 cm, f = 10.0 cm, h = 3.0 cm

   q = ?

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$$

$$\frac{1}{10} = \frac{1}{15} + \frac{1}{q}$$

$$\frac{1}{q} = \frac{1}{10} - \frac{1}{15} = \frac{15-10}{150}$$

$$q = \frac{150}{5}$$

$$q = 30 \text{ cm}$$

$$\frac{\text{Size of image}}{\text{Size of object}} = \frac{\text{image distance}}{\text{object distance}} = \frac{q}{p}$$

$$\frac{S_i}{3} = \frac{30}{15}$$

$$S_i == \frac{30\times 3}{15} = 6.0 \text{ cm}$$

   The image is real, inverted and magnified.

5. Problem 2. An object 3.0 cm high is placed at a distance of 5.0 cm from convex lens of focal length 10.0 cm. Find (a) Position of image, (b) Nature of image, (c) size of image.

   Data

   P = 5.0 cm, f = 10.0 cm, h = 3.0 cm , q = ?

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$$

$$\frac{1}{10} = \frac{1}{5} + \frac{1}{q}$$

$$\frac{1}{q} = \frac{1}{10} - \frac{1}{5} = \frac{5-10}{50}$$

$$q = \frac{50}{-5}$$

$$q = -10 \text{ cm}$$

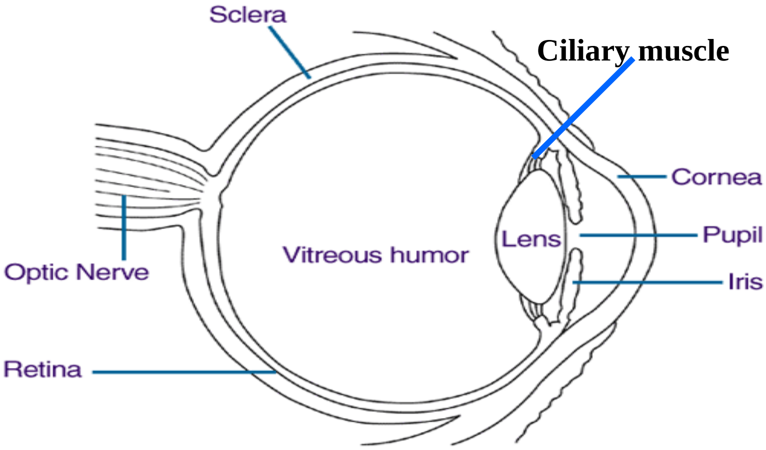
$$\frac{\text{Size of image}}{\text{Size of object}} = \frac{\text{image distance}}{\text{object distance}} = \frac{q}{p}$$

$$\frac{S_i}{3} = \frac{15}{5}$$

$$S_i == \frac{15\times 3}{5} = 9.0 \text{ cm}$$

   The image is Virtual, erect and magnified

6. The Human Eye: eye just behaves like a pin hole camera. The parts of the eye we are concerned with are, the Eye lens, the Eye ball and the Retina. This is because we are only looking at optical defects of the eye and their resolution



Human Eye

7. Image information in eye: Rays of light from the object pass through the lens. For the rays of light parallel to the principal axis, the image is formed at the focal length of the lens. Nature has designed the eyeball in such a way that the retina or the inner surface of the eye ball is at the principal focus of the eye lens. The image is formed on the retina. The nerve cells connected to the retina carry messages to the brain.
8. Defected eye: If the image is formed on the retina, the eye is working properly and the person can see object clearly. Under certain circumstances, the image is not formed on the retina; instead it is formed either in front of the retina or behind it. In both situations, the person is unable to see the objects clearly and the eye is said to be defected.
9. Causes of defects: There are two main causes (reasons) due to which the eye is unable of focus the image properly. These optical defects can be either
   i. Defects in the eye lens: The defect in the eye lens are of two basic types
      a. Thickness of the lens increases and is more than normal.
      b. Thickness of the lens decreases and is less than normal.

   With the variation in the thickness of the lens, the principal focus (the point at which the image is formed) changes. Hence the image is not formed on the retina, and the object cannot be seen clearly.

   ii. Defects in the eye ball: The defects in the eye ball are also two main types
      a. Diameter of eye ball increases and is larger than normal.
      b. Diameter of eye ball decreases and it is smaller than normal.

   If the eye lens is working properly it will focus the image at its principal focus. With the variation in the diameter of the eye ball, the retina connected on the inner of the eye ball will change its position. Again the image will not form on the retina and the object cannot be seen clearly.

10. Defects of Vision: There defects in eyeball or the lens lead to the two main defects of vision.

    i. Short sightedness or myopia.

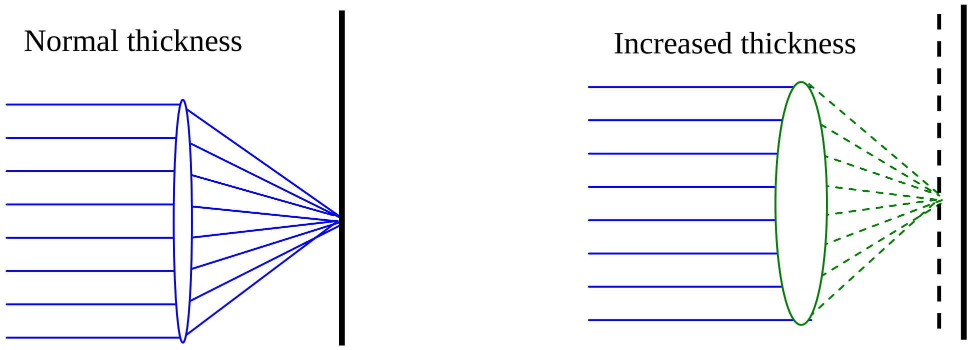
    ii. Long sightedness or hypermetropia.

    Whatever is the type of defect, it can be corrected using appropriate lens.

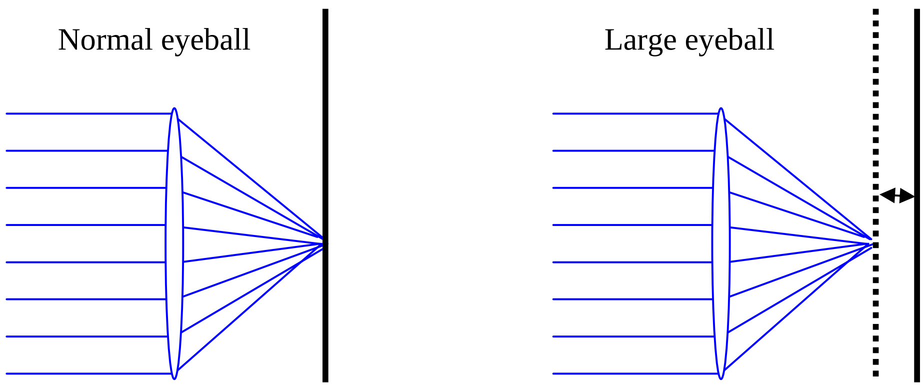
11. Short sightedness: It is the type of defect in which near objects can be seen clearly and distant objects cannot be seen clearly.

    Reason: The main reasons for this defect can be either

    a) Increase in the thickness of the lens. In such a situation the focal length of the lens decreases and the principal focus is in front of the retina instead of being on the retina. (The size of eye ball is same.)



    b) Diameter of the eye ball has increased. In such a situation the size of ball increase and the retina moves backward, again the focal point will be in front of retina, instead of being at the retina. (The thickness of lens is same.)



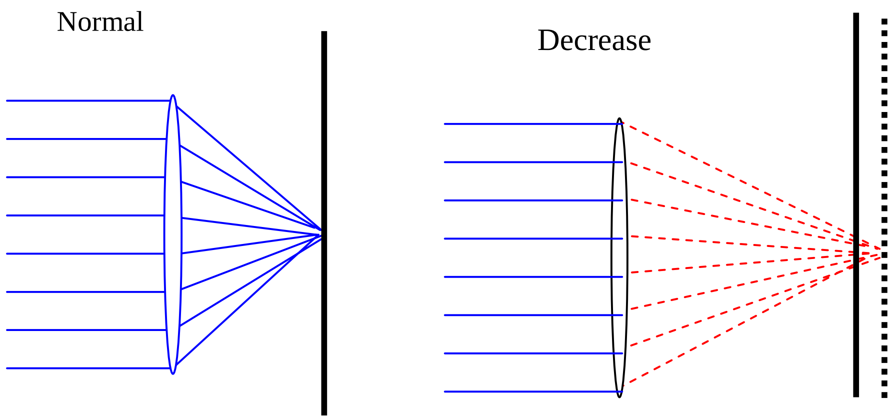
In both cases, the image is formed in front of the retina.

Correction: If spectacles with concave (diverging) lens are use this defect can removed. As the lens of eye is thinner at the edges so, diverging lens diverge the rays of light and the focal point of the combination is adjusted such that the image is formed on the retina and the image can be seen.

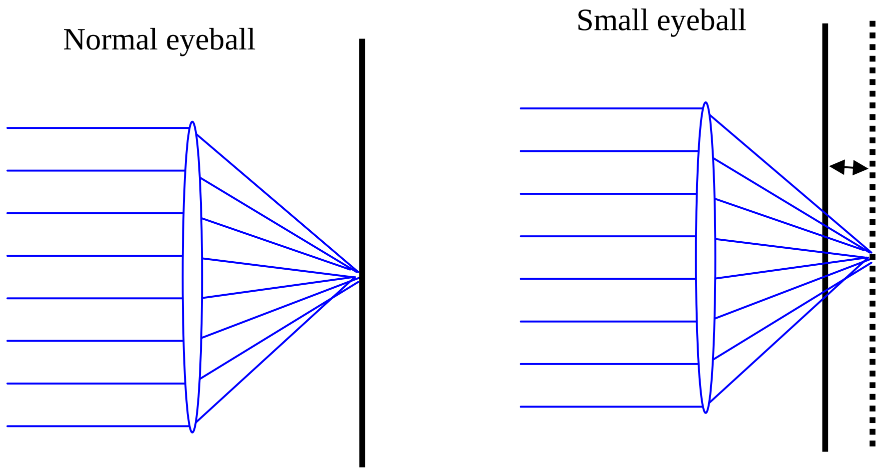
12. Long Sightedness or hypermetropia: It is the type of defect in which distant objects can be seen clearly and near objects can not be seen clearly.

Reason: The main reasons for this defect can be either

a) Decrease in the thickness of the lens: This increase the focal length of the lens and principal focus shifts behind the retina outside the eye-ball. (Size of eye-ball is same)



b) Diameter of the eye ball has decreased: The focal point of lens do not change but the eye-ball shrinks moving the retina forward. The image is formed behind retinal outside eye-ball. (Thickness of lens is same)



In both cases, the image is formed behind the retina.

Correction: Convex (converging) lens can be use to correct long sightedness. Convex lens move the rays of light towards the bottom of lens decrease the focal length of the lens. The focal length of the lens used is adjusted in such a way that the image is formed on the retina.

13. Power of Lens: Reciprocal of focal lens of the lens used is called power of lens.

$$P = \frac{1}{f}$$

Its unit is m-1 (per meter) or Diopter.

14. Significance of power of lens: The power of lens can be positive or negative and gives use information about the type of lens used. As focal length of concave lens is negative so power of such lens will be negative. As the power of lens is inversely related to its focal length so smaller the focal length, greater will be the power of the lens. Thicker lenses have smaller focal length hence have higher power.
15. Question: What happen to the ray of light traveling parallel to the principal axis? The ray of light traveling parallel the principal axis and falls on the lens. If the lens is converging then it meets on the focal point. If the lens is diverging, then it diverges and ray of light will expand. The diverging beam appears as it originates from the focal point. In both the lenses, a parallel ray of light either converges or diverges to the focal point.
16. Why do the thickness of the lens changes with the passage of time? With aging the celery muscles which control the thickness of lens will become weaker and cannot exert the same amount of pressure.
17. Find the power of concave lens of focal length 5cm.

Data

f = 5 cm = 0.05 m

P=? (For concave lens focal length f is taken as negative)

$$P = \frac{1}{-f}$$

$$P = \frac{1}{-(0.05)} = 20 \text{ diopters}$$

Lecture # 15

Fundamental Concepts of Chemistry

Matter and Chemistry:

Chemistry is a branch of science that deals with matter and changes that occur in it. In chemistry we also study theories, laws and principles related to changes in matter. More precisely, in chemistry we study chemical and physical changes and properties of elements and compounds.

In this lecture our focus is on the basic concepts of chemistry. There are many concepts that are used in chemistry. The fundamental concepts include atom, molecule, ion, element, compound, mixture, symbols, formulas, equations, atomic number, mass number, atomic mass, molecular mass, mole, etc.

Matter:

Matter is any substance that has physical existence. That is, any thing that has mass and volume. All that we see around us, or we can feel by touch are material substances. Mass is the quantity of matter that a substance contains in it. Volume is the space that a body occupies.

Physical states:

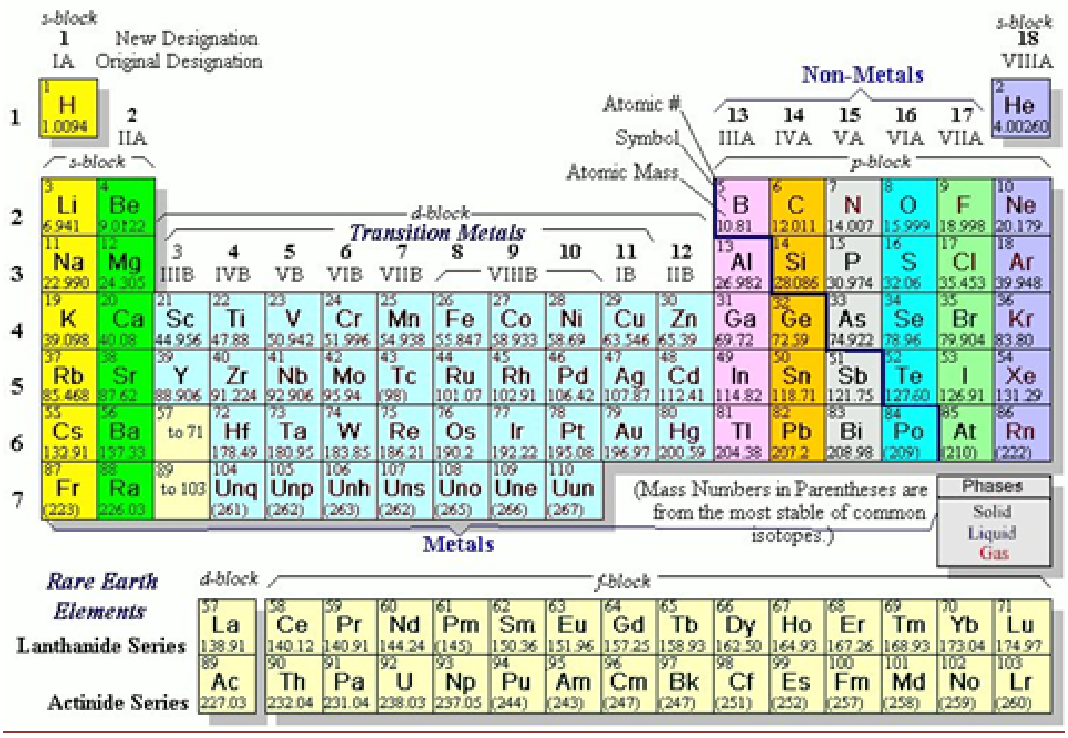
Matter exists in three physical states. These are: solid, liquid and gas. In solids, the particles are very close to one another. In gases, the particles are very away from one another. In liquids, the situation is intermediate. A substance can be changed from one physical state to another. Ice, liquid water and steam are three physical states of water.

Atom:

The atom is the smallest particle of an element that represents the elements in all chemical reactions. There are three types of fundamental particles in an atom.

1. Electrons
2. Protons
3. Neutrons

The electron is a very small particle. It has negative electric charge. The proton is a positively charged particle which is much heavier than electron. Neutron is an electrically neutral particle. It is the heaviest among the three particles. Protons and neutrons are found in the center of atom and collectively constitute a body called nucleus. Electrons revolved around the nucleus.



Atomic Mass:

An atom is a very small particle. But it also has mass. The quantity of this mass is very small. Atomic mass is the mass of one atom of an element and is defined as follows. The relative average mass of one atom of an element which tells us how heavy or light is that atom with respect to one atom of carbon-12. This unit is called amu or atomic mass unit.

One atomic mass unit is one-twelfth of the mass of carbon-12.

1 amu = 1/12 x(mass of one atom of C-12)

In this unit carbon-12 is chosen as standard. Carbon-12 is the most abundant isotope of carbon. For example: the atomic mass of hydrogen is 1.008 amu.

Molecular mass:

By molecular mass we mean the mass of a molecule. It is the sum of atomic masses of all the atoms of all elements present in a molecule. We can calculate the molecular masses of water, sulfuric acid, and glucose as follows.

1. Water, H_2O; 1x2 + 16 = 18amu
2. H_2SO_4: 1 x 2 + 32 +16 x 4 = 98amu

3. $C_6H_{12}O_6$: 12 x 6 + 1 x 12 + 16 x 6 = 180amu

Mole:

The amount of a substance that contains Avogadro's number of particles is called a mole. It is the atomic mass, molecular mass or formula mass expressed in grams. For example, 18 grams of water is one mole of water. If you drink 9 grams of water, it means you have taken a half more of water. The Avodagro's Number is the number of particles that is found in one mole of a substance. Its value is: 6.02×10^{23}. It is a huge number. If a person has eaten 180 g of glucose, he has eaten 6.02×10^{23} of glucose molecules.

Formula mass:

The Formula mass of a substance is the sum of the atomic masses of all the atoms present in the formula of that substance. For example, the formula mass of NaCl is 23+ 35.5 = 58.5.

Molecular mass:

The molecular mass of a substance is the sum of the atomic masses of all the atoms present in a molecule of that substance. For example, molecular mass of water, H_2O, is 1x2+16= 18.

Ion:

An electrically charged atom or molecule is called an ion. It has two types: cations or positive ions, and anions or negative ions. H^+ is a cation whereas Cl^- is an anion. Ions may be simple or compound. Simple ion consists of a single atom, but a compound ion is comprised of two or more atoms. For example, Na^+ is a simple ion but SO_4^{2-} is a compound ion.

Molecule:

An atom or group of bonded atoms which can exist independently.One molecule of helium (He) consists of one atom of helium. It is a monoatomic molecule. The molecules of other noble gases are also monoatomic. One molecule of water (H_2O) consists of three atoms. So it is a polyatomic molecule.

Atomic number:

The total number of protons in the nucleus of an atom is called atomic number. The atomic number of hydrogen is 1. The atomic number of oxygen is 8, sodium is 11 and iron is 26. All the atoms of an element have same atomic number.

Mass number:

The total number of protons and neutrons present in the nucleus of an atom is called the mass number of that atom. The mass number of carbon-12 is 12. It has 6 protons and 6 neutrons. Atoms of an element may differ in the mass number.

Isotopes:

The atoms of the same element having different mass number are called isotopes. Isotopes of an element have equal number of protons but different number of neutrons. Hydrogen element has three isotopes. They are called:

(1) Ordinary hydrogen or protium,

(2) Deuterium or heavy hydrogen, and

(3) Tritium or radioactive hydrogen.

Ordinary hydrogen has no neutron. Deuterium has one neutron. Tritium has two neutrons.

Element:

An element is the simplest form of matter which cannot be converted into simper forms by any physical or chemical means. If in a collection of atoms, all atoms have the same atomic number, they all belong to the same element.

For example, Na, Fe, O etc. are elements.If you look at a periodic table, you will see elements in it. Elements are of many types. They have different physical states. Today, more than 110 elements are known. Of these 90 elements occur naturally. Other elements have been formed in nuclear reactors through nuclear reactions. Majority of the elements are metals, but many elements are non-metals. There are some elements which have properties in-between metals and non-metals. They are given the name metalloids.

Metals are elements which have high electropositivity. They easily lose electrons and have shining surfaces. For example: Cu, Ag, Au are metals. Non-metals are generally less electropositive and more electronegative.

Compound:

A compound is a substance that is formed by the chemical combination of two or more elements in a definite ratio. For example, water (H_2O) and common salt (NaCl) are compounds. At present, many millions of compounds are known.

Both the elements and compounds are pure substances. Elements are represented by symbols and compounds are shown by chemical formulas.

Mixture:

When two or more substances are mixed in any ratio in a manner that no chemical combination occurs is called a mixture. A mixture is a mixed substance formed by the physical combinations of two or more substances(elements or compounds). For example, air is a mixture of nitrogen, oxygen and some other gases. The mixtures are of two types.

1. Homogeneous mixtures, and
2. Heterogeneous mixtures

A homogeneous mixture has uniform composition. It is also known as a solution. For example, a mixture of salt (NaCl) and water is a homogeneous mixture. In a homogenous mixture, one thing is completely "dissolved" in another substance. On the other hand, a heterogeneous mixture does not have uniform composition. For example, a mixture of sand and water is a heterogeneous mixture.

Chemical reaction:

A chemical reaction is a chemical change that involves one or more elements or compounds. It is process in which one or more chemical bonds are broken or formed. In a chemical reaction, one or more substances undergo chemical change and form one or more new substances. The substances before the reaction are called reactants and the substances that are formed as a result of the reaction are called products.

A chemical reactions is shown by a "chemical equation". A chemical equation consists of reactants, products and an arrow sign.

$$\text{Reactants} \rightarrow \text{Products}$$

A chemical equation must be “balanced”. A balanced chemical equation is that in which the number of atoms of all elements involved in the reaction are equal on both sides of equation. That is, the number of atoms of an element in the reactants must be equal to the number of atoms of that element in the product. Look at the following equation. Is it balanced?

$H_2 + Cl_2 \rightarrow HCl$ (not balanced)

No. it is not balanced. Why? Because the number of hydrogen atoms in the reactants side are 2 while in the product side there is only 1 H atom. Similarly, number of Cl atoms are not equal on both the sides. How can you balance it? Write 2 before HCl in the product side. The equation now will be balanced.

$H_2 + Cl_2 \rightarrow 2HCl$ (balanced)

Lecture 16
Atomic Structure

Man has known the fact that matter is composed of very very small particles since ancient times. It is generally accepted that the concept that matter is discontinuous and composed of tiny particles was first given by the Greek philosophers of the fifth century BC, Leucippos and Democritos. It is notable that Plato and Aristotle did not believe in the existence of atoms and regarded the matter as continuous. Later in 100 BC a Roman poet Lucretius illustrated the idea of atom by his poetry. The word atom is from Greek words '*a*' meaning 'not' and '*tomos*' meaning divisible. Thus, the meaning of atom is the particle that is indivisible.

In 1808, John Dalton (1766-1844), an English schoolteacher put forward the concept of atom on the scientific grounds. He proposed that the elements of atoms that are indivisible.
Today, the atom is defined as the smallest particle of an element that can enter into chemical reactions.

Atom is not indivisible. It is, in fact, a tiny *organized system* consisting of smaller particles. These smaller particles that make up the atom are called subatomic particles. Subatomic particles of fundamental importance are electrons, protons and neutrons. These particles combine together in varying number to form atoms of different elements.

The number of protons in its atoms is the characteristic property of an element. All the atoms of an element have the same number of protons. The atoms of different elements have different number of protons. A neutral atom has as many electrons as protons. Number of neutrons is not fixed. Generally, it is equal to the number of protons in the lighter atoms, and much higher than the number of protons in the heavier atoms. Atoms of the same element can have different number of neutrons. Such atoms are called isotopes. Most elements have two or more isotopes.

DISCOVERY OF SUBATOMIC PARTICLES

Now, the question is how were electrons, protons, and neutrons discovered? There are a number of experiments that ultimately led to the discovery of these particles and their arrangement in the atom. These experiments include:

- Passage of electricity through solutions
- Discharge tube experiments
- Radioactivity
- Chadwick's experiment
- Spectroscopic studies

PASSAGE OF ELECTRICITY THROUGH SOLUTION –ELECTROLYSIS

There are numerous substances that pass electricity in solution or in their molten state. They are called electrolytes, and the process is called electrolysis. Electrolysis was thoroughly studied by an English scientist Michael Faraday (1791-1867), who in 1832-1833 found out the relationship between the quantity of electricity passed through the solution and the quantity of matter deposited at the electrodes as a result of the passage of electricity, and put forward his two famous laws.

Faraday's experimental results led George John Stone StoneStoney in 1874 to conclude that electricity like matter is discontinuous and consists of particles. In 1891, he gave the name*electron* to this particle of electricity. (Electron is a Greek word for 'amber' which is electrified when rubbed with wool).

Discharge Tube Experiments
(Crookes Tube Experiments)

Discharge tube experiments provided strong evidence for the existence of subatomic particles. A discharge tube is a glass tube having two electrodes sealed in at each end. It is connected to a high voltage battery to provide required voltage and to a vacuum pump to evacuate air or gas from the tube.

Since William Crookes, a British physicist, was the first of several scientists to construct discharge tubes, these are also known as Crookes tubes.
Working: At ordinary pressure, electricity does not pass through the tube since gases are non-conductor of electricity. As the gas or air from the tube is gradually evacuated with the vacuum pump, pressure decreases in the tube; a number of interesting phenomena are observed one after the other.

When the pressure is reduced to a very small value, around 0.01-0.001 torr, an electric discharge takes place producing a uniform glow inside the tube. Experiments have shown that it is due to a radiation emitted from the cathode, which travels towards the anode. Because the rays are emitted from cathode they are given the name cathode rays. Now the question is what are these cathode rays? The cathode rays are the streams of electrons emitted from the cathode. All electrons have the same charge and mass; they all are identical.

CONCLUSION

All atoms contain smaller particles called electrons. All electrons are identical. An electron is a negatively charged particle. Its charge is -1.6×10^{-19} coulombs. An electron is an extremely small material particle with a mass of 9.1×10^{-28} grams.

DISCOVERY OF PROTON

In 1886, E. Goldstein, a German physicist discovered that in addition to cathode rays, another type of rays is also produced in the discharge tube which travel in the direction opposite to that of cathode rays.The rays were given the name canal rays as they passed through the canals of the cathode. These rays were made up of positively charged particles. These particles are formed due to the *ionization* of the atoms or molecules of the gas present in the tube. In the discharge tube, cathode rays, the electrons, collide with the atoms or molecules of the gas in the tube and knock out one or more electrons from these atoms or molecules leaving them with a positive charge. When an atom or molecule loses one or more of its electrons, it acquires a net positive charge equal to the number of electrons lost. For example, hydrogen and helium may produce H^{+2} and He^{+} ions. They may also produce H^{+} and He^{2+} ions.

Thus, positive rays are the stream of positive ions of the gas present in the tube that are produced due to the ionization of their atoms or molecules.
Out of all positive ions obtained from different gases, the lightest ion was that of hydrogen. This ion, H^+, was named as *proton* (Greek *protos*, 'first') by Rutherford in 1920. It carries a charge equal to that of an electron but opposite in sign. The ions produced from all gases in the discharge tube have been found to have charge that is integral multiple of the charge of a proton (H^+ ion). It shows that atoms contain one or more positively charged particles, the protons.

J.J. THOMSON'S MODEL OF ATOM

By the end of the nineteenth century it became all clear that atoms consist of negatively charged electrons and a positively charged part, but it was not clear how atoms are constructed. In 1898, J.J. Thomson suggested that an atom might be a positively charged sphere in which negatively charged electrons are embedded. This model of the atom is sometimes called the "plum pudding" model. Of course, it was based on insufficient information and soon found to be incorrect.

Today, it is known that neutron is a neutral particle with mass 1.008665 amu or $1.675 x 10^{-24}$ g. The nucleus of every atom contains neutrons alongwith protons except ordinary hydrogen, which has no neutron.

Rutherford's Experiment

In 1909, Ernest Rutherford, with Hans Geiger and Ernest Marsden, performed a very important experiment. In their experiment they shot a stream of high-speed a-particles at very thin sheets of various materials such as gold. They observed that most of the a-particles (about 99.9%) passed through the sheet without any deflection. However, some particles deflected through various angles, and a few almost completely reversed their direction.

Rutherford's atomic model: To explain the results of his experiment, Rutherford in 1911 proposed an atomic model. The main points of his model are as follows:
An atom consists of a nucleus which contains almost all mass and all positive charge of the atom.
Around the nucleus, there are electrons which revolve around the nucleus just as the planets revolve around the sun.

Light

Atomic spectra have greatly helped us in understanding the electronic structure of the atom. The light emitted from an atom gives us information about the electronic structure of that atom.
Light has many forms such as visible or white light, ultraviolet light, infrared light, X-rays and y-rays etc. all these forms of light propagate through space as electromagnetic waves. Like all other waves, electromagnetic waves are described in terms of their velocity, frequency, wavelength, and amplitude. The wavelength, λ(lambda), is the distance between two successive crests or troughs of the wave. The frequency, v (nu), is the number of wave crests or troughs that pass a given point in one second. Light travels with a constant speed of 3.00 x 108 m/s, c. Frequency is inversely proportional to wavelength at constant velocity. Thus,

$$v = c/\lambda$$

all electromagnetic waves have the same speed in space but their wavelengths and frequencies vary. The wavelength of the visible or white light is about 400 to 750 nm, (4000 to 7500A0)

Continuous spectrum

A spectrum is a display of component colours (or wavelengths) of radiation on a screen or photographic plate. Visible light is composed of a mixture of electromagnetic waves of all wavelengths (frequencies) ranging from about 400 nm to 750 nm. When a narrow beam of visible light is passed through a glass prism it is spread out into a band of colours ranging from long-wavelength red light to short-wavelength violet light. A prism *refracts* light to different wavelengths through different angles and thus disperses the beam of light into its component wavelengths to form a continuous spectrum. A continuous spectrum contains all the wavelengths present in that range. All the colours are present in continuity and there is no demarcation or dark band between them.

Atomic Spectrum

When an element in its atomic form is heated, it emits radiation. If a beam of light emitted by a sample of an excited element is passed through a prism, a spectrum containing only a few lines (wavelengths) is obtained. This spectrum is known as a line spectrum. Since the light is emitted by atoms of an element, the spectrum is also called an atomic emission spectrum (or simply emission spectrum or atomic spectrum). The dark regions of the spectrum correspond to the wavelengths for which light is not emitted. On the other hand, if we pass a beam of white light through a sample of unexcited gas (any element in gaseous state) and the transmitted light is passed through a prism, the spectrum obtained is called an absorption spectrum. The absorption spectrum of an element is also a line spectrum. It is the photographic negative of the emission spectrum. The absorption spectrum of an element lacks those wavelengths that are present in its emission spectrum.

Significantly, each element displays a characteristic set of lines in its emission or absorption spectrum. An element emits the same wavelengths that it absorbs. Thus, the emission or absorption spectra can serve as "*fingerprints*" on the basis of which the elements can be identified.

Atomic Spectra of Hydrogen

Hydrogen is the simplest element. A number of scientists studied the emission of radiation from hydrogen atom. The atomic spectrum of hydrogen consists of several series of lines.

Planck's Quantum Theory of Light:

In 1099, Max Planck proposed a revolutionary theory about the nature of light. The theory successfully explained several observations concerning the interaction of light and matter, which could not be explained by the wave theory of light. The theory is called Plank's quantum theory of light. It states:

1. Light is emitted or absorbed by matter discontinuously in the form of discrete packets or bundles of energy called quanta (singular quantum). These quanta of light are also named as photons.
2. Each photon of light has a particular amount of energy which is proportional to the frequency of light.

Here E is the energy, v is the frequency, ?is the wavelength, c is the velocity of light, and h is the constant of proportionality called the Planck's constant. Its value is 6.63 x 10^{-34} joule second.
The Planck's quantum theory, thus, says that light is discontinuous and consists of discrete particles called photons. The light (energy) is absorbed or emitted by a substance in the form of these photons.

Bohr's Atomic Model

Keeping in view the Rutherford's atomic model, the Planck's quantum theory of light, and the results of the studies of atomic spectra, Neils Bohr (1885 – 1962), a Danish physicist, in 1913 put forward his model of atomic structure. The postulates of this model are as follows:

1. Electrons revolve around the nucleus in certain *fixed orbits,* or *stationary states*. It means that the energy of the electrons is quantified, that is, an electron can have only certain discrete quantities of energy and none in between. The orbits are also called *energy levels*.
2. Only those orbits are possible for which the angular momentum (mvr) of an electron is the integral multiple of h/2?. That is,

mvr = n x h/2?   Where n = 1,2,3,4,…

Where m is the mass, v the velocity, r the radius of the orbit of an electron, h is the Planck's constant. n specifies the orbits. When n = 1, this is orbit number 1, when n = 2, this is orbit number 2, and so on.

3. As long as an electron moves in its own orbit, no emission or absorption of radiation occurs.
4. Emission or absorption of radiation takes place when an electron jumps from one orbit to another. An electron jumps from an orbit of lower energy (an inner orbit) to an orbit of higher energy (an outer orbit) as a result of the absorption of radiation. When an electron jumps from an orbit of higher energy to an orbit of lower energy, radiation is emitted. The energy of the light absorbed or emitted is equal to the difference of the energies of the orbits between which the electronic transition occurs.

$$:.\ \Delta E = E2 - E1 = hv$$

Radii or Orbits: Different orbits have different radii. On the basis of Bohr's atomic model, radii of the electronic orbits can be determined.

Ground State and Excited State

The ground state of an electron is the lowest energy state that an electron normally occupies. When energy is absorbed, the electron jumps to a higher energy state. This higher energy state is known as the excited state (higher energy state). The ground state of an electron is the stable state while the excited states are unstable states. As a result of absorption of energy when an electron jumps to an excited state, it immediately jumps back to the ground state with the emission of energy.

Wave Nature of Matter:

In 1924, a French physicist Louis de Broglie, using Planck's equation (E = hv) and Einstein's equation ($E = mc^2$), put forward a hypothesis that electron (and hence matter) possesses wave properties. That is, electron is a wave. Later, Davison and Germer in 1927 experimentally discovered the wave nature of electron. Subsequently, other particles, such as protons, neutrons and helium nuclei (a-particles) were also shown to exhibit wave properties.

The wave behaviour of matter can only be observed for very small particles. For big bodies the associated wavelength is much too small to be observed.

In short, under certain conditions, an electron resembles a particle while under some other conditions, it behave as if it is a wave. The electron and hence the matter possesses dual nature. However, it has been found that electrons can be treated as wave more effectively than as small particles.

Heisenberg Uncertainty Principle

In 1927, Werner Heisenberg (1901–1976), a German physicist, put forward a principle called the Heisenberg uncertainty principle (or Heisenberg indeterminacy principle). It states:

"It is impossible to determine with exact accuracy both the momentum and the position of an electron (or any other body) simultaneously."

It means the more accurately we know the momentum of an electron, the less accurately can we know its position and vice versa.

Thus, Bohr's model of an electron moving with a known velocity (or momentum, as it is mv), in a well-defined orbit (that is, with known position) cannot be correct. In other words, we cannot say where an electron lies around the nucleus.

Quantum Mechanics

The concepts given by Planck, Bohr, de Broglie, Heisenberg, and others ultimately led to the development of a new theory of the structure of atom, known as quantum mechanics or wave mechanics. Quantum mechanics replaced the classical mechanics (the Newtonian mechanics).

If the electron is a wave, then it should be possible to describe it with the help of some mathematical equations like the other waves. In 1926, Erwin Schrodinger (1887–1961) succeeded to develop an equation. This equation is the foundation stone of the quantum mechanics. It offers a mathematical approach to understanding the wave nature of matter.

The quantum mechanical treatment of an electron is highly mathematical as the Schrodinger equation is a very complex equation. Hydrogen is the only atom for which it has been solved. Each solution of this equation is described by a set of constant numbers called quantum numbers.

Quantum Numbers

The quantum mechanics explains the structure of atom with the help of four quantum numbers. These numbers are used to describe the distribution of electrons in space around the nucleus. The quantum numbers and their significance is given below:

1. Principal Quantum Number, *n*

The principal quantum number (*n*) describes the main energy level, or shell, that an electron occupies in an atom. n may be any positive integer:

n = 1,2,3,……

When n = 1, it is the first main energy level, or the first shell. When n =2, it is the second shell. And, so on. A main energy level or shell is the main region around the nucleus in which an electron may be present. Shells 1, 2, 3, 4,…..are also sometimes called K, L, M, N, …….shells.

2. Azimuthal (or subsidiary) Quantum Number, l

Azimuthal quantum number (l) describes subshells or sublevels in shells or main energy levels. It denotes the shape of the region in space an electron occupies. Its values are given by:

l = 0 to (n – 1)

Thus, when n = 1, then

l = 0

When n = 2, then l = 0, 1

When n = 3, then l = 0, 1, 2

And, so on.

Thus, the values of l designate subshells or sublevels that electrons can occupy in a main shell. Each value of l is given a letter notation. Thus:

l = 0, 1, 2, 3, 4, 5, …….

s, p, d, f, g, h,..........

Thus, in the first shell (n = 1, l = 0), there is one subshell and it is *s*. In the second shell there are two subshells, *s* and *p*. in the third shell (n = 3), there are three subshells, *s*, *p* and *d*. In the fourth shell (n = 4), there are four subshells (*s*, *p*, *d*, and *f*). And, so on. Notice that the number of subshells in any given shell is simply equal to the value of n for that shell.

(The first four letters (*s, p, d, f*) find their historical origin in the study of the atomic spectra of the alkali metals. In these spectra four series of lines are observed and they are termed as the *s*harp, *p*rincipal, *d*iffuse and *f*undamental series. For l = 4, 5, …… we just continue with the alphabet.)

Notice that the electrons in their ground state in atoms of all elements occupy only *s*, *p*, *d* and *f*.

3. Magnetic Quantum Number, m

It designates the spatial orientation of the region an electron occupies. This region is called an orbital. An orbital is the region around the nucleus in which the probability of finding an electron is maximum. Each subshell is composed of one or more orbitals. The values of m are given by:

$$m = -l, \ldots\ldots 0 \ldots\ldots +l$$

Thus, when l = 0, m = 0

When l = 1, m= -1, 0, +1

When l = 2, m= -2, -1, 0, +1, +2

When l = 3, m = -3, -2, -1, 0, +1, +2, +3

Values of m serve to determine the orientation of an orbital in space relative to the other orbitals. In subshell *s*, there is only one orbital *s*. In subshell *p*, there are three orbitals, *px*, *py*,*pz*. In subshell d, there are five orbitals, and in subshell f, there are seven orbitals.

4. Spin Quantum Number, s

It refers to the spin of an electron. Electron has a spin, that is, it rotates about its own axis. An electron can spin only in either of two directions, clockwise or anticlockwise. Therefore, *s* has only two values +1/2 and –1/2.

Atomic Orbitals:

From the above discussion we can conclude that in an atom there are various main energy levels or shells. Each shell has one or more sublevels or subshells. Each subshell consists of one or more orbitals. An orbital is the actual region where an electron is found. It can be defined as follows:

"An orbital is the region around the nucleus in which the probability of finding an electron is maximum."

Note that an orbital can have a maximum of two electrons.

SHAPES OF ATOMIC ORBITALS

Each *s* orbital in an atom is spherically symmetrical with respect to the nucleus. That is, an *s* orbital in shape is like a symmetrical sphere such as a football. Each *p* orbital is like a dumbbell. The three *p* orbitals (*px*, *py* and *pz*) are present perpendicular to one another. Subscripts x, y and z indicate the axis along which each of the three two-lobed *p* orbitals is directed. The *d* and *f* orbitals have complex shapes.

ELECTRONIC CONFIGURATION

The arrangement of electrons in shells, subshells and rbitals in an atom is called the electronic configuration. The electronic configuration of an atom is governed by the following rules and principles:

1. Pauli Exclusion Principle,

Since electrons are described by four quantum numbers, any two electrons in an atom must differ in at least one quantum number. Pauli exclusion principle states:

" In an atom no two electrons can have the same values of the four quantum numbers."

It can also be stated as:

"An orbital can accommodate no more than two electrons and these electrons must have opposite spins."

Take the example of helium, He, which has two electrons, both the electrons are in 1s orbital.We express this as 1s2. These two electrons have the same three quantum numbers, for both

$n = 1$

$l = 0$

m = 0

But, they differ in the fourth quantum number. If for one electron

s = + 1/2

then for the other s = -1/2

The two electrons having opposite spins are said to be "*paired*", while if there is only one electron in an orbital, it is called "*unpaired*".

(Pauli exclusion principle was put forward by a Swiss physicist Walgang Pauli (1900-1958) in 1925.)

2. Aufbau Principle

(Aufbau is from German aufbauen meaning "to build up"). This principle states:

"In an atom an electron tends to occupy the lowest energy orbital available."

As we go away from the nucleus, the energy of the shells increases. In writing electronic configuration, we start filling electrons from 1s. When it is completely filled, we go to 2s the to 2p and son on. Consider the following:

H (Z =1)	$1s^1$
He (Z = 2)	$1s^2$
Li (Z= 3)	$1s^2, 2s^1$
Be (Z=4)	$1s^2, 2s^2$
B (Z=5)	$1s^2, 2s^2, 2p^1$
C (Z=6)	$1s^2, 2s^2, 2p^2$
N (Z =7)	$1s^2, 2s^2, 2p^3$
O (Z =8)	$1s^2, 2s^2, 2p^4$
F (Z=9)	$1s^2, 2s^2, 2p^5$
Ne (Z=10)	$1s^2, 2s^2, 2p^6$
Na (Z=11)	$1s^2, 2s^2, 2p^6, 3s^1$

(n+*l*) Rule

This rule states: *"The orbital with the lowest energy is the one for which the sum of n and l is lowest. When two orbitals have the same (n + l) value, the orbital with the lower n value has the lower energy."*

Take the example of potassium (K) that has 19 electrons. The first eighteen electrons have the following arrangement:

$$1s^2, 2s^2, 2p^6, 3s^2, 3p^6$$

Where will go the 19th electron, to orbital 3d or 4s? Let us apply ($n+l$) rule, for 3d
$n + l$

$3 + 2 = 5$

and for 4s

$n + l$

$4 + 0 = 4$

Thus, 4s has lower energy than 3d; the 19th electron will go to 4s.

K (Z = 19) $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^1$

4. **Hund's Rule**

All the orbitals in a subshell have equal energy. How are then electrons filled in a subshell? Hund's rule states:

"As long as the orbitals of same energy available, electrons occupy the separate orbitals and have parallel spins."

Atomic Radius

The size of an atom is measured in terms of radius. It is not possible to determine the precise size of an atom since the outermost shell of an atom has no precise outer boundary. As we go away from the nucleus, the electron density decreases to a very small value but it does not become exactly zero even at a large distance from the nucleus. Moreover, we cannot isolate a single atom and measure its diameter the way we can measure the diameter of a football. We can estimate only the radius of a combined atom. Moreover, the size of the electronic cloud also depends upon its environment. In spite of all these difficulties, we talk about the atomic size because it is very useful in understanding many properties of elements. The atomic radius is defined as follows.

"The half of the bond length of a homonuclear diatomic molecule is called the atomic radius of the bonded atoms."

That is, if two atoms of the same element are covalently bonded, the half of the bond length will be the radius of each atom.

For Example, H-H bond length is 0.78 A. The one-half of this distance is 0.37 A. This is the atomic radius of hydrogen. Similarly, the CI-CI bond length is 1.98 A, the atomic radius of CI is 0.99 A. Other atomic radii can be found in a similar way. This atomic radius is the *covalent radius* since it is the radius of an atom involved in a covalent bond, and not the radius of a free atom.

If we know the length of a bond between two dissimilar atoms (A-B), and the radius of one of them, we can calculate the atomic radius of the other:

rA + rB = A-B bond length

Change of atomic radius in the periodic table

1. Atomic radius decreases as we go from left to right in the periodic table. It is because as we go from left to right in a period, the nuclear charge increases. This increasing nuclear

charge pulls the valence electrons with increasing force and as a result the atomic radius decreases from left to right in the periodic table.

2. Atomic radius increases as we go from top to bottom in a group. It is because the number of shells increases in going from top to bottom. The increasing number of shells increases the atomic radius.

Ionic Radius

When one or more electrons are added to an atom, a negative ion, anion, is formed. While, when one or more electrons are removed from an atom, a positive ion, cation, is formed .In general, cations are always smaller than the neutral atoms from which they are formed, whereas, anions are larger than the neutral atoms from which they are formed.
The decrease in the size of a cation is due to two factors: (1) The removal of electron(s) from the outermost shell. Often all the electrons from the outermost shell areremoved which means the removal of a whole shell. (2) the decrease in the total electron-electron repulsion. For example, radius of Na = 1.86 A and that of Na^+ = 0.95 A.

The increase in the size of an anion is due to the added repulsion between the new electrons and the electrons already present. For example, radius of CI=0.99 A and of CI- = 1.81 A.
In a series of ions of different elements having the same number of electrons (isoelectronic ions) the size decreases with the increase in the nuclear charge.

Ionization Energy

Since electrons are attracted by the nucleus, energy must be supplied to remove an electron from an atom. This energy is called ionization energy or ionization potential, and defined as follows:

"The minimum amount of energy required to remove the most loosely bound electron from an isolated gaseous atom in its ground state is called the ionization energy,"

For example, the ionization energy of Na is 495.8 kJ/mol.
An atom has as many ionization energies as it has electrons. The energy required to remove the first electron is called the first ionization energy, the energy required to remove the second electron is known as the second ionization energy, and so forth. For example, for calcium the first ionization energy (IE) is 590 kJ/ mol.

The second ionization energy is 1145 kJ/ mol.
The ionization energy depends on the following factors

1. **Atomic radius**
   The greater the atomic radius, the farther away is the outermost electron from the nucleus, the easier it is to remove it. Thus, lower will be the ionization energy.
2. **Nuclear Charge**
   The greater the nuclear charge, the more attracted will be the electrons by the nucleus, and the higher will be the ionization energy.
3. **Shielding effect**

The intervening shells between the nucleus and the outermost electrons reduce the attraction between the nucleus and the outermost electrons. This effect is known as the *shielding* or *screening effect*. The greater the shielding effect, the easier it will be to remove the electron, and the lower will be the ionization energy. The shielding effect increases from top to bottom in the periodic table with the increase in the number of shells.

4. Type of orbital

The order of ionization energy with respect to orbitals is

$$s > p > d > f$$

It is most difficult to remove an electron from an s orbital because it is least diffused. The f is the most diffused orbital, so it is the easiest to remove an electron from f orbital.

Change of IP in the period table.

In the periodic table the ionization energy increases from left to right due to decrease in the atomic size and increase in the nuclear charge.

From top to bottom in a group, the ionization energy decreases due to increase in the atomic size and increase in the shielding effect.

Electron Affinity

Electron affinity can be defined as follows. When an electron enters an atom, energy is either released or absorbed. This energy is called electron affinity. Thus:

"The amount of energy evolved or absorbed when an electron is added to a gaseous atom in its ground state is called electron affinity."

Electron affinity shows the ability of an atom to accept one or more electrons. When a chlorine atom accepts an electron 348kJ/mol energy is released.

Cl(g) + e ----------------Cl(g) EA= -348 kJ/mol

The halogens that have the most negative electron affinities readily form negative ions. By accepting one electron a halogen atom assumes the stable electronic configuration of the noble gas immediately following it.

In general, electron affinity becomes more and more negative in going from left to right in the periodic table as the nuclear charge increases and the atomic radius decreases.

Some elements gain more than one electrons to form anions. For example, oxygen gains two electrons to form a bivalent anion.

O(g) + e ---------------- O (g) EA = -142 kJ/mol

O(g) + e ---------------- O(g) EA = +780 kJ/mol

In the second step energy is absorbed. Electron affinities of anions are always positive. This is because of the repulsion between the negative ion and the incoming electron.

Problem: (a) Which element should easily form the cation: K (IP= 419kJ/mol or F (IP= 1680kJ/mol)?

(b) Which element should easily form anion: Na (EA= -53kJ/mol) or Br (EA= -324kJ/mol)?

Answer: (a) K, (b) Br.

Lecture # 17

Chemical Bond

How atoms join with each other?

The existence of solids and liquids is a clear proof that atoms combine with one another. But, the question is why atoms combine with one another and how?

Isolated atoms are unstable and to gain stability they combine with one another. This combination is expressed by the term **chemical bond** (theword *bond* means linkage, attachment, connection, etc.). The chemical bond can be defined as follow:

> *"The chemical bond is a force which holds atoms together in a molecule or a compound"*

It was in 1916 that W. Kossel (Germany) and G.N. Lewis (USA) independently proposed that atoms join together through the involvement of electrons. The noble gases (He, Ne, Ar, etc.) are stable, and have eight electrons in their outermost shells (except helium which has two electrons). It was thought that since the noble gases are stable, all elements tend to achieve the noble gas electronic configuration. This is known as the **octet rule**. (Octet: group of eight.) Now, how can atoms achieve eight electrons in their outermost shells? Kossel suggested that this is done by actual transfer of one or more electrons from one atom to another. Lewis proposed that atoms acquire noble gas electronic configuration by mutual sharing of electrons between two atoms. These views gave the two concepts of bonds: *ionic bond,* and *covalentbond.*

Ionic Bond or Electrovalent Bond

The concept of ionic bond was suggested by W. Kossel in 1916. Ionic bond is formed due to *transfer of electrons*. When electrons are transferred from one atom to another, the atom that loses electrons becomes a positive ion and the atom that gains electrons becomes a negative ion. These oppositely charged ions then attract each other and are attached with each other through the opposite electric charges. Thus, we can define the ionic bond as follows:

"The ionic bond is the bond which is formed between oppositely charged ions due to electrostatic force of attraction."

Take the example of NaCl. Sodium atom has one electron in its valence (outermost) shell. Chlorine atom has seven electrons in its outermost shell.

Sodium atom loses its valence electron and becomes a positive ion, while chlorine atom accepts one electron to form a negative ion. These ions attract each other due to their opposite changes to form ionic bond:

$Na \rightarrow Na^{+} + e^{-}$

$Cl + e^{-} \rightarrow Cl^{-}$

$Na^{+} + Cl^{-} \rightarrow Na^{+}Cl^{-} \rightarrow NaCl$

Energetics of Ionic Bond

Why an ionic bond is formed? The natural principle is that every system tends towards more stability. Atoms form bonds to acquire stability. For most cases we can understand stability as a state of less energy.Thus, in general, we can say that every system tends to acquire a state of lower energy. Let us study the energy changes in the formation of NaCl from gaseous sodium and chlorine atoms.

To remove the outermost electron from sodium atom the energy (the ionization energy) required is 494 kJ/mol. When a chlorine atom gains an electron, the energy (electron affinity) released is 348 kJ/mol.

This shows that the ionization energy of sodium is so high that the energy released when a chlorine atom accepts the electron is not sufficient to provide the energy needed to remove the electron from sodium. An additional 495-348 = 147 kJ energy is required to make possible the transfer of one mole of electrons from isolated sodium atoms to isolated chlorine atoms.

These sodium ions and the chloride ions combine together to form solid crystalline sodium chloride. During this step a high amount of energy (788 kJ/mol) is released.

$$Na^{+}(g) + Cl^{-}(g) \rightarrow NaCl(s) \quad \Delta H = -788 \text{ kJ/mol}$$

This energy is known as the **lattice energy**.

"The lattice energy is the amount of energy evolved when one mole of a crystalline ionic compound is formed from its gaseous ions."

The lattice energy here is high because one mole of sodium ions and one mole of chloride ions are arranged in the formation of crystal in such a way that one sodium ion is surrounded by six chloride ions and vice versa. Thus, it is the large lattice energy, which makes the formation of sodium chloride energetically favorable. The lattice energy is, in fact, the driving force behind the formation of sodium chloride from its elements.

In the same way we can understand the formation of any ionic compound. Ionic bond is formed between the elements having large difference of electronegativity, (usually higher than 1.7). In general the elements of group VIIA (halogens) form ionic bond with metals.

Characteristics of Ionic Compounds

1. Ionic Compounds are Non-molecular

An ion attracts the oppositely charged ions from all directions, so the ionic bond is non-directional. When a large number of cations and anions come closer to one another, they arrange themselves in such a way that one ion is surrounded by a number of oppositely charged ions. Each ion is surrounded by the greatest possible number of oppositely charged ions depending on the relative ionic radii of cations and anions. Thus, ionic bonds do not form freely existing particles called molecules. Therefore, ionic compounds do no consist of molecules.

2. Ionic Compounds are Solids

Under ordinary conditions, all ionic compounds are solids. It is because in ionic compounds, ions are held together by strong electrostatic forces of attraction.

3. Ionic compounds have high melting and boiling points

In ionic compounds, the oppositely charged ions are held in the crystal by strong electrostatic forces. Therefore, high energy is needed to overcome the strong electrostatic forces. Thus, the ionic compounds have high melting and boiling points.

4. Ionic compounds are soluble in polar solvents

Polar solvents like water have high *dielectric constants* (the ability of a solvent to decrease the attractive force between the ions dipped in it). Therefore, such solvents break the forces of attraction between the ions and get them dispersed in them. In nonpolar solvents ionic compounds are generally insoluble.

5. **Ionic compounds are electrolytes**

Ionic compounds conduct electricity in their solutions and in molten sates. This is because in solution or in molten state the ions become free from one another and can move under the effect of electric field.

Covalent Bond

The concept of covalent bond was given by G.N. Lewis in 1916. Covalent bond can be defined as follows:

"Covalent bond is the bond which is formed due to sharing of electrons between tow atoms."

Take the example of a hydrogen molecule. Hydrogen atom has one electron in its valence shell:

H (Z = 1) $1s^1$

When two hydrogen atoms come close to each other, they share their electrons to form a covalent bond:

$H^{\cdot} + H^{\cdot} \rightarrow H{:}H$

This *shared pair* of electrons holds the two atoms together; each electron of the pair is attracted by both the nuclei. The shared pair of electrons is also known as *bonding pair* of electrons.

Covalent bond is a *unidirectional* bond and holds the bonded atoms to form a freely exiting particle called a molecule. Therefore, the covalent bond is generally shown by a small line drawn between the symbols of the bonded atoms. The line represents the bonding pair of electrons. Thus

H:H is represented as H–H

Type of Covalent Bond

A covalent bond between two atoms may be formed by mutual sharing of one, two or three pairs of electrons. Therefore, the covalent bonds are of three types.

Single Covalent Bond: The bond that is formed due to sharing of one pair of electrons between two atoms is called the single covalent bond. The H-H bond is a single covalent bond. Similarly, H-C1, Cl-C1, F-F Br-Br are single covalent bonds.

Double Covalent Bond: The bond that is formed due to sharing of two pairs of electrons between two atoms is called a double covalent bond. Each atom contributes two unpaired electrons that are paired with the electrons of the other atom. Take the example of O_2. An oxygen atom has the following electronic configuration.

O $1s^2, 2s^2, 2p_x{}^2, ap_y{}^1, 2p_z{}^1$

It has two unpaired electrons, one in orbital $2p_y$ and other in $2p_z$. Two oxygen atoms share two pairs of electrons to form a double covalent bond:

O:+ :O→ O::O

or

O=O

Similarly, ethene has a carbon-carbon double bond:

$H_2C{=}CH_2$

Triple Covalent Bond

When a bond is formed due to sharing of three pairs of electrons between two atoms, it is called a triple covalent bond. Take the example of N_2. A nitrogen atom (z = 7) has the following electronic configuration:

N $1s^2, 2s^2, 2p_x{}^1, ap_y{}^1, 2p_z{}^1$

It has three unpaired elections. Two nitrogen atoms form a triple bond by sharing three pairs of electrons. Similarly, ethyne has a carbon-carbon triple bond.

Coordinate Covalent Bond

Coordinate covalent bond is a special type of covalent bond, which differs from the simple covalent bond in the *way* of formation:

"The covalent bond between two atoms in which both of the bonding electrons are donated by one of the atoms, is known as the coordinate covalent bond."

The H^+ ion has no electron, yet it forms a bond. For example, it forms a bond with the nitrogen of ammonia. It is because the nitrogen of ammonia has a non-bonding, or lone, pair of electrons which it donates to form a bond with hydrogen ion:

$$H^{+} + :NH_3 \rightarrow NH_4^{+}$$

A coordinate covalent bond is also represented by an arrow sign showing the direction of the donation of electron pair.

The atom that donates the pair of electrons is called the donor, and the atom that accepts the pair of electrons is called the acceptor.

Coordinate covalent bond is also known as *dative* bond or *co-ionic* bond.

Characteristics of Covalent Compounds

1. **Covalent compounds are molecular:** The atoms bonded by covalent bonds form independently existing units known as molecules.
2. **Covalent compounds may be solids, liquids or gases:** The covalent compounds consist of molecules. In gases these molecules are free from one another and exert practically no force of attraction under ordinary conditions. In liquids and solids intermolecular forces of attraction, van der Waals forces, or hydrogen bonds hold the molecules together.
3. **Non-electrolytes:** In general, the covalent compounds arenon-electrolytes**.** Exceptions includeacids and bases.
4. **Insoluble in water:** In general, the covalent compoundsare insoluble in polar solvents like water, and soluble in nonpolar solvents like organic liquids.

Electronegativity

A shared pair of electrons is attracted by both of the bonded atoms. For example in H:C1 both H and C1 attract the bonding pair. This power of an atom to attract the bonding pair of electrons is called electronegativity, which can be defined as follows:

"The ability of an atom to attract the shared pair of electrons towards it is known as electronegativity."

Fluorine is the most electronegative element. Its electronegativity is 4. Then comes oxygen whose electronegativity is 3.5.

Polar and Nonpolar Bonds

If two bonded atoms have equal electronegativity, the bonding electrons pair will be shared equally between the two atoms. In other words, the electron density of the bonding electron pair is distributed equally and symmetrically between the two atoms. Such a bond is known as a nonpolar bond. Thus;

" the bond between two atoms having equal electronegativity is a nonpolar bond."

For example, C1-C1, O=O, N=N bonds are nonpolar bonds.

On the other hand, if the atoms forming a bond have different electronegativities, the bonding pair is shared unequally. The more electronegative atom acquires a greater share of the bonding electrons as compared to the less electronegative atom. Due to this the more electronegative atom acquires a partial negative charge and the less electronegative atom acquiresa partial positive charge. These charges are of equal magnitude, and the overall charge is zero. Such a bond is known as a polar bond. It has negative and positive poles. Thus:

"The polar bond is the bond between two atoms having differentelectronegativities."

Take the example of H–C1. Chlorine is more electronegative than hydrogen. Thus, the bonding pair of electrons is shared unequally, and chlorine has greater share of electrons than hydrogen. As a result, chlorine is partially negatively charged and hydrogen is partially positively charge.

Problem:

Which of the following molecules are polar and which are nonpolar?

$BeCl_2$, H_2S, CS_2, BF_3, NH_3, PCl_3

Answers:

$BeCl_2$ is a linear molecule, and is nonpolar.

H_2S is an angular molecule (like H_2O) with polar bonds, so it is polar.

CS_2 is a linear molecule (like CO_2), so it is nonpolar.

BF_3 is a trigonal planar molecule. Its bond moments cancel one another so the molecule is nonpolar.

PCl_3 is also a trigonal pyramidal molecule (like NH_3) and is polar.

Bond length

"The distance between the nuclei of two bonded atoms is called the bond length".

The bond length of a single bond is longer than a double bond, which in turn is longer than a triple bond.

Bond Energy

When a bond is formed between two atoms a certain amount of energy is released during this process. When that bond is broken the same amount of energy is required to do so. This energy is known as bond energy

"The bond energy is the energy evolved when a bond is formed between two atoms."

Or

"The bond energy is the energy required to break a bond between two atoms."

The bond energy is also known as *bond dissociation energy*.

The Modern Concept of covalent Bonding

There are two important modern concepts of chemical bonding, both are based on the quantum mechanics: valence bond theory (VBT), and molecular orbital theory (MOT). According to VBT

"a covalent bond between two atoms is formed due to the overlap of two half-filled orbitals, one from each atom."

Molecular orbital theory (MOT) treats a molecule like an atom. An atom consists of atomic orbitals surrounding a nucleus. Likewise, a molecule consists of molecular orbitals surrounding two or more nuclei present in the molecule. Atomic orbitals are monocentric, they surround only one nucleus while the molecular orbitals are polycentric, and surround more than one nuclei.

Summary: A chemical bond is the force which holds atoms together.The bond may be ionic or covalent. Ionic bond is formed by the transfer of 1 or more electrons and covalent bond is formed by the sharing of electrons.In ionic bond there is complete transfer of electrons which result in formation of positive and negative ions which are called cations and anions these cations and anions are held together by the strong electrostatic force of attraction. So the ionic bond is very strong bond.The electrons which are present in the outer most shell of an element are called valence electrons. It the valence electrons which take part in bonding, for example there are one valence electrons in Na and seven in Cl.

Differentiation between ionic and covalent bond:

- Ionic compounds have ionic compounds while covalent compounds have covalent bonds.
- Since in ionic compounds, ions are held together through very strong electrostatic forces, ionic compounds are solids at room temperature. Whereas covalent compounds consist of molecules which are held together through weak inter molecular force, there for they may be solids, liquids or gases.
- Ionic compounds have higher melting and boiling points than covalent compounds.
- In general, ionic compounds are soluble in water and insoluble in organic solvents. While covalent compounds are generally insoluble in water and soluble in organic solvents.
- Ionic compounds don't conduct electricity as such but do so in molten state. Covalent compounds don't conduct electricity in general.

Explain bond formation in H2 and NaCl?

H_2 In H2 two hydrogen atoms are held together through a covalent bond. Each hydrogen atom contributed 1 electron. So there are two shared electrons this is known as a shared pair of electrons. It is this shared pair of electrons which holds two H atoms together.

$H^{\cdot} + H^{\cdot} \rightarrow$ H–H

NaCl In NaCl there is ionic bond Na^+ is positive ion while Cl^- is negative ion, these ions are held together through very strong electrostatic force of attraction.

$Na^+ + Cl^- \rightarrow NaCl$

Lecture 18

Chemical Reactions

Chemical Reactions:

A chemical reaction is a chemical change in which one or more substances change into one or more other substances. In other words, a chemical reaction is a process in which one or more bonds are broken and one or more bonds are formed. For example, rusting of iron is a chemical reaction. Similarly burning of natural gas is a chemical reaction.

Chemical and physical change:

During a chemical change a new substance is formed while during a physical change no new substance is formed. For example, burning of wood is a chemical change while change of water into ice is a physical change. During a chemical change a chemical reaction occurs whereas during a physical change no chemical reaction occurs. Chemical change is generally a permanent change, while physical change is only a temporary change and can be reversed easily.

Chemical property of a substance is a property in which that substance undergoes a chemical change. For example, it is a chemical property of an acid to react with a base and form salt and water.

Exothermic and endothermic reactions:

When a chemical reaction takes place, change in energy also occurs. The reaction during which heat is evolved is called an **exothermic reaction**. On the other hand, the reaction during which heat is absorbed is called an **endothermic reaction.**

Heat of reaction:

When a chemical reaction occurs, certain amount of heat is either evolved or absorbed. This amount of heat which is evolved or absorbed during a chemical reaction is known as heat of reaction. It is also known as enthalpy of reaction and is denoted by ΔH. Its units are joules per mole or Kcal per mole.

Types of Reactions:

There are a number of types of reactions.

1. **Addition reactions:** the reactions in which two or more substance react to form a single substance. Ethene reacts with hydrogen to form ethane.

$$C_2H_4 + H_2 \rightarrow C_2H_6$$

2. **Substitution reaction:** the reactions in which one substance is replaced by another substance from a molecule:

$$CH_3\text{-}Cl + NaOH \rightarrow CH_3\text{-}OH + NaCl$$

This reaction is also known as double displacement reaction.

3. **Elimination reaction:** the reactions in which one or more atoms are eliminated from a molecule. For example, removal of H_2O from ethanol to form ethene.

$$CH_3\text{-}CH_2\text{-}OH \rightarrow CH_2{=}CH_2 + H_2O$$

4. **Oxidation-Reduction Reactions**

Many reactions involve transfer of electrons from one atom to another atom. These reactions are known as **oxidation-reductionreactions.** The loss of electrons from an atom is known as **oxidation**, while the gain of electrons by an atom is called **reduction.** Oxidation and reduction always take place simultaneously and the extent of oxidation is equal to the extent of reduction. That is, the loss of electrons is equal to the gain of electrons. The substance that undergoes oxidation is known as the **reducing agent**, and the substance that undergoes reduction is known as the **oxidizing agent.**

5. **Combustion reactions:** combustion means burning, and it is the reaction of a substance with oxygen. In a combustion reaction heat is produced. For example, the reaction of methane with oxygen is a combustion reaction.

   $CH_4 + O_2 \rightarrow CO_2 + H_2O$

   Generally in a combustion reaction, carbon dioxide and water are produced.

6. **Neutralization reactions:**

   When an acidic solution is added to a basic solution in the right proportion, the properties of each are lost, and a salt and water are formed. This process is called **neutralization.**

   "The reaction between an acid and a base that forms a salt and water is called neutralization".

   For Example,

   $HCl\ (aq) + NaOH\ (aq) \rightarrow NaCl\ (aq) + H_2O$

   $HNO_3\ (aq) + NaOH\ (aq) \rightarrow NaNO_3\ (aq) + H_2O$

Chemical reactions may occur in solution or gaseous form. Generally, the chemical reactions are carried out in solution. Water and organic solvents are used for this purpose.

Rate of Reaction:

When a reaction occurs, one or more bonds are broken and then one or more bonds are formed. This process of bond breakage and formation takes some time. How much a reactant changes into a product in a given time is important. By the rate of reaction we mean the amount of reactant that is converted to product per unit time. It can also be defined on the bases of the appearance of a product. So, the rate of a reaction is the amount of product formed per unit time.

The rate of reaction is also called speed or velocity of reaction. It is measured in moles/seconds. Thus, the rate of a reaction is the amount of product which is formed in one second.

Rate of Reaction = concentration of product formed/time

On the basis of the rate of reactions, we can classify the reactions into the following categories.

- Very slow reactions: some reactions are very slow. For example, conversion of graphite into diamond in the earth crust is a very slow process.

- Slow reactions: some reactions occur with slow speed, e.g. rusting of iron is a slow process.
- Moderate reactions: most organic reactions occur with moderate speed.
- Fast reactions: many reactions occur with a fast speed. Strong acid strong base reactions are fast reactions.
- Very fast reactions: some reactions are very fast such as explosions.

Lecture # 19
Mixture and Solution

Mixture:

A mixture is a “mixed” substance which obtained on mixing two are more substances without undergoing any chemical reaction.

Types of mixtures: Mixtures are of two types:

- Homogenous Mixtures
- Heterogeneous. Mixtures

Homogeneous mixture

A Homogeneous mixture has uniform composition throughout its body. They are known as solutions. For example, when sugar or salt is dissolved in water it forms a solution in which the sugar or salt and water are uniformly mixed (the sugar or salt is dissolved uniformly in water). Another common example is air.

Heterogeneous mixture

A Heterogeneous mixture is that which does not have uniform composition. e.g. granite which consists of quartz, feldspar and mica and you can identify each of the substances separately in the mixture.

Heterogeneous mixtures can be suspensions or colloids.

Solution:

“A solution is a homogenous mixture of atoms, ions or molecules of two or more substances.”

A homogenous mixture is that which has uniform composition throughout its body. In other words, it has only one phase. Suppose, we stir some sugar into a glass of water. The grains of sugar disappear and we have a clear liquid that looks just like pure water. The sugar molecules have dispersed among the water molecules, and sugar and water thus form a solution.

Types of solution

Solutions can be classified on the basis of their state: solid, liquid, or gas. Thus there are nine types of solutions. The most common type of solutions is a solid dissolved in liquids. The liquid is mostly water.

Solvent and Solute

The solvent is the component of a solution that is visualized as dissolving another component called a solute. Usually the component present in the larger quantity is called the solvent, and the component present in the smaller quantity is called the solute.

Concentration and its units

By concentration we mean the relative amounts of the components of a solution. It tells us the ratio of the quantity of one component to the quantity of the other or to the total quantity of solution. It has many units. Some common units are discussed below.

Percentage

The ratio of the mass of the solute to the mass of the solution multiplied by 100 is called mass percentage.

$$\text{Mass Percentage of a solute} = \frac{\text{Mass of the solute}}{\text{Mass of solution}} \times 100$$

Example

A solution contains 25 grams of sugar in 150 grams of water. What is the %age by mass of sugar in the solution? (14.3%)

For liquid-liquid solutions, it is sometimes more convenient to express the concentration in the units of percentage by volume:

$$\text{Volume Percentage of a liquid} = \frac{\text{Volume of the liquid}}{\text{Total volume}} \times 100$$

Example

A solution of 10 ml acetone and 50 ml water was prepared. Calculate the percentage by volume of acetone. (16.67%)

Molarity (M)

Molarity is the most common unit of concentration used in chemistry.

"Molarity or the molar concentration is the number of moles of solute dissolved per dm^3 of solution". (1 dm^3 is equal to 1 Liter)

Thus

$$\text{Molarity} = \frac{\text{Number of moles of solute}}{\text{Volume of solution in liters}}$$

Example: 15g of NaOH were dissolved in enough water to prepare 100 cm^3solution. Calculate the molarity of NaOH. (3.75 mol/dm^3)

Molarity (m)

"Molarity is the number of moles of solute dissolved per kilogram of solvent".

Example: 15 g of NaOH was dissolved in 100 g of water. Calculate the molality of NaOH. (3.75 mol/Kg)

Molality is independent of temperature as it is mass-to-mass ratio, while molarity is temperature dependent as it is mass to volume ratio.

Solubility and Saturation

This is an important question that how much a solute at maximum can be dissolved in a given quantity of a solvent. The maximum amount of a solute dissolved in a given amount of a solvent is called **solubility** of that solute. It can be precisely defined as follows:

"*The solubility of a solute in a given solvent is the concentration of that solute in its saturated solution at a specific temperature*".

Solubility can be expressed in any of the units of concentration. However, it is commonly expressed in grams per dm^3.

"A saturated solution is the solution which can dissolve no more amount of the solute, at the given temperature".

If we start slowly adding sugar (sucrose) to water taken in a beaker. At first it dissolves rapidly, but then gradually the dissolution process becomes slow. The continued addition of sugar eventually brings the solution to saturation, after which any additional sugar simply falls to the bottom of the container where it remains undissolved. At this point, there is an equilibrium between the excess undissolved solute and the dissolved one.

This solution of sugar is said to be saturated, and the concentration of sugar in this solution is called its solubility.

Dissociation of Solutes

When sugar dissolves in water, the solute particles that are dispersed through out the resulting solution are sugar molecules. On the other hand many solids (electrolytes) undergo dissociation or ionization when dissolve. For example, NaCl forms sodium and chlorine ions in solution.

The solubility of NaCl at 25^oC have been estimated to be 5 mol/dm^3 or 292.5 g/dm^3.

Sparingly Soluble Substances

The substances that have very low solubility are known as **sparingly soluble** or slightly soluble substances. Example, AgCl.

Hydration

When an ionizable substance (an acid, base or salt) is added to water to form a solution, it breaks up into ions. The ions are surrounded or encaged by water molecules due to attraction between the ions and water molecules. This process is known as hydration.

Water is a polar molecule in which the hydrogen atoms are partially positively charged and the oxygen atom is partially negatively charged. Being polar, water molecules surround the ions dipped in it. Thus, in water solution all cations and anions are hydrated. The cations are attracted by the negative ends (oxygen) of water molecules and the anions are attracted by the positive ends of the water molecules (hydrogens).

Water of hydration

Water can become incorporated in solid compounds by occupying specific crystal sites in the solid without being strongly bonded to a specific atom. This water is called water of hydration or water of crystallization. The compounds having water of hydration are called hydrates. Some examples are $CaSO_4.2H_2O$, $CuSO_4.5H_2O$, $CaC1_2.6H_2O$. Many hydrates lose their water of hydration upon heating and form anhydrous compounds. For example, crystalline copper sulfate pentahydrate (blue) changes into anhydrous copper sulfate (white) on heating.

Hydrolysis

"The reaction of water with an anion or a cation or both of a salt causing a change in the pH is called hydrolysis".

Colloids:

Colloids form the dividing line between solutions and heterogeneous mixture. They are not true solution. In colloids the disperse particles are larger than typical molecules. In colloids we don't have solute or solvent. Rather, we have dispersed phase and dispersion medium colloids scattered light. This is called Tyndal effect.

Solution	Colloid
i. This is the homogeneous and stable mixture of a solute in solvent.	i. This is the heterogeneous and stable mixture of particles in the solvent.
ii. Particle sizes of solutes are very small does not visible under light microscope.	ii. Particles are larger sized and visible through the light microscope.
iii. Solute evenly distributed does not show. Brownian movement, tyndal effect etc.	iii. Particles are remaining scattered does not steeled down longer perion. They show Brownian motion and exhibit tyndal effect.

What is a saturated solution?

A saturated solution is that solution which cannot dissolve more solute at a given temperature. If in such a solution you add more solute at that temperature, it will not dissolve and will settle down at the bottom.Thus, the solution which can not dissolve more solute at a particular temperature is called a saturated solution.

What is solubility?

The amount of solute needed to form a saturated solution in a given quantity of solvent at specific temperature is called the solubility of that solute in that solvent at temperature. In other words solubility is the maximum amount of solute that will dissolve in a given amount of solvent at a particular temperature.

How molarity is different from molality?

Molarity is a unit of concentration. It is the number of moles of solute present per litter of solution.

Molality is another unit of concentration. It is the number of moles of solute present per Kg of solvent. So, molarity is mass per volume whereas molality is mass per mass. Therefore, molarity varies with temperature but there is no effect of temperature on molality.

Lecture # 20
Acids, Bases and Salts

Arrhenius concept of acid and base:
According to Arrhenius theory an acid is substance which produces H^+ ions when dissolved in water, examples; HCl, HNO_3 etc.

$HCl \rightarrow H+ \quad + \quad Cl^-$

According to this theory a base is a substance which produces OH^- when dissolved in water. Examples includeNaOH and KOH.

$NaOH \rightarrow Na^+ \quad + \quad OH^-$

When an acid and a base react, they cancel each other. This reaction is known as neutralization and in neutralization reaction a salt and water is formed. Example;

$HCl + NaOH \longrightarrow NaCl + H_2O$
Acid Base Salt Water

Some bases	Their uses
Ammonia (NH_3)	Production of fertilizers (ammonium and nitrate salts), used in the manufacture of nitric acid, neutralize the acid (in the petroleum industry) and prevent premature coagulation in natural / synthetic latex.
Aluminium hydroxide ($Al(OH)_3$)	Manufacture other aluminium compound and to make gastric medicine (antacid)
Calcium hydroxide ($Ca(OH)_2$)	To make cement, limewater, neutralize the acidity of soil and application of sewage treatment.
Sodium hydroxide (NaOH)	Used in the manufacturing of soaps, detergents, and cleaners.

Lowry-Bronsted concept of acid and base:
According to Lowry-Bronsted concept, an acid is a proton donor and a base is a proton acceptor. When acid-base reaction occurs, another set of acid and base is formed. They are called **conjugate** acids and bases.

Example: When HCl is dissolved in water the following reaction occurs.

$HCl + H_2O \longrightarrow H_3O^+ + Cl^-$

Hydronium (H_3O^+) ion is a **conjugate** acid whereasCl^- ion is conjugate base.

Reaction of acids with metals:
$Al + HCl \longrightarrow AlCl_3 + H_2$
$Mg + H_2SO_4 \longrightarrow MgSO_4 + H_{2s}$

$Fe + H_2SO_4 \longrightarrow FeSO_4 + H_2$

Acid-base reactions:

$NaOH + HNO_3 \longrightarrow NaNO_3 + H_2O$

$KOH + CH_3COOH \longrightarrow CH_3COOK + H_2O$

Reactions of acids with metal oxides:

$Al_2O_3 + 6HCl \longrightarrow 2AlCl_3 + 3H_2O$

$3K_2O + 2H_3PO_4 \longrightarrow 2K_3PO_4 + 3H_2O$

Acid and Base Strength

According to **Arrhenius definitions**, an acid furnishes H^+ ions and a base furnishes OH^- ions in their aqueous solutions. For example:

$HCI(g) \rightarrow H^+ (aq) + CI^- (aq)$

$NaOH (s) \rightarrow Na^+ (aq) + OH^- (aq)$

However, all acids, and all bases are not equally strong. The strength of an acid or a base is estimated by a number of parameters, such as:

1. Degree of dissociation
2. Percent degree of dissociation
3. Dissociation constant

Degree of dissociation

It tells us how fast an acid or base undergo dissociation of ionization when they are put in water. Degree of dissociation is the ratio of the number of the moles or molecules dissociated and the total number of the moles or molecules initially taken. Thus

$$\text{Degree of Dissociation} = \frac{\text{Number of moles dissociated}}{\text{Total Number of moles taken}}$$

The higher the degree of dissociation of an acid or a base, the stronger they are. The maximum value of the degree of dissociation is 1.

Percentage Degree of Dissociation

Percent degree of dissociation is obtained by multiplying the degree of dissociation by 100.

Strong acids and bases are almost 100% dissociated in water, while weak acids and bases are not 100% dissociated. HCI, HNO_3, NaOH and KOH are almost 100% dissociated in dilute water solution, while CH_3COOH is only 1.4% and NH_4OH is again 1.4% dissociated.

Dissociation Constant (Ka and Kb)

According to Lowry-Bronsted concept an acid is a proton donor. Thus, in general, an acid, HA, forms the following equilibrium in water:

$$HA + H_2O \rightleftharpoons A^- + H_3O^+$$

The equilibrium constant expression for this reaction is:

$$K_c = \frac{[A^-][H_3O^+]}{[HA][H_2O]}$$

Water is present in large amount so its concentration is almost constant. Thus, the product Kc $[H_2O]$ is also constant and known as the dissociation constant of an acid and is given the symbol K_a.

$$K_a = \frac{[A^-][H^+]}{[HA]}$$

Strong acids, such as HCI, HNO_3 have very large values of dissociation constants. While weak acids have very small values of Ka, for example:

CH_3COOH	K_a	=	1.8×10^{-5}
HCN	K_a	=	4.9×10^{-10}
H_2O	K_a	=	1.0×10^{-14}

According to Lowry-Bronsted concept a base is a proton acceptor. Thus, in general, a base, B, reacts with water as follows:

$$B + H_2O \rightleftharpoons BH^+ + OH^-$$

pH and pOH

Pure water is only about $2x10^{-7}$ percent dissociated (self-dissociation) into ions at 25^oC.

$$H_2O \rightleftharpoons H^+ (aq) + OH^- (aq)$$

Then, the equilibrium constant, Kc, is

$$Kc = \frac{[H^+][OH^-]}{[H_2O]}$$

Since water is in excess, $[H_2O]$ is constant:

$$K_c[H_2O] = [H^+][OH^-] = K_w$$

Thus, $K_w = [H^+][OH^-]$

K_w is known as **ionic product** of water. Its value has been experimentally found as:

$K_w = 1x10^{-14}\ mol^2\ dm^{-6}$

Or $K_w = 1 \text{ x } 10^{-14}\ mol^2\ lit^{-2}$

In pure water (or in a neutral aqueous solution)

$$[H^+] = [OH^-] = 10^{-7} mol/dm^3$$

The H^+ ion concentration in solution can range from more than 10 mol/dm^3 to less than $1x10^{-15} mol/dm^3$. The pH scale was devised as a convenient way of expressing such a wide range of concentration. The pH is defined as follows:

"*The pH of a solution is the negative logarithm to the base*

10 of the hydrogen ion (or hydronium ion) concentration".

Mathematically,

$$pH = -\log_{10}[H^+]$$

$$\text{or} \quad pH = -\log_{10}[H_3O^+]$$

The concept of the pH was proposed in 1909 by the Danish chemist Soren Sorenson (1868-1939).

In the same way we can also define pOH.

$$pOH = -\log[OH^-]$$

$$pH = pK_a + \log\frac{[A^-]}{[HA]}$$

Table: 7.1 pH, pOH, (25oC), and H+ ion, oH ion concentration

	[H+], M	pH	[OH], M	pOH	
More acidic ↑	10	-1	10-15	15	More acidic ↑
	1	0	10-14	14	
	10-1	1	10-13	13	
	10-2	2	10-12	12	
	10-3	3	10-11	11	
	10-4	4	10-10	10	
	10-5	5	10-9	9	
	10-6	6	10-8	8	
Neutral	10-7	7	10-7	7	Neutral
More basic ↑	10-8	8	10-6	6	More basic ↑
	10-9	9	10-5	5	
	10-10	10	10-4	4	
	10-11	11	10-3	3	
	10-12	12	10-2	2	
	10-13	13	10-1	1	
	10-14	14	1	0	
	10-15	15	10	-1	

At 25 ^{o}C,

$$[H+][OH-] = 1 \times 10^{-14}$$

$$pH + pOH = 14$$

Thus,

The pH of a neutral solution is 7, the pH of acids is less than 7 while that of bases is higher than 7.

Problem:

What is the pH of a 0.016 mol/dm^3 solution of NaOH?

Solution:

NaOH is a strong base and dissociates almost 100% to form OH^- ions, thus

$$[OH^-] = [NaOH]$$
$$= 0.016 \text{ mol/dm}^3$$

Therefore,

$$pOH = -\log [OH^-]$$
$$= -\log 0.016$$
$$= 1.8$$
$$pH + pOH = 14$$
$$pH = 14 - pOH$$
$$= 14 - 1.8$$
$$= 12.2$$

Measurement of pH

The pH of a solution can be determined by two general methods:

1. Indicators 2. pH meters

Indicators

Indicators are chemical compounds which change colour with pH and thus give an approximate value of the pH of a given solution. There are a number of indicators. A special indicator is the universal indicator, which is a mixture of several indicators that has several colour changes over a wide range of pH.

pH Meters

A pH meter is an electrical instrument that employs two electrodes to measure the potential difference between the solution to be tested and a standard solution of known pH. This potential difference is related to the pH of the solution being tested. The pH is read directly from the dial of the instrument.

Common Indicators:

To determine the end-point in an acid-base titration or to determine the pH of a solution, various compounds are used, that are called indicators. Broadly speaking, *"an indicator is any compoundwhich changes colour with the change in pH"*. An acid-base indicator is a weak acid (or base) whose colour is different from that of its conjugate base (or acid). Take the example of phenolphthalein (C20H13O4H):

$$C_{20}H_{13}O_4H\ (aq) \rightarrow C_{20}H_{13}O_4^-\ (aq) + H^+\ (aq)$$

(colourless) (red) conjugate base

Table: Some indicators and their colour changes

Indicators	Approximate pH range	Corresponding coloru change
Methyl orange	3.1 – 4.4	Orange to yellow
Bromophenol blue	3.8. - 4.6	Yellow to blue
Methyl red	4.4 – 6.2	Red to yellow
Phenolphthalein	8.0 – 10.0	Colourless to red

A paper strip impregnated with a universal indicator is often used. This is known as pH paper. When a part of this strip is dipped in a solution, the paper shows a colour from which the pH can be judged.

Neutralization

When an acidic solution is added to a basic solution in the right proportion, the properties of each are lost, and a salt and water are formed. This process is called **neutralization.**

"The reaction between an acid and a base that forms a salt and water is called neutralization".

For Example,

$$HCI\ (aq) + NaOH\ (aq) \rightarrow NaCI\ (aq) + H_2O$$

$$HNO_3\ (aq) + NaOH\ (aq) \rightarrow NaNO_3\ (aq) + H_2O$$

Buffers or Buffer Solutions

Normally, solutions change their pH when an acid or a base is added to them. For example, pure water, when kept open, changes its pH from neutral to acidic due to the absorption of CO_2 from air forming carbonic acid (H_2CO_3).

However, there are certain solutions, which tend to maintain their pH. These are known as **buffers** or **buffer solutions**.

Definition:

"A buffer solution is a solution which undergoes only a slight change of pH when an acid or a base is added to it".

A buffer offers resistance against any change in its pH.

Most commonly:

"A buffer solution is a solution of a weak acid and a salt of it, or a buffer solution is a solution of a weak base and a salt of it."

For example, a solution of acetic acid and sodium acetate forms a buffer:

($CH_3COOH + CH_3COONa$) solution

and a solution of ammonium hydroxide and ammonium chloride forms a buffer:

($NH_4OH + NH_4CI$) solution

Buffers maintain their pH upon addition of acids or bases by shifting equilibrium position.

Buffers play a very important role in many chemical and biological processes. For example, the control of the pH is very important in the treatment of sewage in electroplating, and in the manufacturing of photographic materials. Maintaining a constant pH is essential for many metabolic processes; the pH of the blood has to be close to 7.4 and the pH of saliva is close to 6.8.

Oxidation and Reduction

Many reactions involve transfer of electrons from one atom to another atom. These reactions are known as **oxidation-reductionreactions.** The loss of electrons from an atom is known as **oxidation**, while the gain of electrons by an atom is called **reduction.** Oxidation and reduction always take place simultaneously and the extent of oxidation is equal to the extent of reduction. That is, the loss of electrons is equal to the gain of electrons. The substance that undergoes oxidation is known as the **reducing agent**, and the substance that undergoes reduction is known as the **oxidizing agent.**

Oxidation Number

A very important question is how to decide whether a given reaction is an oxidation-reduction reaction or not. To recognize such reactions, we can use the concept of **oxidation number**, also known as oxidation state:

"The oxidation number of an atom is an apparent charge that is assigned to it on the basis of certain rules."

For compounds, the oxidation number may be defined as follows:

"Oxidation number of an atom in a compound is the apparent charge on the atom if both electrons of each bond are arbitrarily assigned to the atom of higher electronegativity".

The oxidation number is not the real electrical charge. It is the charge that *would be* associated with a particular atom if we assign both the electrons of each bond to the atom of higher electronegativity. The oxidation number is the measure of the extent or degree of oxidation of an element in its compounds.

Lecture # 21

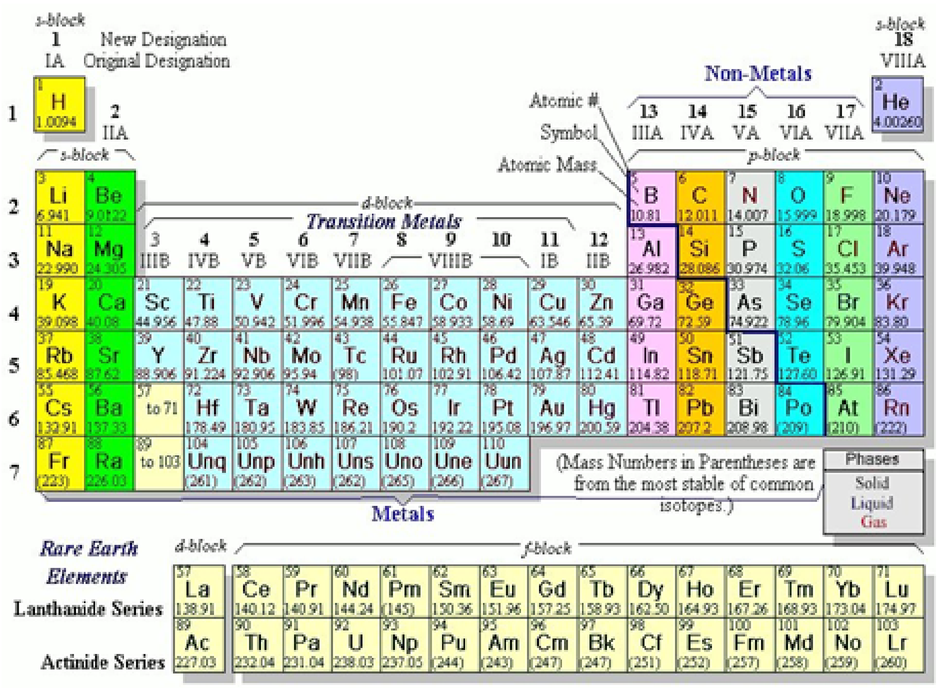
Metals and Nonmetals

The modern classification of elements is based on the modern **periodic law**.

The modern periodic law states that the physical and chemical properties of elements are the periodic function of their atomic numbers.

When elements are arranged on the basis of the modern periodic law, we get modern periodic table.

In the modern periodic table the elements are arranged in the order of increasing atomic number. When the elements are arranged in the order of increasing atomic number, the elements with similar properties appear at definite intervals. When elements with similar properties are placed in the same column, we get groups or families of elements having similar properties. Thus, in the modern periodic table, we have vertical columns and horizontal rows. The horizontal rows are also called periods.



Periods in the periodic table:

Rows of elements are called periods. There are 7 period in the periodic table. The number of elements in a period increases as you move down the periodic table.

Groups in the periodic table:

Columns of elements in the periodic table are called groups. Elements within a group show similarity in properties. In a group, the elements have the same outer electron arrangement. The outermost electrons are called valence electrons. Why the elements belonging to the same group have similar properties? It is because they have the same number of valence electrons.

Representative elements: In the periodic table there are two sets of groups. The group A elements are called the representative elements. The group B elements are the non-representative elements. Representative elements are named after the first element of the group. So we have, lithium family, beryllium family, boron family, carbon family, nitrogen family, oxygen family, fluorine family or halogens, and helium family or noble gases. Group IA and IIA are also called alkali metals and alkaline earth metals respectively.

Transition metals:

The transition elements are located in groups IB to VIIIB. Copper, zinc, iron, silver, mercury and gold are examples of transition metals. These elements are very hard, with high melting points and boiling points. The transition metals are good electrical conductors and are very malleable.

Periodic properties:

There are a number of properties which change in a definite manner as we move from one end to the other end of periodic table. Such properties are called periodic properties. Periodic properties include: atomic and ionic radii, melting points and boiling points, metallic character, ionization potential, electron affinity, electronegativity, etc. take the example of electronegativity. The electronegativity of an element is the ability of the element with which it attracts the shared pair of electrons towards it. The electronegativity increases as we go from left to right in the periodic table. It decreases from top to bottom in a group.

Physical states of elements:

Most elements in the periodic table are solids. At room temperature all metals are solids except mercury. Only a few elements are liquids such as bromine and mercury. Some elements are gases. These are nonmetals. Nitrogen, oxygen, fluorine, chlorine and noble gases are found in gases state at room temperature.

Ores:

An ore is a material that contains a metal in such quantities that it can be mined and worked commercially to extract that metal.

Metals are not found in free state. They are found in the form of minerals and ores.

The metal is usually contained in chemical combination with some other element in addition to various impurities. For example, iron is found in the form of ores such as hematite (Fe2O3), magnetite (Fe3O4), limonite (FeO(OH).n(H_2O)).

Properties of metals and nonmetals (ref. (http://chemistry.about.com/od/periodictableelements/a/Metals-And-Nonmetals.htm)

Metal Physical Properties

- lustrous (shiny)
- good conductors of heat and electricity
- high melting point
- high density (heavy for their size)
- malleable (can be hammered)
- ductile (can be drawn into wires)
- usually solid at room temperature (an exception is mercury)
- opaque as a thin sheet (can't see through metals)
- metals are sonorous or make a bell-like sound when struck

Metal Chemical Properties

- have 1-3 electrons in the outer shell of each metal atom
- corrode easily (e.g., damaged by oxidation such as tarnish or rust)
- lose electrons easily
- form oxides that are basic
- have lower electronegativities
- are good reducing agents

Nonmetals

Nonmetal Physical Properties

- not lustrous (dull appearance)
- poor conductors of heat and electricity
- non-ductile solids
- brittle solids
- may be solids, liquids or gases at room temperature
- transparent as a thin sheet
- nonmetals are not sonorous

Nonmetal Chemical Properties

- usually have 4-8 electrons in their outer shell
- readily gain or share valence electrons
- form oxides that are acidic
- have higher electronegativities
- are good oxidizing agents

Metalloids or semimetals:

There are some elements which have properties between metals and nonmetals. They are called metalloids or semimetals. The metalloids or semimetals are located along the line between the metals and nonmetals in the periodic table. The metalloids are boron, silicon, germanium, arsenic, antimony, and tellurium.

- Electronegativities between those of metals and nonmetals
- Ionization energies between those of metals and nonmetals
- Possess some characteristics of metals/some of nonmetals
- Reactivity depends on properties of other elements in reaction
- Often make good semiconductors

Metals are generally good conductor of electricity. It is because metal has free electrons in it, according to modern bonding concepts metals have a special type of bond which is called metallic bond. The metal atom held together in a way there valence electrons are delocalized and free to move in the entire crystal. This is known as sea model. These free electrons help in conduction of electricity.

For example cooper wires are commonly used to conduct electricity because they have free electrons which conduct electricity.

On the other hand most nonmetals are poor conductor of electricity it is because they donot possess free electrons like metals. Some nonmetals do conduct electricity. For example, Graphite has layer structure and posses free electrons which conduct electricity.

Chemical properties:

Differences between Metals and Nonmetals

Metals	Nonmetals
Lose their valence electrons easily.	Gain or share valence electrons easily.
Form oxides that are basic.	Form oxides that are acidic.
Are good reducing agents.	Are good oxidizing agents.
Have lower electro negativities	Have higher electro negativities
Usually have 1-3 electrons in their outer shell.	Usually have 4-8 electrons in their outer shell.

Physical properties

How can you compare physical properties of Metals and Nonmetals? Some differences are given below:

Metals	Nonmetals
Good electrical conductors and heat conductors.	Poor conductors of heat and electricity.
Malleable - can be beaten into thin sheets.	Brittle - if a solid.
Ductile - can be stretched into wire.	Non-ductile.
Possess metallic luster.	Do not possess metallic luster.
Opaque as thin sheet.	Transparent as a thin sheet.

Lecture # 22

Metallurgy of Copper & Aluminum

Almost all metals are found in the combined state as compounds on the crust of the earth. So we have to extract them. This process of metal extraction is called Metallurgy.

Metallurgy is the science and art of extracting a metal from its ores and carrying out different processes to bring metals into their useful forms. Thus, the various processes involved in the extraction of metals from their ores and refining them are broadly known as metallurgy.

Minerals: The natural materials in which the metals or their compounds occur in the earth are called minerals.

Ores: Those minerals from which the metals can be extracted profitably are called ores.

Gangue or Matrix: The rocky impurities, including silica and earthly particles, present in an ore are called gangue or matrix.

Metallurgy of Aluminium:

Aluminum is the most abundant metal. It is the third most abundant element in the earth crust (about 7%). Aluminium is a reactive metal and so does not occur free in nature. It occurs in clays in the form of aluminium silicates.

Ores of aluminium:

Aluminium has a number of ores. Some important ores are as follows:

1. Oxide Ores:

    Bauxite, $Al_2O_3.xH_2O$

    Corundum, Al_2O_3

2. Fluoride Ore:

    Cryolite, $3NaF.AlF_3$ or Na_3AlF_6

3. Silicate Ores:

   Kaolin,$Al_2O_3.2SiO_2.2H_2O$

   Potash mica, $K_2O.3Al_2O_3.6SiO_2.2H_2O$

Extraction of aluminium:

(Ref: **http://www.s-cool.co.uk/gcse/chemistry/extraction-of-metals/revise-it/the-electrolysis-of-bauxite)**

Aluminium is commonly extracted from its ore bauxite. The bauxite (red-brown solid) - aluminium oxide mixed with impurities - is extracted from the earth.The extracted aluminium oxide is then treated with alkali, to remove the impurities. This results in a white solid called aluminium oxide or alumina.The alumina is then transported to huge tanks. The tanks are lined with graphite, this acts as the cathode. Also blocks of graphite hang in the middle of the tank, and acts as anodes.The alumina is then dissolved in molten cryolite - this lowers the melting point.

Electricity is passed and electrolysis begins. Electrolysis is the decomposition of a compound using electricity.

When dissolved, the aluminium ions and oxide ions in the alumina can move.

Reaction at Cathode:

$$4Al^{+} + 12e^{-} \longrightarrow 4Al(s)$$

Reaction at Anode:

$$3C + 6O^{2-} \longrightarrow 3CO_2\,(g) + 12e^{-}$$

Purification of Bauxite:

Bauxite when obtained from the earth crust contains many ipurities such as ferric oxide, silica, and titanium oxide. These impurities are removed. Baeyer process is commonly used for the purification of bauxite. In this process, the ore is treated with concentrated NaOHsolution called caustic soda. The following reaction takes place:

$$Al_2O_3 + 2NaOH \longrightarrow 2Na[Al(OH)_4](aq)$$

Then CO_2 is passed.

Reaction with CO_2

$$2Al(OH)_4^- + CO_2 \longrightarrow 2Al(OH)_3(s) + CO_3^{2-} + H_2O$$

The product is filtered and heated at 1000 °C. The process is called calcination. As a result of this process, pure alumina is obtained.

$$Al(OH)_3 + Heat \longrightarrow Al_2O_3\ (s) + 3H_2O\ (g)$$

Now we have pure alumina.

Electrolysis of Alumina to obtain Aluminium:

The process used for the electrolysis of alumina is called Hall’s process. Alumina is aluminium oxide, Al_2O_3. This is subjected to electrolysis. The cell used for electrolysis is a steel container whose inner surface is lined with graphite. The powdered alumina is mixed with fused cryolite and fluorspar. The melting point of alumina is very high, but it dissolves in molten cryolite at about 1000 °C. when electricity is passed, aluminium is deposited at the graphite cathode. From there it is drawn out in molten form**.**This aluminium is 99% pure. Further purification is carried out through a process called Hoope’s method.

Refining of Aluminium:

In the Hoope’s process, aluminium is purified by electrolytic method. For this purpose a box-like cell is used. The cell is operated in a manner that in it three layers are maintained. The lower layer consists of impure aluminum alloyed with copper. The middle layer consists of a solution of cryolite and barium fluoride. The upper layer consists of pure aluminium. Theselayers remain separated due to difference is specific gravity. The lower layer acts as anode where aluminium is oxidized and Al^{3+} ions move toward the upper layer which is negatively charged. This layer acts as cathode and when Al^{3+} ions reach in this layer they gain electrons and are deposited as aluminium metal there.

Reaction at Anode:

$Al \rightarrow Al^{3+}$ + $3e^-$

Reaction at cathode:

Al^{3+} + $3e^- \rightarrow$ Al (pure aluminium)

The aluminium obtained in this process is about 99.99% pure.

Metallurgy of Copper:

Copper is a common metal. It is used for a wide variety of purposes. It is a good conductor of electricity so its wires are used in electrical appliance and cables.

Over 360 ores of Copper are known. Some important ores are as follows:

Sulfide ores:

Copper pyrite or chalcopyrite, CuS.FeS or $CuFeS_2$

Chalcocite, Cu2S

Carbonate ores:

Malachite, $CuCO_3.Cu(OH)_2$

Azurite, $2CuCO_3.Cu(OH)_2$

Oxide ores: Cuprite, Cu_2O

Extraction of Copper:

Extraction of copper is good example of pyrometallurgy. In the metallurgy of copper the following steps are commonly used:

- Mining of ore from its mines
- Crushing and grinding of the ore
- Concentration of the ore and its purification
- Chemical process to obtain metal from the ore
- Purification of the metal

- Conversion of the metal into alloys

Important process employed in the extraction of copper:

- Concentration through Froth-flotation
- Roasting
- Smelting
- Reduction (Bessemerization)
- Refining

<u>Concentration by Froth flotation method:</u>

By concentration here we mean to free the ore from impurities. Copper is commonly extracted from copper pyrite. Copper pyrite is concentrated by a process called froth-floatation. Ore is crushed and ground to make a powder. This is placed in a large tank containing water and oil (such as pine oil). The mixture is stirred by blowing air through it. The ore is wetted by oil and rises to the surface from where it is skimmed off. The impurities (called gangue) are wetted with water settle down at the bottom.

<u>Roasting</u>:

By roasting here we mean heating in air strongly but below the melting point of the ore. As a result, impurities are converted into silicate slag. The slag floats at the surface from where it is removed. The ore undergoes the following reaction:

$$CuS.FeS + 4O_2 \longrightarrow Cu_2S\ (s) + 2FeO\ (s) + 3SO_2\ (g)$$

<u>Smelting</u>:

By smelting here we mean heating the product obtained from roasting strongly in a Reverberatory furnace. The product from the roasting is mixed with silica (SiO2) and heated at 1100 °C. Following reaction takes place in the furnace:

$$FeO + SiO_2 \longrightarrow FeSiO_3$$

Ferrous silicate is formed which is a slag. It is less dense that molten copper matte, Cu_2S, and so floats the surface from where it is removed.

<u>Reduction (Bessemerization):</u>

Molten copper(I) sulfide, Cu_2S, is put in Bessemer converter and heated strongly. As a result of this elemental copper is produced. The copper obtained is called the blistered copper.

$$2Cu_2S + 3O_2 \longrightarrow 2Cu_2O + 2SO_2$$

$$2Cu_2O(l) + Cu_2S(l) \longrightarrow 6Cu\ (l) + SO_2(g)$$

This copper is called blistered copper because it has blisters on it which are produced due to evolution of sulfur dioxide. When copper solidifies, sulfur dioxide escapes from it and produces blisters. Blistered copper is about 99% pure.

Refining of Copper:

Copper is refined by electrolytic process. In the electrolytic cell CuSO4 solution is used as an electrolyte. Impure copper is used to act as anode, while pure copper is used to act as a cathode. At anode, copper atoms lose electrons and become copper ions. These copper ions move through the solution and reach at the cathode. At cathode these copper ions gain electrons and deposit there a atoms. So in this way refined copper is obtained which is almost 100% pure.

Reaction at Anode:

$Cu \rightarrow Cu^{2+} + 2e^-$

Reaction at Cathode:

$Cu^{2+} + 2e^- \rightarrow Cu\ (s)$ pure copper

Summary GSC101 lecture # 23

Lecture 9

Iron and its Metallurgy

Ores:
An ore is the naturally occurring compound of a metal from which that metal can be extracted. In the earth crust, metals are generally found in the form of compounds which are found mixed with other substances these naturally occurring minerals of metals are called ores. For example; halite is an ore of Na and hematite and magnetite are the ores of Fe.

Alloys:
A material that has metallic properties and is composed of two or more chemical elements of which at least one is a metal (i.e. steel is an alloy of carbon in iron; stainless steel is an alloy of carbon, chromium and sometimes nickel in iron.)

Metallurgy:
It is the science and art of obtaining a metal from its ores. There are number of types of metallurgy.
In electrometallurgy, electricity is used to obtain a metal. Electrolysis is carried out of the molten or solution form of the ore and metal is obtained at the cathode. For example; Na is obtained by the electrolysis of NaCl by the Downs process.

In pyrometallurgy strong heat is used to extract a metal from its ores. For example, Fe is extracted from its ores by heating at high temperature.

Iron is extracted through pyrometallurgy in a furnace called Blast Furnace. Commonly hematite and magnetite are used to obtain iron. A number of reactions occurs at high temperature in the blast furnace.

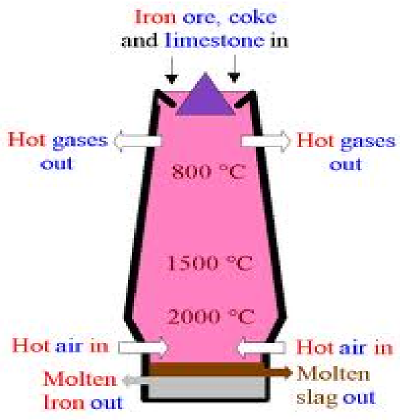
The reactions occurring in blast furnace are as follows.

- Reactions in blast furnace:

  $Fe_2O_3 + CO \rightarrow 2Fe_3O_4 + CO_2\ (g)$

  $Fe_3O_4 + CO \rightarrow 3FeO + CO_2\ (g)$

  $FeO + CO \rightarrow Fe(l) + CO_2\ (g)$



Iron is a common metal. It has been known since prehistoric ages. Iron is soft, malleable, and ductile.

Occurrence:

Iron is a common metal. How it occurs?

- Metallic iron occurs in the free state in only a few localities in the world.
- In chemical compounds the metal is widely distributed.
- After aluminum, iron is the most abundant of all metals, and ranks fourth in abundance among all the elements in the earth's crust.
- It is found in meteorites, usually alloyed with nickel.
- Iron is found in the earth crust in the form of ores. Its principal ore is hematite and other important ores are magnetite, siderite, and limonite.
- Pyrite, FeS, the sulfide ore of iron, is not processed as an iron ore because it is too difficult to remove the sulfur.
- Small amounts of iron occur in combination in natural waters, in plants, and as a constituent of blood.

Physical properties of Iron metal:

What are the common physical properties of iron?

- The atomic number of iron is 26, and atomic weight is 55.847.
- Pure iron melts at about 1535° C and boils at 2750° C.
- The specific gravity of iron is 7.86.
- It is a metal which is easily magnetized at ordinary temperatures, but at about 790° C the magnetic property of iron disappears.

Chemical Properties:

Describe some common properties of iron.

➢ Iron reacts with a number of elements. For example, it make compounds with the halogens (fluorine, chlorine, bromine, iodine), sulfur, phosphorus, carbon, and silicon.

- Iron reacts with acids and displaces hydrogen from dilute acids.
- It reacts with oxygen to form ferrosoferric oxide, Fe_3O_4.
- Rust: When exposed to moist air, iron undergoes deterioration or corrosion and forms a reddish-brown, flaky, hydrated ferric oxide commonly known as rust.
- When iron is dipped into concentrated nitric acid, it forms a layer of oxide that renders it *passive*—that is, it does not react chemically with acids or other substances.

Give some uses of iron:

- Iron has a wide variety of applications. It is used in processed forms, such as wrought iron, cast iron, and steel.
- Commercially pure iron is used for the production of galvanized sheet metal and of electromagnets.
- Many compounds of iron are used in different purposes. Ferrous sulfate (FeSO4), which is also called green vitriol or copperas. It is used as a mordant in dyeing, as a tonic medicine, and in the manufacture of ink and pigments.

Metallurgy of Iron: what are the reactions that take place in the Blast Furnace?

- Combustion of Coke
  $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$ + heat
  $CO_{2(g)} + C_{(s)} \rightarrow 2CO_{(g)}$
- Reduction of Fe_2O_3
  $2Fe_2O_{3(s)} + 3C_{(s)} \rightarrow 4Fe_{(l)} + 3CO_{2(g)}$
  $Fe_2O_{3(s)} + 3CO_{(g)} \rightarrow 4Fe_{(l)} + 3CO_{2(g)}$
- Calcination
  $CaCO_{3(s)}$ + heat $\rightarrow CaO_{(s)} + CO_{2(g)}$
- Slag formation
  $CaO_{(s)} + SiO_{2(s)} \rightarrow CaSiO_{3(l)}$ (slag)
  $CaO_{(s)} + Al_2O_{3(s)} \rightarrow Ca(AlO_2)_{2(l)}$

What are the Products which are formed in the Blast Furnace?

- Pig iron - 93-95% Fe, 3-5% C, 1% Si, 0.1- 0.3% P, <1% S
- Waste gases – CO_2 and CO
- Slag – $CaSiO_3$ and $Ca(AlO_2)_2$

Pig Iron:

Pig iron usually refers to the iron alloy with carbon content of the 2 to 4.3%, also known as cast iron. Besides carbon, pig iron also contains silicon, manganese and small amounts of sulfur and phosphorus. It cannot be forged, but can be cast. According to the presence of carbon under the different forms, pig iron can be divided into steel making pig iron, foundry pig iron and ductile iron.

What is cast iron?

This is pig iron melted with scrap Iron. It is the least pure of all forms of iron containing 93% Fe and 5% C.

The cast iron with carbon content of less than 0.2% is called wrought iron or pure iron. The cast iron with carbon content of 0.2-1.7% is called cast steel. So, cast steel is a kind of special cast iron. More than 2% of content is called pig iron.

What is wrought iron?

It is the purest form of iron produced when impurities are removed. It contains 0.5% impurities. Wrought iron is very soft, plastic and easily deformed, but its strength and hardness are lower, so not widely used.

What is steel?

Steel is a common form of iron which usually contains 0.1 to 2% carbon. Steel has many types. Since the pure iron metal is not very strong, impurities are added into it.
For example, carbon is added in iron to make steel which is much stronger than iron.

Summary GSC101 lecture # 23

Lecture 10

Corrosion and its Prevention

We all are aware of the rusting of iron. In the same manner most other metals also deteriorate with time. This process is called corrosion.

Corrosion occurs in all substances. It is the chemical or electrochemical reaction between a material, usually a metal, and its environment that produces a deterioration of the material and its properties. However, the term is commonly used with reference to metals. It can be broadly defined as follows.

"The deterioration of a metal as a result of its reaction with the environment is called corrosion".

Chemically corrosion is an oxidation process that occurs at the surface of a metal. The rusting of iron, tarnishing of silver, the development of a green coating on copper are well known forms of corrosion. Corrosion is a great cause of the damage of metallic articles. Bridges, ships, vehicles, and other metallic things suffer from corrosion badly.

Sources of Corrosion:

Following are the common causes or sources of corrosion.

- Contact with atmosphere
- Submersion in water or water solutions
- Underground soil attack.
- Contact with chemicals.

There are two major factors which increase the rate of corrosion rapidly. They are;

- Temperature
- Moisture

Rate of corrosion:

Corrosion is a chemical process. It is an oxidation-reduction reaction that occurs at the surface of a metal. In this process the metal undergoes oxidation. Different metal corrode with different speeds. Gold is so stable that it does not corrode. Alkali metals like sodium and potassium corrode rapidly when exposed to atmosphere. Iron corrodes slowly, and silver, copper and tin corrode very slowly.

Rusting of Iron:

The corrosion of major concern is the rusting of iron. It is the cause of huge economic loss every year. From common person to big industries all suffer from corrosion in one way or the other. Now the question is what the rust is.

Rusting is a chemical reaction. When iron cones in contact with oxygen and moisture it is oxidized to hydrated ferric oxidized, $Fe_2O_3.xH_2O$. This is rust. This substance is porous and flaky. So it is removed away continuously. Thus the whole metal is eaten away.

Iron + Oxygen + Water ==> Hydrated Iron(III) oxide

Protection of iron form Rusting:

The protection of corrosion can be classified as follows:

- Active corrosion protection
- Passive corrosion protection
- Permanent corrosion protection
- Temporary corrosion protection

Active corrosion protection:

The aim of active corrosion protection is to influence the reactions which proceed during corrosion. It is possible to control the corrosion reaction in such a manner that corrosion is avoided. Examples of such an approach are the development of corrosion-resistant alloys and the addition of such materials to the metal which can inhibit corrosion.

Passive corrosion protection:

In passive corrosion protection, the metal is mechanically isolated from the damaging environment. For example by using protective layers, films or other coatings rusting can be avoided.

Permanent corrosion protection:

The purpose of permanent corrosion protection methods is mainly to provide protection at the place of use. Machines are located, for example, in factory sheds and are thus protected from extreme variations in temperature, which are frequently the cause of condensation.

Prevention of Corrosion:

There are a number of methods which are used to avoid or slow down corrosion in a metal and rusting of iron in particular.

Protective metallic coating:

In this method a metal is coated with a thin layer of another metal which is resistant to corrosion. Rusting of iron can be prevented by coating it with tin, zinc or chromium. Tin plating is a well known technique. In this technique, a layer of tin is applied on the surface of ion container. Tin cans are good example. When zinc is coated on iron, the process is called galvanizing, and the iron coated with zinc is called galvanized iron. However, zinc is not used in food cans because it readily reacts with acids found in food stuff and fruit juices.

Coating with paints:

Metal can be protected against corrosion by applying acoating of paints on their surfaces. For this purpose, any paint can be used. However, red lead and zinc chromate are commonly used. Grease, plastic emulsions, and enamels can also be used for this purpose. Oiling is a common household and small scale industrial method to protect small tools from rusting.

Cathode Protection:

Corrosion is actually an electrochemical process. During the corrosion reaction the metal plays the role of anode where oxidation occurs which eats out the metal. If we connect iron through a conductor to a more reactive metal in a manner that the electrical circuit is established, then oxidation will occur on the other metal and iron will be acting as cathode. This method will then protect iron from corroding. For example, if an underground iron pipe is connected to a zinc rod. The zinc rod will undergo corrosion and iron will not. This method can be used to protect ship and underground foundations of bridges from rusting.

Alloying:

Many metals can be made more resistant to corrosion by making their alloys. Steel, bronze, brass are metal alloys and are more stable than their pure metals.

Stain less steel is an alloy of iron. A wide variety of stainless steels are made today for different purposes. The common stain less steel has the following composition. C = 0.18 %, Cr = 18 %, Ni = 8 %, rest is iron or Fe. Stainless steel is used to make surgical instrument and cutlery etc.

Applications of Alloys:

Alloys are very important, as they have special properties and are more viable and useful than the pure metals. They have greater resistance to corrosion. For example, steel is mire resistance to corrosion than pure iron.

Many alloys also have useful magnetic properties. For example, **Alnico**has a strong magnetic properties. It is **Fe-Al-Ni-Co**.

Very hard steel is used to make jaws of rock crushers. It has Manganese and Vanadium.

Some alloys also have attractive colours, For example, Au-Cu is an alloy which has red or yellow colour.

Tin plating and methods of tin plating:

The art of applying tin on the surface of a metal is called tin plating. The purpose of tin plating is to protect the metal from corrosion. Tin plating of iron is very common.

There are a number of ways to coat tin on iron.

Electroplating is commonly used for large scale tin plating. This is an electrolytic process. For this purpose, an electrolytic cell is made in the cathode is made of iron sheet and tin is used as anode. The electrolytic solution contains a salt of tin such as tin sulfate or tin chloride. When electric current is passed, tin ions move to the iron cathode and are deposited on it. In this way a layer of tin is coated on the surface of iron sheet.

Another method to coat tin layer on iron surface is **hot-dip method**. In this method, sheets of iron are dipped in molten tin.

Classical method of tin plating is a manual technique. A metal tool or article is polished with tin with the help of a rag or brush. Traditionally, brass and copper utensils are tin plated by this method.

Stainless steel:

Steel is an alloy of iron. There are many types of steel. A very useful type of steel is the stainless steel. It is so called because it is resistant to corrosion or rusting. The composition of common stainless steel is as follows: chromium 18%, nickel 8% and carbon 0.18 %.

The stainless steel is hard and has a high tensile strength. Why it is resistant to rusting? This is due to the thin film of chromium oxide which is developed on the surface due to the reaction of chromium with oxygen. This is hard and tough film and does not corrode.

Applications of Stainless Steel:

- It is used to make cutlery
- It is used to make surgical instruments
- It is also used to make different household utensils and containers.
- It is also used to make automobiles parts, decoration aricles and electronic appliances.

Summary GSC101 lecture # 23

Lecture 11

Hydrogen and Oxygen

In this lecture we will discuss two important elements, namely hydrogen and oxygen.

Hydrogen:
Hydrogen is unique element. Its atom is the smallest atom and has only 1 proton and 1 electron. It is generally placed at the top of group IA along with alkali metals but it is not a metal and it is not fully justified to place it in group IA.

Hydrogen is the most abundant element in the universe. The stars are mostly composed of hydrogen. In the earth crust hydrogen is found in the form of compounds. The most abundant compound of hydrogen is H_2O. Petroleum and natural gas also contains hydrogen. Hydrogen is also a part of organic compounds.

Isotopes of hydrogen: Hydrogen exists in the form of three isotopes. They are ordinary hydrogen or protium, heavy hydrogen or deuterium, and radioactive hydrogen or tritium.

Industrial Preparation of hydrogen:

On large scale hydrogen is prepared by a number of process. Some of them are discussed below.

- **Electrolysis of Water:**

  In this method, electricity is passed through water containing a small amount of sulfuric acid. Hydrogen is obtained at cathode. At anode oxygen is obtained.

  $$2H_2O \rightarrow 2H_2 + O_2$$

- **Coke and Steam Process:**

  Coke (a form of carbon) is mixed with steam and strongly heated. Water gas is produced which is a mixture of carbon monoxide and hydrogen

$$C + H_2O \xrightarrow{1200\,°C} [CO + H_2] \text{ Water gas}$$

gas.

How to separate H_2 from CO ?
(1) Liquefaction process: the b.p. of CO = -192 °C andb.p. of H_2 = -253 °C. When this mixture is liquefied, CO first liquefies and thus separated leaving behind hydrogen gas.
(2) Bosch Process:

Then more steam is added and the mixture is heated strongly in the presence of ferric oxide. A mixture of carbon dioxide and hydrogen gas is obtained. This is known as Bosch process.

$$CO + H_2 + H_2O \xrightarrow[Fe_2O_3]{1000\ ^\circ C} CO_2 + 2H_2$$

How to separate CO_2?

Carbon dioxide is separated by passing the mixture through water under pressure. Carbon dioxide is dissolved in water and hydrogen is liberated.

- **Steam and hydrocarbon process:**

In this process a mixture of methane and steam is passed over a nickel catalyst at about 900 C under high pressure. A mixture of carbon monoxide and hydrogen gas is obtained.

$CH_4 + H_2O \rightarrow CO + 3H_2$

Carbon monoxide is separated by the method discussed above.

Laboratory Preparation:

In the laboratory, hydrogen gas can be prepared by the action of a dilute solution of a strong acid on reactive metals like zinc.

Action of dil. Acids on metals:

- $Zn + 2HCl \longrightarrow ZnCl_2 + H_2\ (g)$
- $Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2\ (g)$

Action of Water on CaH_2

$CaH_2 + 2H_2O$ $Ca(OH)_2 + 2H_2\ (g)$

Chemical reactions of hydrogen:

1. Reaction with Oxygen: Burning of H_2

   $2H_2 + O_2 \longrightarrow 2H_2O + \text{Heat}$

2. Reaction with N_2

   $3H_2 + N_2 \longrightarrow 2NH_3$

3. Reaction with Sulfur

   $H_2 + S \longrightarrow H_2S$

4. Reaction with Phosphorus

   $3H_2 + 2P \longrightarrow 2PH_3$

5. Reaction with Chlorine

$H_2 + Cl2 \longrightarrow 2HCl$

Applications of H_2

- Preparation of NH_3 (heating H_2 and N_2at 500 °C using Fe_2O_3/Al_2O_3 as catalyst. The process is called Haber process.
- Preparation of HCl: Hydrogen gas is reacted with chlorine gas to obtain HCl.
- Preparation of methanol: heating water gas with ZnO_2/Cr_2O_3catalyst:

  $CO + 2H_2 \longrightarrow CH_3OH$

- Hydrogenation of vegetable oils to ghee

Hydrides:

The binary compounds of hydrogen with other elements are called hydrides. Hydrogen reacts with almost all elements and forms binary compounds. Common examples are H_2O, NH_3, HX (X is a halogen), CH_4 and other hydrocarbons.

Ionic Hydrides: With alkali metals and calcium, hydrogen forms ionic hydrides.

$2Li + H_2 \rightarrow 2LiH$

$2Na + H_2 \rightarrow 2NaH$

$Ca + H_2 \rightarrow CaH_2$

They are ionic compounds and show typical properties of ionic compounds.

Covalent Hydrides: The hydrides of p-Block elements are covalent hydrides.

Common examples: CH_4, NH_3, H_2O, HCl, PH_3, H_2S, HBr, HI.

They are molecular. Have low b.p., m.p.

Metallic hydrides: The hydrides of transition metals are called metallic hydrides.

They are non-stoichiometric.They are interstitial compounds and they retain properties of the original metal.

Complex hydrides: common examples are $LiAlH_4NaBH_4$

Nascent Hydrogen: The hydrogen at the time of its generatioin in a reaction is called nascent hydrogen. It is atomic hydrogen. It may react with any reactant available, or atomic hydrogen may produce hydrogen gas. For example:

$Zn + 2HCl \rightarrow ZnCl_2 + 2[H]$

$2[H] \rightarrow H_2$

Oxygen:

Oxygen is a common element. In the earth crust, it is the most abundant element. Oxygen atom has 8 protons and 8 electrons. Common isotope of oxygen has 8 neutrons. Molecular formula of oxygen gas is O_2. Oxygen gas is about 20% of the air by volume. Oxygen is necessary for life. Most organic compounds also contain oxygen.

Characteristics of Oxygen:

- Abundance: most abundant in Earth crust, 50%
- In the air: 21% by volume
- Most abundant compounds: H_2O, SiO_2
- In the periodic table, group VIA,
- Electronegativity: 3.4.
- Electronic configuration:
- O_2 is paramagnetic

Allotropes of Oxygen: there are two allotropes of oxygen:

- Ordinary oxygen, dioxygen, oxygen gas, O_2
- Ozone, O_3

Formation of O^{2-} ions: oxygen has high electron affinity, so it absorbs electrons. Absorption of first electron is exothermic while that of the second electron is endothermic.

$$O + 2e^- \rightarrow O^{2-}$$

Preparation of Oxygen:

Laboratory preparation: By heating potassium chlorate using MnO_2 as catalyst: heated at 240°C

$2KClO_3 \rightarrow 2KCl + 3O_2$ (g)

Industrial preparation: On the industrial scale, oxygen is prepared by the following methods.

- **Electrolysis of water:** Electrolysis of water produces hydrogen and oxygen gases.
- **Liquefaction of air:** The major components of air are oxygen and nitrogen. Their boiling points are given below.

b.p. of O_2 = -183°C

b.p. of N_2 = -196°C

So these gases can be separated by liquefaction.

Chemical properties:

Oxygen is a reactive element and reacts with almost all metals and non-metals, the compounds the oxygen formed with other elements are of different types.

1. Reaction with C, S, P, H_2 oxides are formed.

   $C + O2 \rightarrow CO2$

   $S + O2 \rightarrow SO2$

   $P4 + 5O2 \rightarrow P4O10$

   $2H2 + O2 \rightarrow 2H2O$

2. With sodium

The following reaction occurs at room temperature:

$4Na + O_2 \rightarrow 2Na_2O$ sodium oxide

At higher temperature:

$2Na + O_2 \rightarrow Na_2O_2$

sodium peroxide

3. With potassium

Potassium reacts with oxygen to for superoxide:

$K + O_2 \rightarrow KO_2$ potassium superoxide

4. With Mg, Ca and Ba

   $2Ca + O_2 \rightarrow 2\ CaO$

5. Reaction with Fe

   $2Fe + O_2 \rightarrow 2FeO$

$4FeO + O_2 \rightarrow 2Fe_2O_3$

6. Reaction with CH4 (Combustion)

   CH4 and other hydrocarbons burn:

   $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ + Heat

Oxides: The binary compounds of oxygen:

The binary compounds of oxygen with other elements called oxides. Oxides are of three types.

1. Normal oxides; in which the oxidation number of oxygen is -2.
2. Peroxides; in which the oxidation number of oxygen.
3. Super oxides; in which the oxidation number of oxygen is -1/2

Normal oxides are very conmen. H_2O, CO_2, NO_2 are its examples. H_2O_2 is hydrogen per oxide. KO_2 is potassium super oxide.

Types of Oxides:

1. Covalent oxides or acidic oxides. They are oxides of nonmetals, CO2, H2O, NO2, SO2, etc. When dissolved in water, they form acids:

   $CO2 + H2O \rightarrow H2CO3$

   $SO2 + H2O \rightarrow H2SO3$

   $SO3 + H2O \rightarrow H2SO4$

2. Basic oxides: The basic oxides are the oxides of metals. They react with water to form bases:

   $Na2O + H2O \rightarrow 2NaOH$

   $CaO + H2O \rightarrow Ca(OH)2$

   $BaO + H2O \rightarrow Ba(OH)2$

Interesting chemistry of KO_2: How O_2gas is produced in rescue masks? It is done by the reaction of K_2O with water:

$4KO_2 + 2H_2O \rightarrow 4KOH + 3O_2$

$2KOH + CO_2 \rightarrow K_2CO_3 + H_2O$

Applications of Oxygen gas:

1. Oxidizing agent: it is used in steel making, and is used to burn impurities.
2. To bleach pulp and paper (oxidation of coloured compounds usually gives colourless products).
3. Medical use (to ease breathing difficulties)
4. To produce oxy-acetylene flame

   2C2H2 + 5O2 → 4CO2 + 2H2O
5. To produce oxy-hydrogen flame

Compounds of Oxygen: Sulfuric Acid

Preparation of H2SO4 by Contact Process involves the following reactions:

1. **S + O2 → SO2**
2. **$2SO_2$ O_2 → $2SO_3$ Catalyst: V_2O_5**
3. **SO_3 + H_2SO_4 + $H_2S_2O_7$**
4. **$H_2S_2O_7$ + H_2O → $2H_2SO_4$**

Summary GSC101 lecture # 26

Chemistry Lecture 12

Nitrogen

Nitrogen is a common element, it occurs in the form of element and compounds. Nitrogen gas is composed of N_2 molecules. Nitrogen gas is found 78% by volume in air. Nitrogen molecule N_2 is very stable because there is a triple bond which binds nitrogen atoms together. In the triple bond, 1 bond is sigma and other 2 bonds are pi bonds. Nitrogen compounds are numerous; examples includeammonia, urea and nitric acid. Many organic compounds also contain nitrogen.Naturally occurring minerals of nitrogen are saltpeters KNO_3 and $NaNO_3$.

Laboratory preparation of nitrogen gas: By heating NH_4NO_2 which is prepared by the action of ammonium chloride with sodium nitrite:

$NH_4Cl + NaNO_2 \rightarrow NH_4NO_2 + NaCl$

$NH_4NO_2 \rightarrow N_2 + 2H_2O$

Large scale obtaining: On large scale nitrogen gas is obtained by liquefaction of air:

b.p. of O_2 = -183°C

b.p. of N_2 = -196°C

Chemical Properties:

1. Reaction with oxygen:

   $N_2 + O_2 \rightarrow 2NO$ heating at 1500-2000 °C

2. Heating with Mg, Ca, B

   Nitrides are formed: BN (boron nitride), Ca_3N_2 (calcium nitride)
3. Reaction with H_2 (Haber process) produces ammonia (NH_3).

Applications of Nitrogen gas:

1. Nitrogen is used to prepare ammonia which is then used to prepare nitric acid and fertilizer.
2. It is used as an inert gaseous blanket to exclude O_2 to a processing and packaging of foods.
3. Liquid nitrogen is used as a coolant to freeze foods rapidly.

Ammonia, NH_3

Ammonia is a base. It is because it has a lone pair of electrons which can be donated to a proton, thus ammonia is electron pair donor or it is an proton acceptor.

$$N_2 + H^+ \longrightarrow NH_4^+$$

Ammonia is a binary compound of nitrogen and hydrogen. Its molecular formula is NH_3. It is prepared on industrial scale by the method called Haber process. In this process nitrogen is reacted with hydrogen in the presence of catalyst Fe2O3/ Al2O3.

$$N_2 + 3H_2 \longrightarrow 2NH_3$$

The reactants are heated at 500 ^{0}C.

Laboratory preparation of ammonia:

In the laboratory ammonia can be prepared by the action of base on ammonium chloride.

1. $NH_4Cl + NaOH \longrightarrow NH_3 + NaCl + H_2O$
2. $NH_4Cl + Ca(OH)_2 \longrightarrow NH_3 +$ H2O $+ CaCl_2$

Nitric Acid, HNO_3

Nitric acid is an important compound of nitrogen. It is one of the common acids used extensively in laboratories and industries.

Preparation of Nitric acid:

Nitric acid is prepared industrially by a method known as **Ostwald's method**.

In this method nitric acid is prepared by the oxidation of ammonia.

There are three main steps:

1. Oxidation of ammonia to nitric oxide

2. Oxidation of nitric oxide to NO_2.
3. Reaction of NO_2 with water to produce nitric acid.

Chemical reactions are shown by the chemical equations as follows:

$$4NH_3 + 5O_2 \longrightarrow 4NO + 6H_2O$$

$$2NO + O_2 \longrightarrow 2NO_2$$

$$3NO_2 + H_2O \longrightarrow 2HNO_3 + NO$$

Summary GSC101 lecture # 27

Chemistry Lecture # 13

Halogens and Chlorine gas

The elements of group VII are called halogens, which means salt formers. Halogens include the following elements:

1. Fluorine (F)
2. Chlorine (Cl)
3. Bromine (Br)
4. Iodine (I)
5. Astatine (At)

Atomic Numbers of Halogens are given below along with the name of the element:

1. F Fluorine (9)
2. Cl Chlorine (17)
3. Br Bromine (35)
4. I iodine (53)
5. At Astatine (85

Occurrence: halogens occur in the form of different compounds in the earth crust.

1. Salts e.g., NaCl, Br^- , I^-
2. Fluorspar, CaF_2
3. Cryolite, Na_3AlF_6,
4. Fluorapatite, $Ca_5(PO_4)_3F$

Halogens form diatomic molecules: F_2 Cl_2 Br_2 I_2

Physical States: In their elemental forms, halogens occur as diatomic molecules. They have different physical states. Fluorine and chlorine are gases, bromine is a liquid and iodine is a solid.

Electronegativity: The electronegativity of an element is the ability of the element to attract the shared pair of electrons toward it. The halogens are very electronegative elements. Fluorine has the highest electronegativity among all the elements. The electronegativity values of halogens are given below:

1. F 4.0
2. Cl 3.0

3. Br 2.8
4. I 2.5

Electron affinity: The electron affinity of an element is the energy absorbed or evolved when an electron enters into an atom of the element. A halogen atom absorbs an electron to make a negative ion (anion). During this process energy is evolved. Electron affinity values of halogens are given below:

	Electron affinity (kJ/mol)
F	-333
Cl	-348
Br	-324
I	-295

Chlorine gas (Cl_2)

In this lecture we will study chlorine as a typical halogen. Chlorine is a yellowish green coloured gas.

Laboratory preparation: In the laboratory, chlorine gas is prepared by the action of hydrochloric acid on manganese dioxide.

$4HCl + MnO_2 \rightarrow MnCl_2 + 2H_2O + Cl_2(g)$

Industrial preparation:

On the industrial scale chlorine gas is prepared by sodium chloride.

1. Electrolysis of molten NaCl (Downs Cell Process):

It may be prepared by the electrolysis of molten NaCl. For this purpose a special electrolytic cell is used which is called Downs cell and the process thus is called the Downs cell process. The melting point of NaCl is 801°C, which is a very high temperature. To lower the melting point of NaCl, calcium chloride is added. The electrolytic mixture in the Downs cell contains 40% NaCl and 60% $CaCl_2$. Chlorine gas is obtained at anode.

$$2NaCl \rightarrow 2Na + Cl_2(g)$$

2. Electrolysis of Brine (Castner-Kellner Cell Process): In this method aqueous solution of sodium chloride (common salt) is electrolyzed. The aqueous solution of NaCl is called brine. Chlorine gas is obtained at the anode. In the Castner-Kellner cell Moving mercury cathode is used. Sodium is discharge at the mercury electrode and forms sodium amalgam. The sodium amalgam is taken into another compartment where it react with water to produce NaOH and hydrogen gas. Mercury is recirculated.

$$2NaCl + 2H_2O \rightarrow 2NaOH + H_2(g) + Cl_2(g)$$

Physical properties:

1. Chlorine is a greenish yellow gas.
2. It has pungent smell.
3. Chlorine is a toxic gas. If it comes in contact, it produces inflammation of lungs, throat and nose.
4. Its boiling point is -34.6 C, and melting point is -101.6C.
5. It is fairly soluble in water.

Chemical properties of Chlorine gas:

Chlorine is a reactive gas. It reacts with many metals and non-metals. It also reacts with compounds.

Reactions with metals:

$2Na + Cl_2 \rightarrow 2NaCl$

$2K + Cl_2 \rightarrow 2KCl$

$2Sb + 3Cl_2 \rightarrow 2SbCl_3$

$2Fe + 3Cl_2 \rightarrow 2FeCl_3$

$Sn + 2Cl_2 \rightarrow SnCl_4$

Reactions with non-metals

$P_4 + 6Cl_2 \rightarrow 4PCl_3$

$P_4 + 10Cl_2 \rightarrow 4PCl_5$

$2S + Cl_2 \rightarrow S_2Cl_2$

Reaction with hydrogen:

$H_2 + Cl_2 \rightarrow 2HCl$

Reactions with Compounds

Reaction with Ammonia:

$2NH_3 + 3Cl_2 \rightarrow N_2 + 6HCl(g)$

$6NH_3 + 6HCl \rightarrow 6NH_4Cl(s)$

Oxidation of FeCl2 to FeCl3

$2FeCl_2 + Cl_2 \rightarrow 2FeCl_3$

Chlorine replaces bromine and iodine from their compounds. It is a stronger oxidizing agent than bromine and iodine.

$2NaBr + Cl_2 \rightarrow 2NaCl + Br_2$

$2KI + Cl_2 \rightarrow 2KCl + I_2$

Photochemical reactions: chlorine also undergoes photochemical reactions. In these reaction a photon of light breaks the chlorine molecule into chlorine free radicals which are chlorine atoms. The chlorine radicals then react with other compounds such as methane.

$$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$$

Chlorine as a bleaching agent:
Chlorine reacts with water to form HCl and HOCl. HOCl then breaks up to form atomic or nascent oxygen. The atomic oxygen is very reactive and is a strong oxidizing agent. It reacts with the spots and remove them. This is called bleaching action.

$H_2O + Cl_2 \rightarrow HCl + HOCl$

$2HOCl \rightarrow 2HCl + 2[O]$ Nascent Oxygen

Uses of Chlorine:

Chlorine is a useful element. It is used for a variety of purposes.

- For sterilizing drinking water
- To prepare PVC (Polyvinyl chloride) plastic
- To prepare CCl_4 and $CHCl_3$
- To prepare HCl
- To prepare bleaching powder, $CaOCl_2.H_2O$

Hydrochloric Acid (HCl)

One of the important compounds of chlorine is HCl**which** hydrogen chloride. It is a gas. When it is dissolved in water, we obtain hydrochloric acid. Hydrochloric acid is a commonly used acid. Hydrogen chloride can be prepared by a number of methods.

Laboratory preparation: In laboratory HCl can be prepared by the action of sulfuric acid on sodium chloride.

$$NaCl + H_2SO_4 \rightarrow NaHSO_4 + HCl(g)$$

Industrial preparation: On industrial scale, HCl is prepared by the reaction of chlorine with hydrogen gas.

$$H_2 + Cl_2 \rightarrow 2HCl$$

Chemical reactions of HCl:

- Reaction with a base, NaOH or KOH
  $HCl + NaOH \rightarrow NaCl + H_2O$
  $HCl + KOH \rightarrow KCl + H_2O$
- Reaction with ammonia
  $HCl + NH_3 \rightarrow NH_4Cl$
- Reaction with calcium oxide
  $2HCl + CaO \rightarrow CaCl_2 + H_2O$
- Reaction with sodium carbonate
  $2HCl + Na_2CO_3 \rightarrow 2NaCl + CO_2 + H_2O$

Summary GSC101 lecture # 28

Chemistry Lecture 14:

Organic Chemistry

Organic Chemistry:

Organic chemistry is a branch of chemistry that involves the study of carboncompounds. It deals with the structures, composition, and synthesis of organic compounds. Organic compounds are obtained from natural sources like plants, animals and microbes. They are also synthesized in laboratory. There are millions of organic compounds. They have wide variety of application such as in medicine, fertilizer, food, clothing, communication, transportation etc.

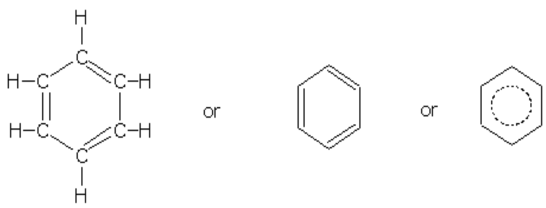
Catenation:

Carbon has a very unique ability that its large number of atoms can bond with each other to make chains of different lengths. This property of carbon to make chains is called catenation.

C-C   C-C-C   C-C-C-C   C-C-C-C-C   C-C-C-C-C-C-C

Hydrocarbons:

Hydrocarbons are the compounds of carbon and hydrogen. There are different classes of hydrocarbons such as aliphatic, aromatic, cyclic, acyclic, saturated and unsaturated, etc.Aromatic compounds are benzene and those which resemble benzene. They burn with black soot. They possess aromaticity and are comparatively more stable than expected. They are unsaturated compounds but are resistant to addition reactions. Their characteristic reactions are electrophilic substitution reactions. The structure of benzene is given below.



Classification of organic compounds:

There are millions of organic compounds and this makes it physically impossible to study each individual compound. To facilitate their study, organic compounds are classified into various groups and sub-groups.

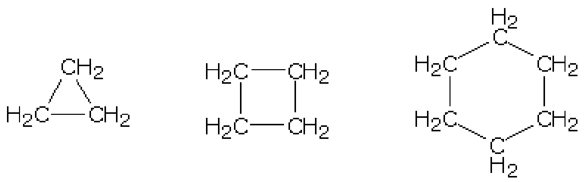
They may be broadly classified into the following classes:

- Open chain or acyclic compounds
- Closed chain or cyclic compounds

Open chain or acyclic compounds:

These compounds contain an open chain system of carbon atoms. The chains may be either straight chains (non-branched) or branched. The open chain compounds are also called aliphatic compounds. The name aliphatic is derived from the Greek word aleiphar meaning fats, as the earlier known compounds of this class were either obtained from animal or vegetable fats, or had fat like character.

CH_3-CH_2-CH_2-CH_3 ,CH_3-CH_2-CH_2-CH_2OH, $H_2C = CH_2$



Closed chain or cyclic compounds.

These compounds contain one or more closed chains (rings) of atoms and are known as cyclic or ring compounds.

The aliphatic hydrocarbons are the organic compounds which contain no benzene ring. They may be open chain or closed chain. The closed chain compounds are also called cyclic compounds. The major classes of aliphatic hydrocarbons are alkanes, alkenes, alkynes and cycloalkanes, etc.

Functional groups:

An atom or group of atoms which imparts some specific properties to a compound is called a functional group. For example, -OH is functional group. It is known as hydroxyl group. The compounds which have this functional group show specific properties. They are phenols and alcohols.

Structural formula:

It is very common in organic chemistry that two or more compounds have same molecular formula. For example, both ethanol and dimethyl ether have same molecular formula, C_2H_6O. Why they are different? They are different because they have different arrangements of atoms in their molecules. The arrangement of atoms in molecule is represented by a formula which is known is the structural formula. The structural formula of a compound is the formula which shows the arrangement of atoms in its molecule. The structural formula of a compound shows which atom is attached with which atom.

Isomers and isomerism:

Two or more different compounds which have same molecular formula are called isomers. This phenomenon is known as isomerism. Ethanol and dimethyl ether are isomers. Similarly, n-butane and isobutene are isomers. They are two different compounds, and have same molecular formula (C_4H_{10}) but different structures. Isomerism is very common in organic compounds. There are many types of isomerisms.

Sources of organic compounds:

There are many sources of organic compounds. Plants, animals, petroleum, natural gas, coal are common sources of naturally occurring organic compounds. A huge number of compounds have been synthesized in laboratories by chemists. A great number of new compounds are being added continuously.

All organic compounds must contain carbon. Almost organic compounds also possess hydrogen. Many compounds also contain oxygen and/or nitrogen. Other common elements found in organic compounds are halogens, sulfur, and phosphorus.

Oxygen containing organic compounds:

Oxygen-containing organic compounds are very numerous. Many functional groups contain oxygen. Some examples are given below.

Alcohols:

Alcohols are common organic compounds. They contain –OH functional group. This is called hydroxyl group. Examples: Methanol, CH_3-OH; ethanol, CH_3-CH_2-OH.

Both methanol and ethanol are liquids and are used as solvents.

Phenols:

Phenols also contain –OH functional group, but in a phenol the –OH group is attached to an aromatic carbon.

Aldehydes:

Aldehydes are those organic compounds which have aldehydic carbonyl functional group,-CHO. Formaldehyde, acetaldehyde, benzaldehyde are common aldehydes.

Ketones:

Ketones are those organic compounds which contain ketonic carbonyl functional group. This group is –CO–. There is a double bond between carbon and oxygen, C=O. Acetone is a common ketone (H_3C-CO-CH_3). It is a liquid and used as a solvent.

Carboxylic acid:

Carboxylic acids are compounds which contain carboxylic group, –COOH. Carboxylic acids are important organic compounds. Examples: formic acid, acetic acid, benzoic acid. Carboxylic acids are common in living organisms, proteins are composed of amino acids. Citric acid is found in citrus fruits. Milk contains lactic acid. Gapes have tartaric acid.

Carboxylic acids are weaker than mineral acids. Oils and fats are esters of glycerol with fatty acids.

Esters:

Esters are also common organic compounds. They are formed by combination of carboxylic acids and alcohols. Ethyl acetate is a common ester. Its formula is: CH_3-$COOCH_2$-CH_3. Fats and oils are esters of fatty acids with glycerol. Glycerol is a triol, i.e., it has three –OH groups.

Ethers:

Ethers are also a common class of organic compounds. They have C-O-C bonding. Dimethyl ether, and diethyl ether are common ethers. Diethyl ether is commonly called ether. It is anesthetic. It is used as a solvent in laboratory and industry.

Nitrogen containing organic compounds:

Nitrogen containing organic compounds are also very common. Amino acids contain nitrogen. Similarly DNA and RNA also contain nitrogen. Another important class of natural products called alkaloids also contains nitrogen. Common nitrogenous compounds have amino groups.

Amines:
Amines are nitrogenous organic compounds which contain amino group. Amines may be primary, secondary and tertiary. Examples: CH_3-NH_2 (Methyl amine), CH_3-NH-CH_3 (Dimethyl amine) and $(CH_3)_3N$ (Trimethyl amine).

Carbohydrates, proteins and lipids (Fats and oils) are naturally occurring common organic compounds. They are also part of our food.

Organic Reactions:

A chemical reaction is a chemical change. It is a process in which one or more bonds and broken and one or more bonds are formed.Coutlessnumber of reactions occur involving organic compunds. But all these reaction belong to only a few types of reactions. Most common types of organic reactions are given below.

- Substitution reactions
- Elimination reactions
- Additions reactions

In substitution reactions, one group is replaced by another group.

OH^- + CH_3-Cl → CH_3-OH + Cl^-

In the reaction $Cl^-$is replaced by OH^- group.

In elimination reactions, groups are eliminated from a molecule.

CH_3-CH_2-Cl → H_2C=CH_2 +HCl

In this reaction HCl is eliminated from chloroethane and ethene is formed.

Addition reaction is reverse of elimination reaction. In an addition reaction, a molecule adds to another molecule. So, two molecules of reactants combine to form one molecule of product.

H_2C=CH_2 + HBr→ H_3C-CH_2-Br

Applications of Organic Compounds:

Organic compounds are very important chemical substances. They have a wide variety of applications in modern human life. Organic compounds are essential part of our food. The fibers and dyes are organic compounds. Similarly, fragrances and flavours are organic substances. Plastic and other polymers are also organic compounds.

Numerous organic compounds are used as medicines for different diseases. The number of such compounds is rapidly increasing.

Many fertilizers are also organic compounds. Similarly, soaps and detergents and other household materials are organic compounds.

Summary GSC101 lecture # 29

Biology lecture # 1

Levels of Organization in Life

(From Atom to Biosphere)

WHAT IS LIFE?

Anything is living if:

- It can acquire energy from the environment, e.g., plants acquire energy using sunlight and carbon dioxide and animals gain energy by eating plants like goats eat plants.
- It is capable of reproducing itself, e.g., all animals produce young ones like lions produce cubs. Plants also reproduce seeds to give rise to new plants.
- Mutating / changing itself: all organisms have a property of mutations, i.e., their heredity material – DNA changes itself during division or other times and the result is change in any characteristic of the organism. This characteristic may be beneficial or harmful; organisms survive better if mutation is beneficial and may die if it is harmful.

BIOLOGY – THE STUDY OF LIFE

Biology (Bio – life; logos – study, reasoning); biology is hence the study of life or living organisms. Biology is about exploring the living part of the world, e.g., studying about animals, plants and even microorganisms is biology.

Biology have many subdivisions; for example, anatomy – the study of structures, physiology – the study of functions, microbiology – the study of microorganisms and many more.

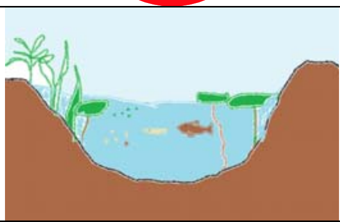
The exploration of life helps in understanding the phenomena of nature and effective utilization and management of natural resources. We can find solutions to various problems for example treatment for various diseases could be discovered, methods for energy production from biological materials may be found, e.g., few bacteria can produce fuel from grasses.

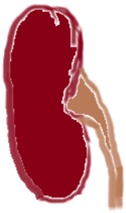
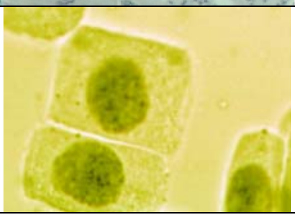
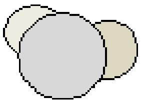
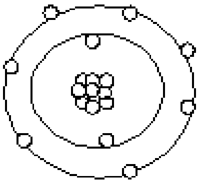
LEVELS OF ORGANIZATION IN LIFE

- Atoms
- Molecules
    - Micromolecules

    - Macromolecules
- Cells
- Tissues
- Organs
- Organ-systems
- Organisms
- Populations
- Communities
- Ecosystems
- Biosphere

Diagram below:

Biosphere	
Ecosystem	
Community	
Population	
Organisms	

Organ systems	
Organs	
Tissues	
Cells	
Molecules	
Atoms	

LEVELS OF ORGANIZATION IN LIFE – MORE DETAILS

Atoms

Greek: a, not; tom, to cut: The smallest component of an element that have all the properties of that element. In nature, 92 kinds of elements are present, out of which only 16 make the living organisms, called **bioelements**. Bioelements are Oxygen (O), Carbon (C), Hydrogen (H), Nitrogen (N), Calcium (Ca), and Phosphorus (P). These elements make 99% of living mass. Others ten elements make 1 % of total living mass named Potassium (K), Sulfur (S), Chloride

(Cl), Sodium (Na), Magnesium (Mg), Iron (Fe), Copper (Cu), Manganese (Mn), Zinc (Nz), and Iodine (I).

Atoms

All living things consist of atoms, like all other forms of matter. Atoms consist of "subatomic particles"; charged or not charged. These include electrons which are negatively charged particles, protons which are positively charged and neutrons which have no charge. Protons and neutrons are present inside the center and the electrons revolve around these in orbits.

Atoms do not live in isolation but join together to make molecules (compounds).

Molecules

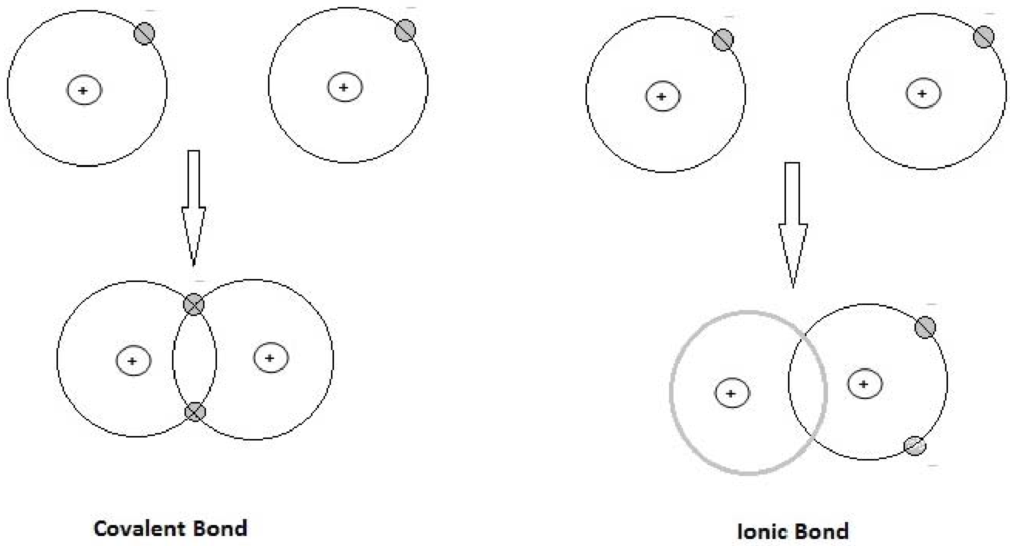
Atoms join together by a process called "bonding" to each other to construct molecules. Bonding is of two types.

- ionic bonds
- covalent bonds

In **inonic bonding** one atom gives one or more of its electron to the other atom which is called a donor and the other receive the electron called recipient. The donor atom then becomes positively charged and the recipient becomes negatively charged. In **covalent bonding**, however, the atoms share one or more of their electrons and these electrons revolve in the orbit of both atoms. Covalent bonding is more strong form of bonding.

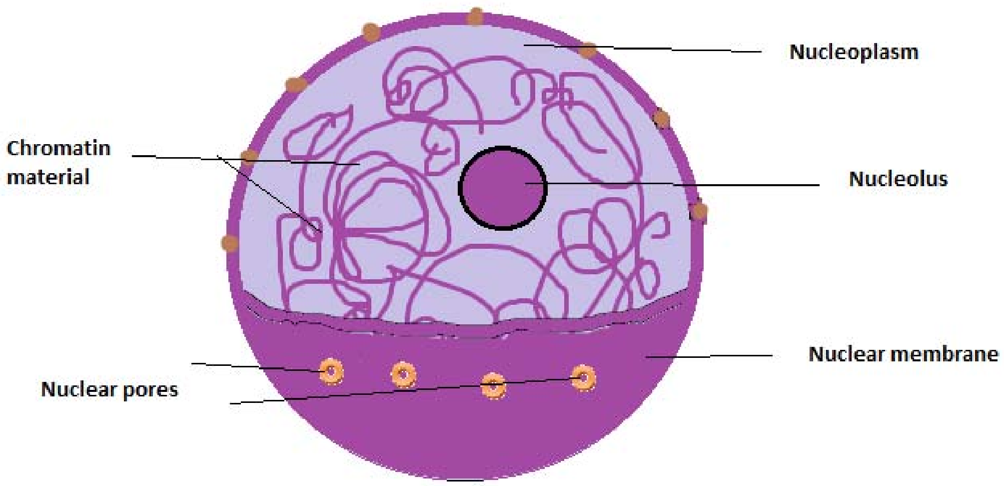
On the bsis of their size molecules are categorized into micromolecules and macromolecules. Micromolecules are the molecules with low molecular weight, e.g., glucose, water. Macromolecules are the molecules with high molecular weight, e.g., proteins, carbohydrates and lipids.

An organism consists of enormous number of biomolecules different types. Though some organisms are unicellular, i.e., consist of one cell only. Many other organisms are multicellular, i.e., these consist of many cells.



Organelles

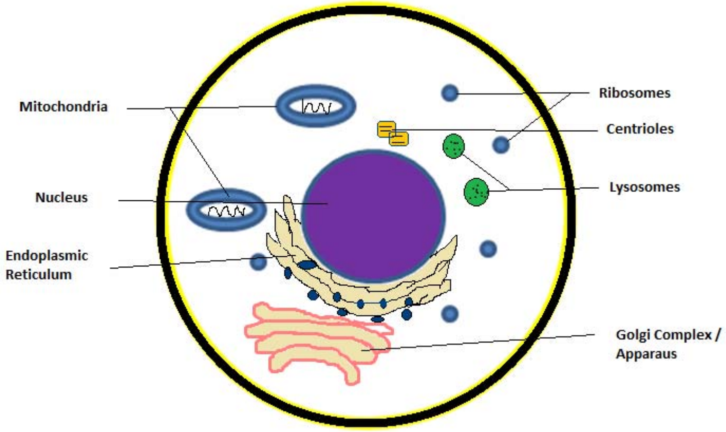
Molecules make organelles. Organelles are sub-cellular structures, assemble together to make cells – the units of life, e.g., mitochondria, lysosomes, Golgi bodies, nucleus. For example, mitochondria of a cell (Singular: mitochondrion) is called “powerhouse” of the cell. This organelle is present in the cytoplasm of the cells and makes energy for the cells hence called “power house”. These are found in both plants and animals. Another example is nucleus present in almost all cells.



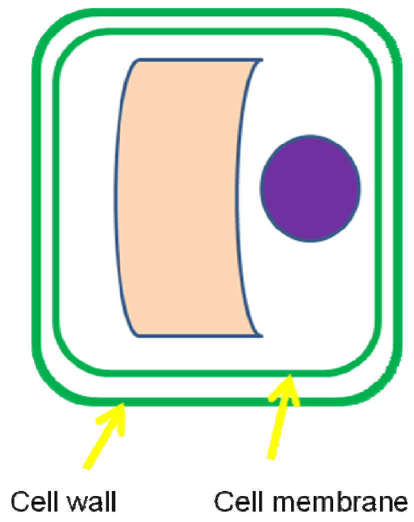
Organelle: nucleus.

Cells – the basic unit of life

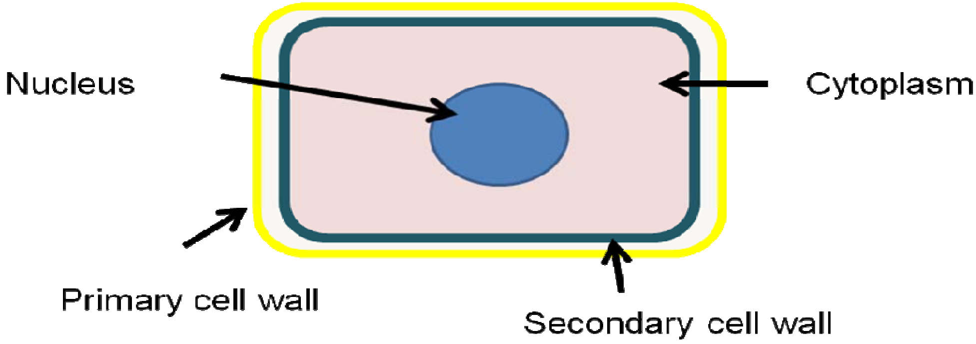
All the living organisms consist of cells. Cells are called the basic units of life. Cells are specialized in their structure and functions. There are different types of cells present in the bodies of multicellular organisms. But some organisms like amoeba consist of only one cell. Cells are categorized based upon the placement of their nuclear material into prokaryotic and eukaryotic cells. Prkaryotic (Pro: old, Karyotic: related to nucleus) cells are those cells that do not have a true nucleus – it means that their nuclear material is not covered by a membrane. While eukaryotic cells have a true nucleus, i.e., their nuclear material is covered by a membrane called nuclear membrane. Sometimes a cell makes a whole unicellular organism, like Prokaryotes and Protists. A variety of cells makes a single, multi-cellular organism.



Animals Cell



Plant Cell



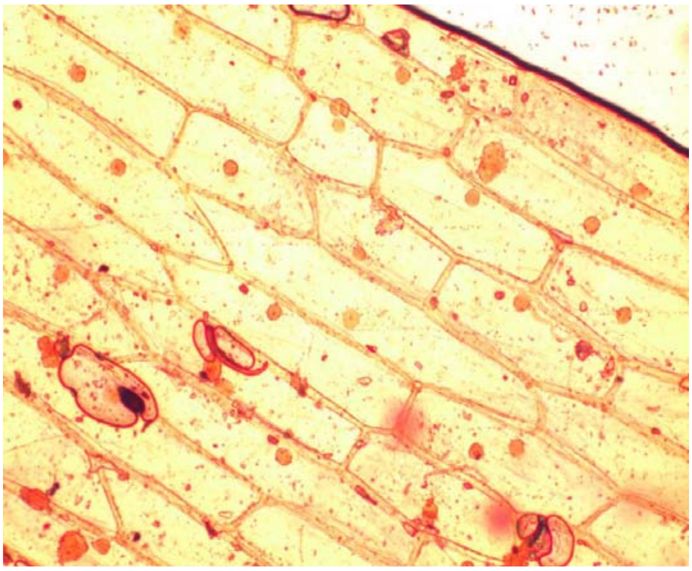
Bacterial Cell

Stem Cells

These are the undifferentiated cells in which most of the genes are switched on and these have a potential to make almost all cells of the body. These cells are present in a few places in adult organism or present in the embryos. These are useful for human beings because these can be used in making organs of any type which may be damaged by for example a disease.

Tissues

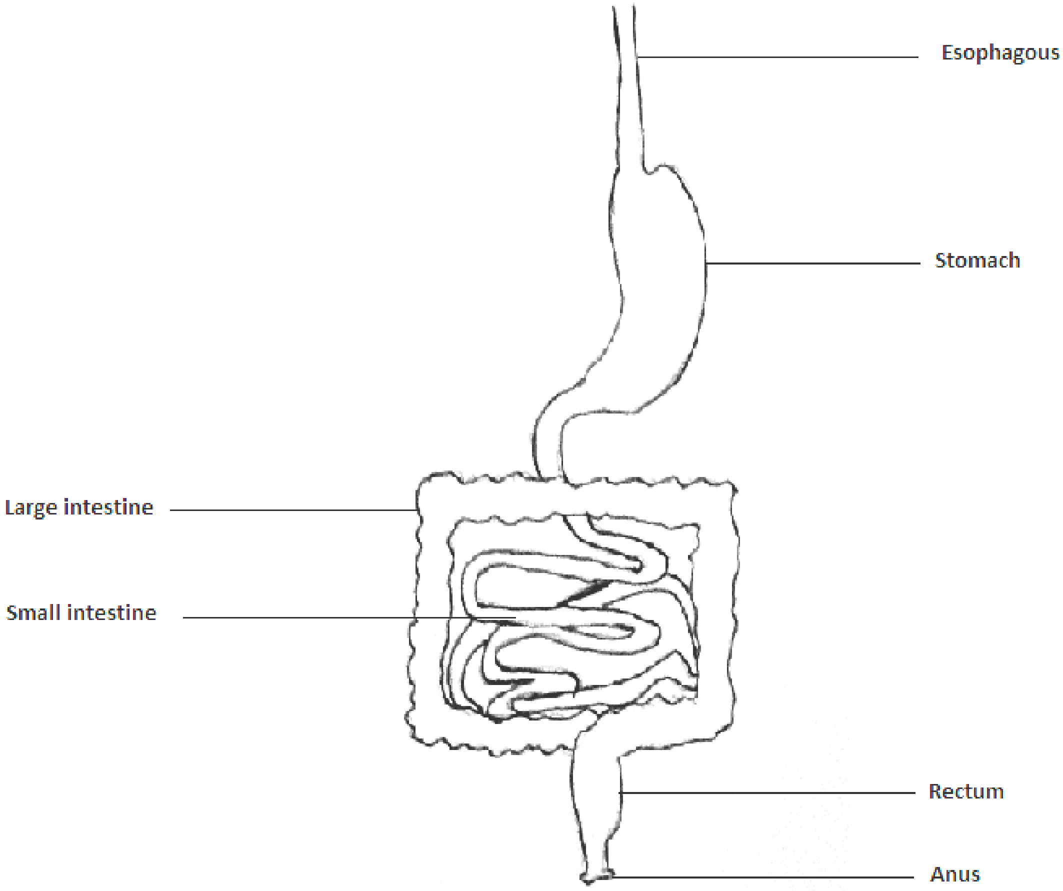
These are the groups of similar kind of cells which perform a same function. The tissues perform a common function, specialized to the tissue. For example, epithelial tissue that makes the skin.



Onion Epidermis (tissue)

Organs and organ systems

Tissues group and work together to make a unit called organ. Different tissues in an organ work differently to perform collective function of the organ. For example in stomach, there are muscle tissues that contract and relax for grinding and there are secretory cells which secrete gastric juices to digest the food. Collective action is the secretion of gastric juices and its mixing.



Digestive system in humans.

In the simple to complex organisms, many organ-systems are present, for example, in humans digestive system, cardiovascular system, respiratory system and many more are present that work for a specific purpose. Digestive system consists of oral cavity, esophagus, stomach, intestine, pancreas, liver and rectum. Cardiovascular system consists of heart, vessels and blood.

Organism

Organ-systems join together to constructs organisms. In an organism, the organs and organ-systems coordinate to perform the activities of the whole organism. For example, in humans brain control the activities of most of the organs and organ-systems. If a person is running; cardiovascular system provides it oxygen and nutrients, muscles contract and relax for movement and nervous system coordinate all of these functions.

Population

All organisms of a species living in an area at a particular time are called population, like all deer in a forest. Biologists study populations to explore the interactions between organisms. For example, interactions between male-male, female to female or else.

Ducks in a local park

Community & Ecosystem

Different populations living in an area in a particular time, for example, in a forest plants, animals, algae, fungi live together are called a **community**. Populations interact with each other and also to the abiotic factors of the area to make Ecosystem, for example, a lake ecosystem.

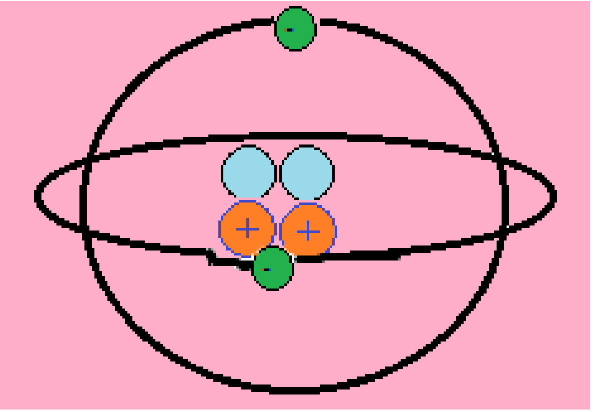
Plant community in a forest.

Biosphere

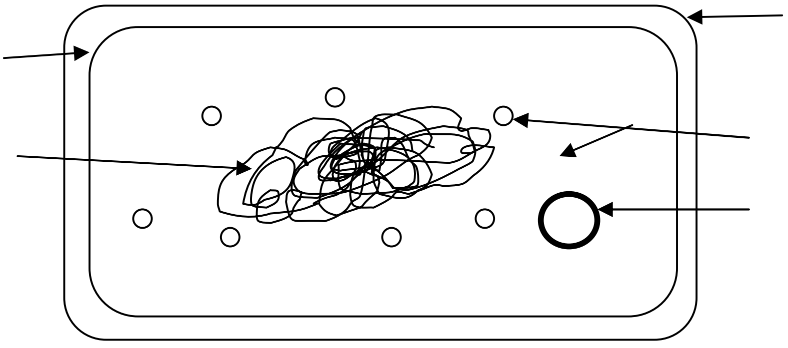
The part of the world covered or inhabited by the living organisms is called biosphere. This is also called zone of life on Earth. Biosphere includes all ecosystems, like forests, lakes, oceans and valleys where biotic components exist.

Exercise

1. Draw a flow chart to demonstrate the levels of organization in life.
2. Label various parts of atom in the following diagram:



3. Label various parts of a bacterial cell in the following diagram:

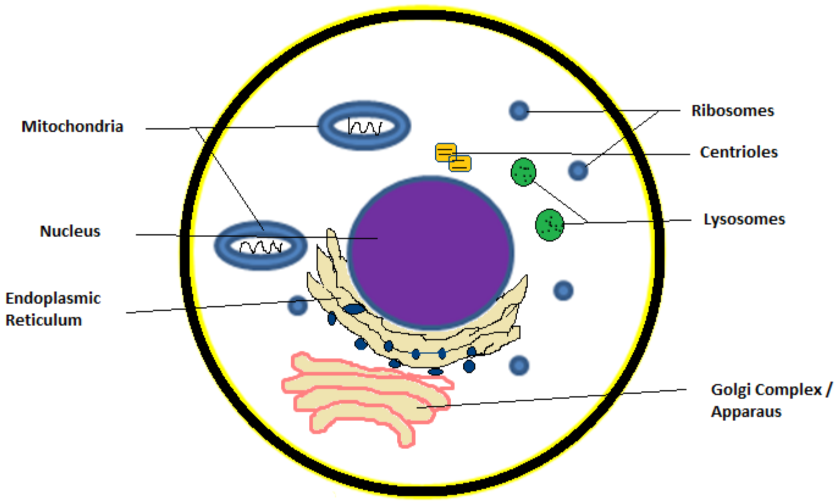


Summary GSC101 lecture # 31
Biology lecture # 3

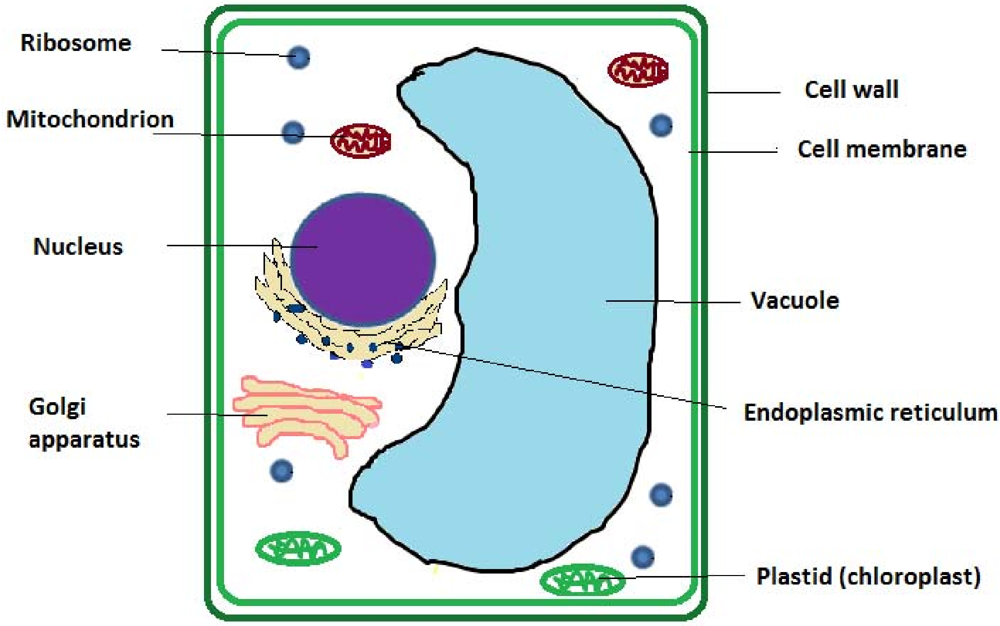
Diversity of Cells and Mitosis

Animal Cell Vs Plant Cell

Animal Cell	Plant Cell
▪ Cell membrane is outer most layer ▪ *Many small vacuoles* ▪ Nucleus in the center ▪ *Roughly round and/or have variable shapes* ▪ Plastids are absent ▪ *Cilia present* ▪ Centrioles present	▪ Cell wall is present outside the cell membrane ▪ *Have a large central vacuole* ▪ Nucleus on a side ▪ *Roughly rectangular shape due to presence of cell wall* ▪ Plastids are present ▪ *Cilia rarely present* ▪ Centrioles absent in most of the plants



A typical animal cell.



A typical plant cell.

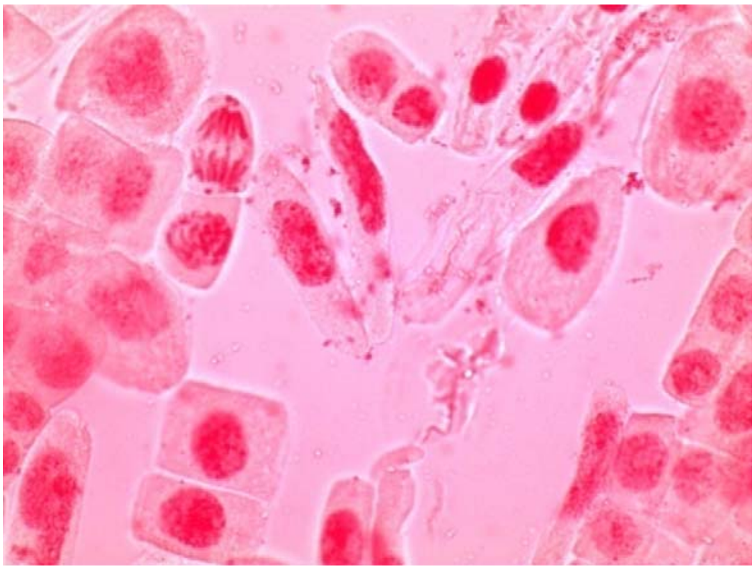
Prokaryotic Cell Vs Eukaryotic Cell

Prokaryotic Cells	**Eukaryotic Cells**
▪ No defined nucleus but a nucleoid region ▪ No membrane bound organelles ▪ Small in size (e.g. 1-2 microns in bacteria) ▪ Cell wall consist of peptidoglycan (a polymer of amino acids and sugars)	▪ Defined nucleus with nuclear membrane ▪ Membrane bound organelles are present ▪ Larger than prokaryotic cells on average (20 microns of animal cells) ▪ Cell wall consist of cellulose (plants) and chitin (fungi)

CELL DIVISION

Division is the property of cells. Cells have to divide for various purposes, for reproduction or for growth and repair of the tissues. There are two types of the cells called somatic cells and germ line cells. Somatic cells are those which make all the tissues of the body except for some cells which are involved in reproduction. Few cells involved in reproduction and are meant for making gametes for reproduction.

There are two types of the cell divisions called Mitosis and Meiosis. Mitosis is the division of the somatic cells and also serves as means of asexual reproduction. Meiosis is however involved in division of the germ line cells.



Stages of mitosis in onion root tip cells.

CELL CYCLE

Cells go through a cyclic process in which they pass by various phases over time. These phases include a phase of rest, high metabolic activity and division. It is also defined as the sequence of events or a cyclic process between divisions of the cell. The cell cycle consists of the following phases:

- Interphase (consist of Gap 1 phase, Synthesis Phase, Gap 2 phase)
- M Phase (Mitosis or Division Phase)
- Resting or G0 Phase (Gap 0, read as Gap not)

Interphase

Interpahse consist of following phases. This is normally called as rest phase but actually it is a phase of high metabolic activity.

Gap 1

Cells increase in size in Gap 1. They produce materials required for DNA synthesis. The *G_1 checkpoint* control mechanism ensures that everything is ready for DNA synthesis.

Synthesis phase

DNA replication occurs during this phase. An S phase check point checks that whether the synthesis of DNA is correctly done or not. If everything is correct cell continue to the next phase and if not then cell wither have to die or correct its errors.s

Gap 2

During the gap between DNA synthesis and mitosis, the cell will continue to grow. Cell prepares all the materials required for division, e.g. microtubule proteins. *The G_2 checkpoint control mechanism ensures that everything is ready to enter the M (mitosis) phase and divide.*

Cell Division or M- Mitosis Phase

Cell growth stops at this stage and cellular energy is focused on the orderly division into two daughter cells. A checkpoint in the middle of mitosis (called *Metaphase Checkpoint*) ensures that the cell is ready to complete cell division.

Resting or G_0 (Gap 0)

A resting phase in which the cell has leaves the cycle and has stopped dividing. G0 starts from G1 and cell may sustain in G0 may be for years.

Mitosis

Mitosis is the cell division that results in two daughter cells which are like each other. Though, mitosis is a term that is used to describe the nuclear division.
Cell division consists of following phases:

Karyokineses – division of nucleus

- Divided into Prophase, Metaphase, Anaphase and Telophase

Cytokinesis – division of cell

- Different in animal and plant cells

Karyokinesis

1. ***Prophase***
    - Chromatin material condenses and chromosomes becomes visible
    - Each chromosome is replicated (duplicated) and consist of two sister chromatids
    - At the end of the stage nuclear membrane disappear
    - Centrioles move towards poles of the cell and microtubules starts forming

2. **Metaphase**
    - Chromosomes arrange themselves at the equator
    - Kinetochores are attached to the microtubules

3. **Anaphase**
    - Chromosomes starts moving towards the poles
    - The sister chromatids separate from each other, so each sister chromatid move towards a pole

4. **Telophase**
    - Chromosomes (sister chromatids) reaches at the poles

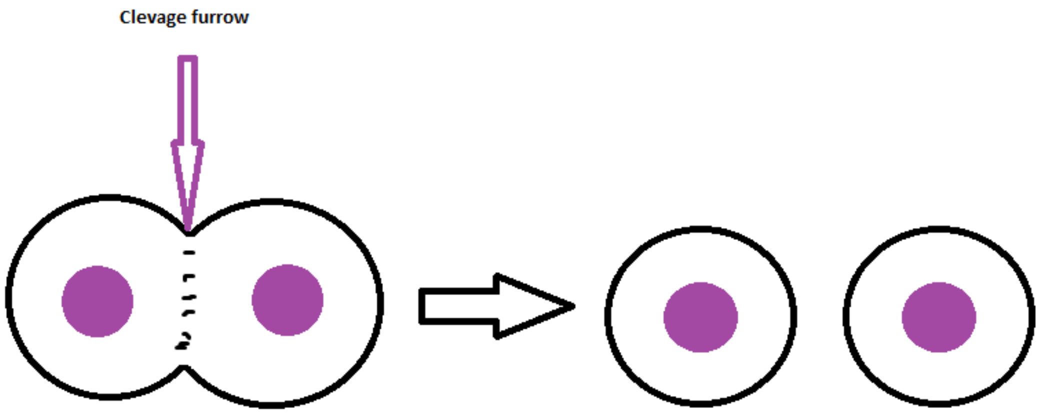
- Nuclear material starts ***de-condensing*** again
- Nuclear membrane starts forming

The nuclear division is complete, next is the **Cytokinesis or division of the cell.**

Cytokinesis

Cytokinesis in plant and animal cells is different from each other. In plant cells, a **cell plate** starts forming in the center of the cell and moves towards sides. The cell plate divides the cell into two cells. The cell plate consists of material produced by Golgi bodies in vesicles. This material contains the cell membrane and cell wall components.

Cytokinesis in animal cells occurs in a different way. In animal cells a cleavage furrow is formed by invagination of cell membrane. This process occur with the help of cytoskeleton (microfilaments particularly). The furrows divide the cell into 2 daughter cells.



Cleavage in animal cells.

Importance of Mitosis

Mitosis is the cell division which helps in development and growth processes of the cells and hence the tissues. Development of new cells is a requirement in many parts of the body like epithelia usually keep growing. Replacement of cells and wound healing is another requirement of the organisms which also need new cells. Regeneration is a capability of some organisms. They came make their lost parts. This process also needs mitosis. Mitosis also serves as a means of asexual reproduction in various organisms.

Errors in Mitosis

Cells divide correctly most of the times because of many check points at various phases but sometimes it may go wrong. If it happens due to any reason the result is usually serious problems. Uncontrolled division of the cells may result into abnormal tissue growth and cancer.

Exercise

1. Draw various steps of mitosis.
2. Demonstrate the process of cytokinesis in animal cells.
3. Give any two examples of regeneration in animals.
4. Show the process of cytokinesis in plant cells with the help of a diagram.

Summary GSC101 lecture # 32
Biology lecture # 4

CELL DIVISION – MEIOSIS

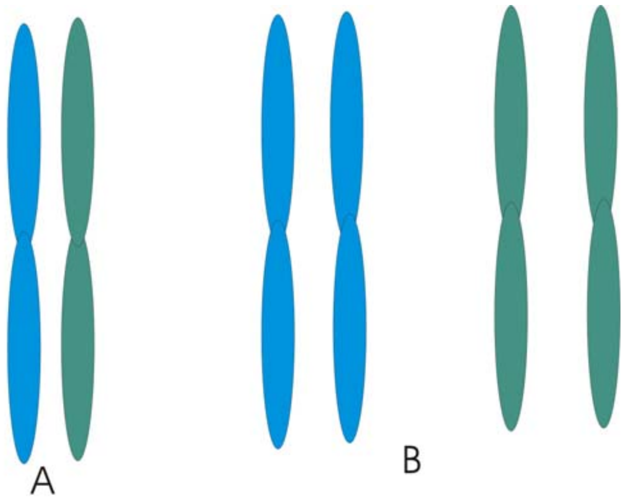
Reduction Division

MEIOSIS - CONSIST OF TWO DIVISIONS

Meiosis occur in germ line cells to make gametes, gametes are formed for sexual reproduction. Meiosis is also called reduction division because it results in four daughter cells which are haploid. We know that chromosomes occur in pairs e.g. human have 46 chromosomes in 23 pairs which is called a diploid number. The chromosomes in each pair are called homologous because these are like each other and are complementary to each other. Meiosis makes cells that have a half number of the chromosomes in each daughter cell called a haploid number also.

Diploidy and Polyploidy

The condition of having two sets of chromosomes is called diploidy (2N number of chromosomes). The gametes formed by meiosis, hence, are called haploid (N number of chromosomes). For example, in humans 2N is 46 and N is 23 in each gamete, when gametes combine in fertilization the chromosome number is retained to 2N. Some plants have more than two sets of chromosomes and are called polyploids. This characteristic is called polyploidy.



Homologous chromosomes (A. before replication; B. After replication

Phases of Meiosis

- Meiosis I
  - The reduction division
  - Chromosome number becomes half in each daughter cell (N)

- Cytokinesis I
- Meiosis II
  - Just like mitosis
  - Chromosome number remains same in daughter cells

- Cytokinesis II

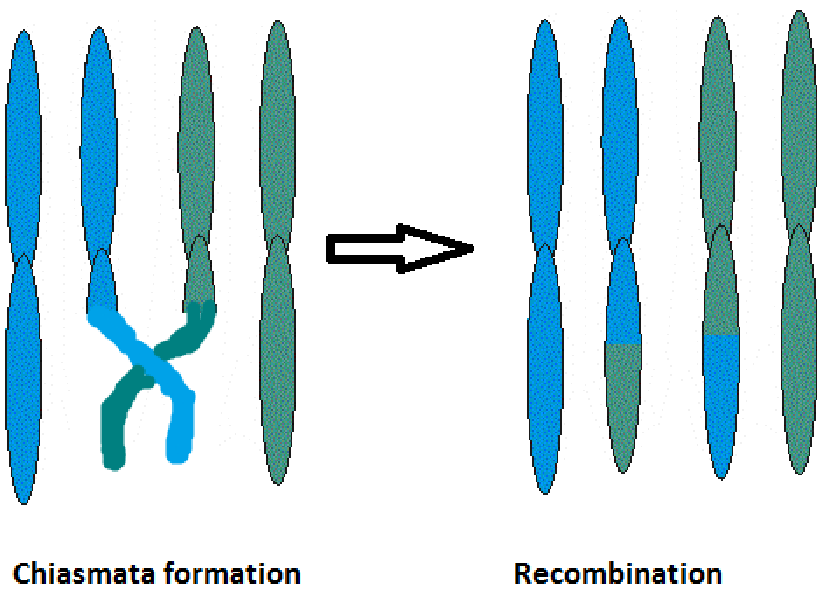
Meiosis I

- **Meiosis I consist of following phases:**
  - Prophase I
  - Metaphase I
  - Anaphase I
  - Telophase I

Stages of Meiosis I

- ***Prophase I*** is a long phase in meiosis. It consist of following stages:

  - It is marked by the pairing of homologous chromosomes (synapses) and recombination (exchange of the parts of chromosomes.
  - Paired chromosomes are called **Bivalents or Tetrads.**



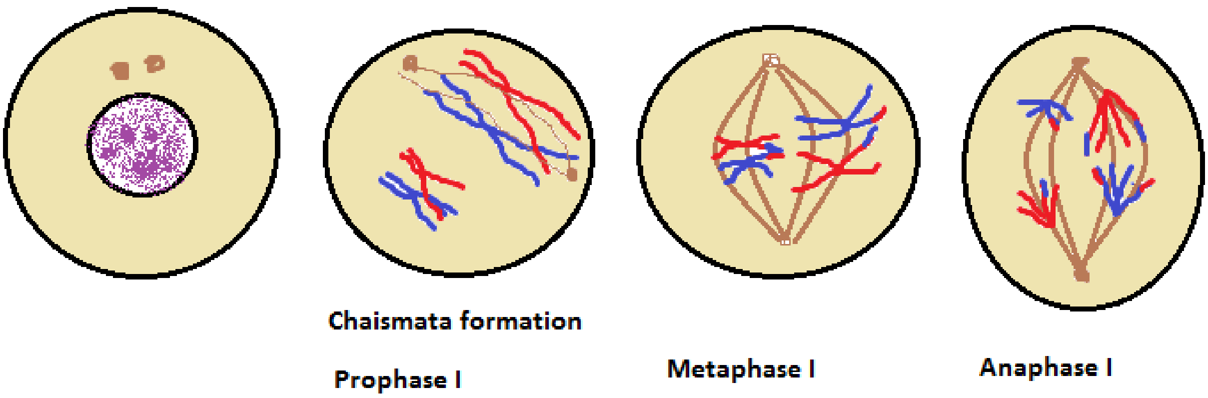
Homologous chromosomes carry out recombination during meiosis.

- **Metaphase I**

- Chromosomes attach to the spindle fibers by kinetochore, one kinetochore per a chromosome and not per chromatid.
- One homologue on each side so there is a 50-50 chance to get each parents chromosome.

- **Anaphase I**
  - The chromosomes move towards the poles.
  - A homologue, consist of two chromatids moves and sister chromatids do not separate.
  - The result is half number of chromosomes towards each pole.

- **Telophase I and Cytokinesis**
  - Chromosomes reach at poles, half on each side.
  - Cell divides and then starts meiosis II.



Events of Meiosis II

- Karyokinesis
  - Prophase II
  - Metaphase II
  - Anaphase II
  - Telophase II
- Cytokinesis
  - Each cell divides into two cells.

At the end of meiosis each cell divides into **4 haploid cells.**

This division is different in males and females.

In females, after first meiotic division (meiosis I), cytoplasm is unequally distributed and one large and other small cell are produced. The small cell is called a polar body. Then both of these cells carry out meiosis II. Polar body divides into 2 polar bodies. The large cell however is

divided into one ovum (large) and another polar body. So that meiosis results into 1 ovum and 3 polar bodies.
In males, both meiotic divisions results into equal sized cells called sperms.

Comparison of Mitosis and Meiosis

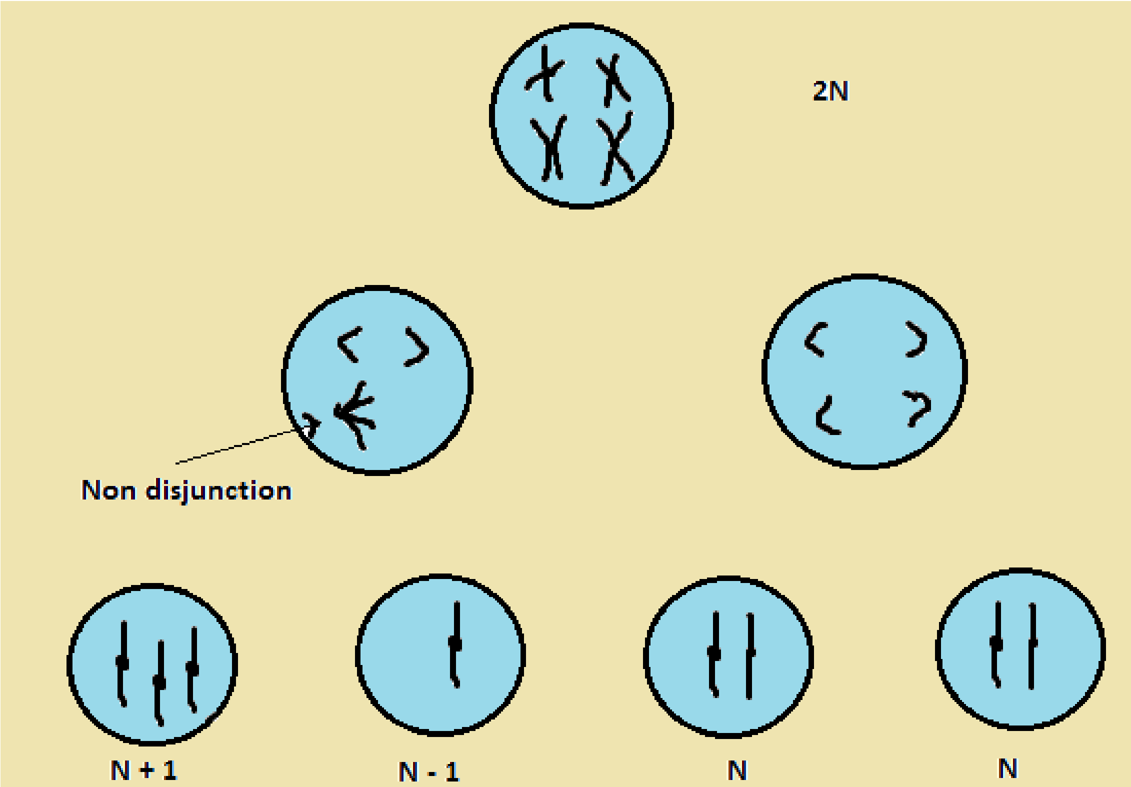
Mitosis	**Meiosis**
• Cell divides into 2 daughter cells • Alike in males and females • Chromosome number remains equal (2N) in daughter cells	• One cell divides into 4 daughter cells • Different in males and females • Chromosome number becomes half (N) in daughter cells

Importance of Meiosis

Major advantage of meiosis is the genetic variations by recombination (crossing over). During prophase I of the meiosis crossing over takes place which result in genetic recombination. When gametes combine to make a zygote, more variations arise. This variation assures new combinations resulting in increase in adaptability of the organism.

Errors in Meiosis

Meiosis is a well regulated process but sometimes errors may arise which may lead to mostly serious disorders. The common cause of disorders in non-disjunction of the homologous pairs of chromosome abnormally. This may results into unequally distributed chromosomes in the gametes and when these fertilize, they give rise to individuals with disorders.
For example, in Down's syndrome the affected individual have 3 homologues in the 21st pair of chromosomes.



Non-disjunction results into abnormal gametes, e.g., in above diagram N and N are normal and N +1 or N -1 are abnormal gemetes.

Twins

There are two types of twins.

- ***Fraternal twins***
    - These are produced by separate eggs (also called dizygotic twins)/ These are produced if two eggs are released and fertilized.
    - These are genetically different from each other and may be both males, females or both male and female.
- ***Identical twins***
    - These are produced by division in the same egg (also called monozygotic twins). These are produced by division in the zygote.
    - These are genetically same / identical and have same characteristics. Both of these are either males or females.

Environment and twins

Environment may affect even the identical twins. Identical twins may also have different characteristics if they are brought up in different environments. We know that the genes interact with environment to produce various characteristics. This characteristic also affects the twins.

Exercise

1. Draw various steps of meiosis I.
2. Demonstrate difference between the meiosis in females and males.
3. What are the effects of non-disjunction? Describe with the help of a diagram.

Summary GSC101 lecture # 33
Biology lecture # 5
Chromosomes, DNA and Genes

Heredity Information Flow

Reproducing itself is a property of life. Transferring characteristics to next generation is a property of living organisms. Heredity information flow in living organisms is carried out by the genes. The "Chromosome theory of heredity" states that the genes are present on chromosomes and are responsible for the transfer of characteristics from generation to generation. Genes are present in the form of DNA molecules, organized in a structure called chromosome (chromatin material).

Chromatin - the Genetic Material

Genetic material is present in the nucleus of the cell in eukaryotes and in the nucleoid region in prokaryotes. These are called chromatin material. Chromatin material is not visible during interphase (non-dividing state) of the cell. These become visible during cell division due to condensation of chromosomes.

Functions of Genetic Material

There are some important properties of genetic material, which are following:

- It replicates itself.
- It regulates the growth and development of the organism.
- It allows the organism to adapt to the environmental changes.

Chromosomes - DNA – Genes

Chromosomes consist of DNA molecule associated with proteins. In chromosomes, DNA is wrapped around proteins. Few of these proteins are called histones and few others. DNA is associated with histone and non-histone proteins in a chromosome.

Introduction of DNA and Gene

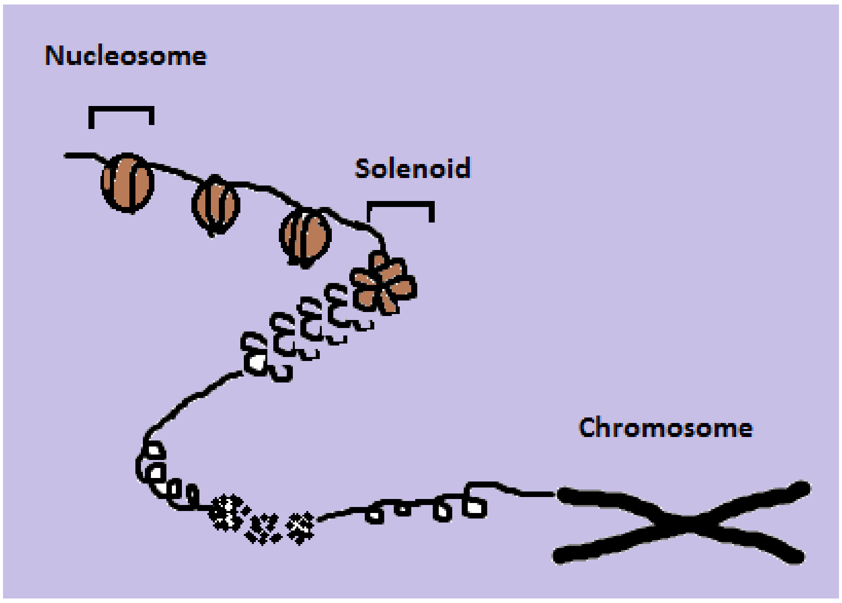
DNA is a macromolecule (large molecule) organized in structure chromosome. In prokaryotes DNA is a circular molecule. In eukaryotes it is a long linear molecule. Mitochondria and chloroplast also have their own circular DNA molecules.
Gene is a length of DNA that codes for a peptide or protein. So that gene is a part or length of DNA.

Condensation of Genetic Material

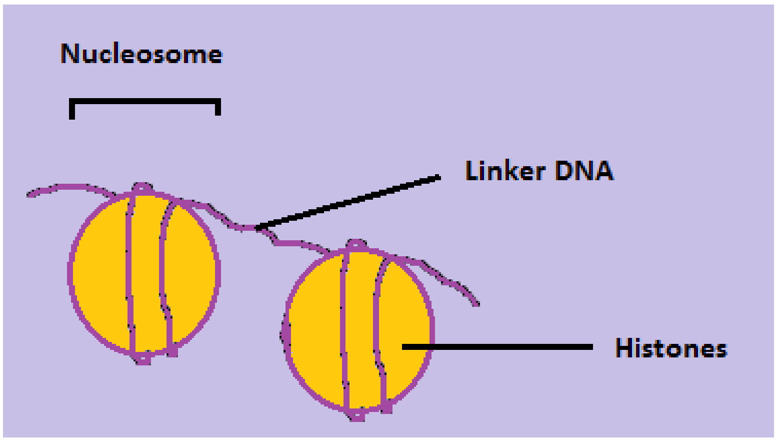
Chromatin material condenses during prophase of mitosis in the form of chromosomes. Chemical analysis shows that chromosome consist of DNA and proteins. DNA is a long molecule about 2nm thick running continuously within each chromosome. Chemical analysis shows that DNA is acidic in nature.

The Structure of Chromosomes

Chromosome consists of a DNA molecule wound around proteins. DNA in human cell (all chromosomes) is about 6 feet long, packed in a microscopic nucleus of a cell. In one human chromosome, it is 1.7-8.5 cm long. How is this possible? The answer is "coiling" and "super-coiling". The chromosome consists of highly condensed structure. If we can open this like a thread, then the long thread will appear like a flower like structure called solenoid which consists of many smaller units. These small units are called "nucleosomes". A nucleosome is a length of DNA coiled around a set of proteins. The DNA coils around histones twice, which is up to 200 base pairs long. Two nucleosomes are connected to each other by a length of DNA, which is called "linker DNA" (up to 80 base pairs long).



Chromosome coiling and nucleosome.



Two nucleosomes.

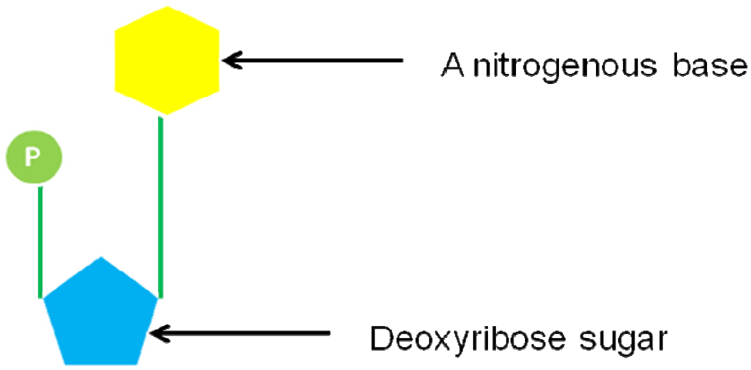
Chemical Composition of DNA

DNA is a complex macromolecule (large molecule). DNA stands for Deoxyribose Nucleic Acid. The smallest unit of DNA is called a “nucleotide”; nucleotides join to make polynucleotide. We can say that DNA consists of nucleotides joined together.

Nucleotides

Each nucleotide consists of:

1. Deoxyribose sugar
2. Phosphate group
3. Nitrogenous base



Structure of a nucleotide.

There are four nucleotides based upon four different nitrogenous bases attached to them. Nitrogenous bases are of two types: purines and pyrimidine. Purines include two bases Adenine and Guanine which have a double ringed structure. Pyrimidine bases include the other ones called Thymine and Cytosine that have single ringed structure.

Mechanism of Gene Action

Genes express themselves by making proteins. Making the proteins by DNA occur by two processes called transcription and translation. **Transcription** is formation of a form of RNA from DNA called messenger RNA (mRNA). mRNA is formed inside the nucleus in eukaryotes and in nucleoid region in prokaryotes. The next process is **translation**, which is formation of a protein or peptide by mRNA with the help of another organelle called ribosome.
Replication is another function of DNA. It is doubling of DNA molecule to make two copies of itself. Replication occurs before cell division to make copies of DNA for the daughter cells.
Genetic code is a term used for the parts of DNA that code for proteins. A codon is a 3 nucleotides code for an amino acid, i.e., codon is a 3 nucleotide set of DNA molecule that codes for a protein.

Transcription and Translation

- Transcription = DNA ⟶ mRNA
- Translation = mRNA ⟶ Protein

- *The following scheme is called the central dogma of molecular biology / genetics*

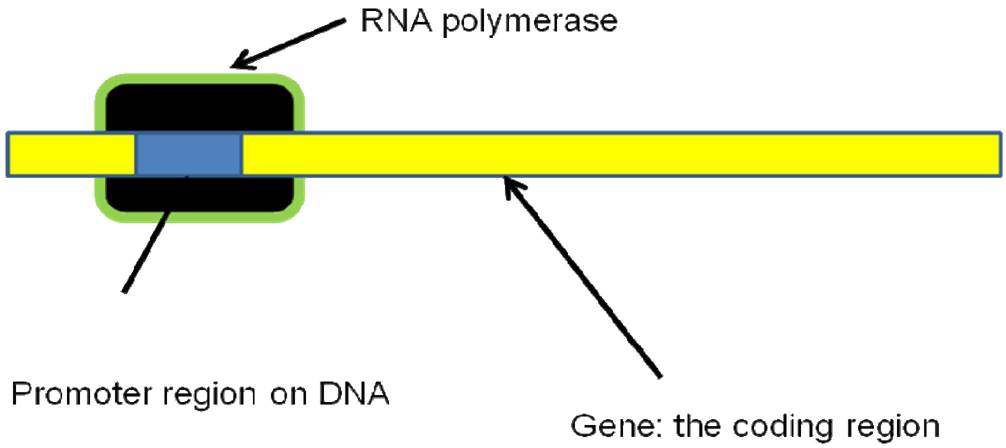
DNA ⟶ RNA ⟶ Protein

Transcription

- DNA ⟶ mRNA

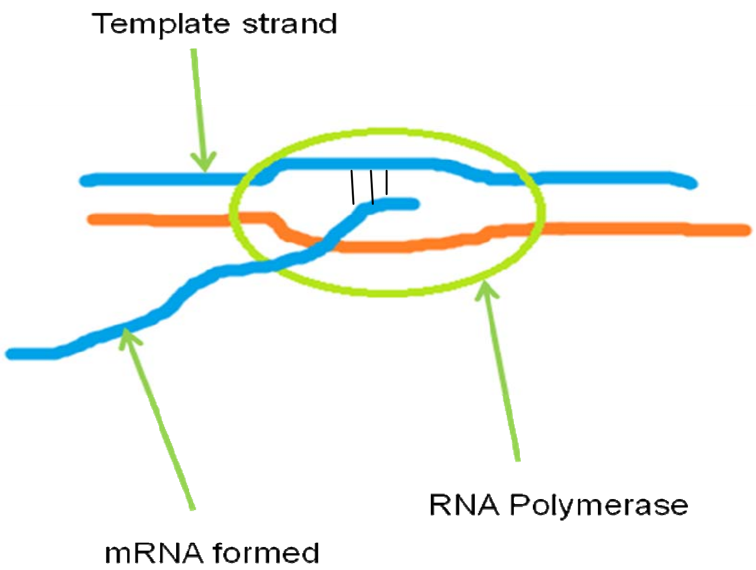
The process of transcription involves an enzyme called RNA polymerase. One strand of DNA act as the template strand which is actually coded into the mRNA.

- ***Steps of transcription***
    - RNA polymerase identifies and attaches to a region called promoter on the DNA *upstream* the gene.
    - RNA polymerase open the double helix chain which results in the formation of transcription bubble.



Transcription Process

- RNA polymerase moves on the gene, the helix unwinds and make a complementary strand of RNA. This strand of mRNA protrudes out of transcription bubble.
- At end of the gene there is a stop sequence. Usually it is a series of GC base pairs followed by a series of AT base pairs.
- These sequences make a hair pin loop like structure which stops RNA polymerase from transcribing.
- Thymine is coded as uracil in mRNA.

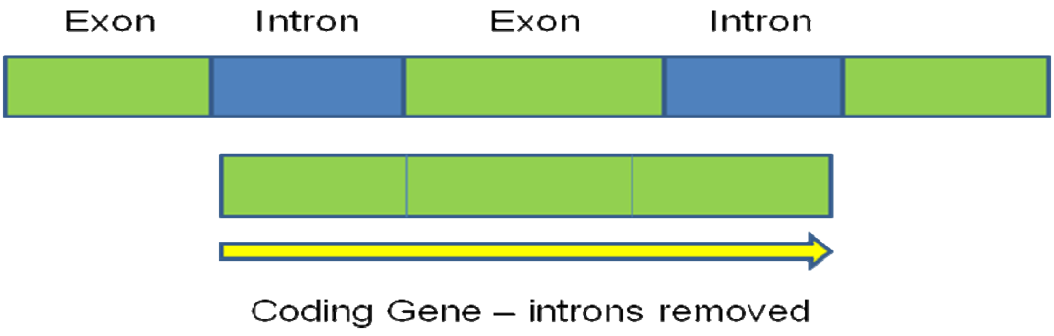


Transcription in Prokaryotes and Eukaryotes

In prokaryotes, the mRNA directly moves into cytoplasm and its translation starts because there is no nuclear membrane, nucleoid region is continuous with cytoplasm. In eukaryotes, mRNA formed moves out of nucleus through nuclear pores and then it is translated in the cytoplasm with the help of ribosomes.

Modification of mRNA in eukaryotes

mRNA in eukaryotes has to travel from nucleus to cytoplasm, to protect it from the action of nucleases (the DNA cutting enzymes) and proteases (protein cutting enzymes), it is modified. On its 5’ end a cap of 7 methyl GTP is added; while on the 3’ end a poly A tail is added. Introns are also removed. Introns are DNA sequences in the eukaryotes which are non coding and should be removed from the mRNA. The coding regions are called exons.



mRNA in eukaryotes have regions – exons and introns

Translation

- mRNA ------- Protein

The process of translation consists of three major steps: initiation, elongation, and termination.

Steps of Transcription

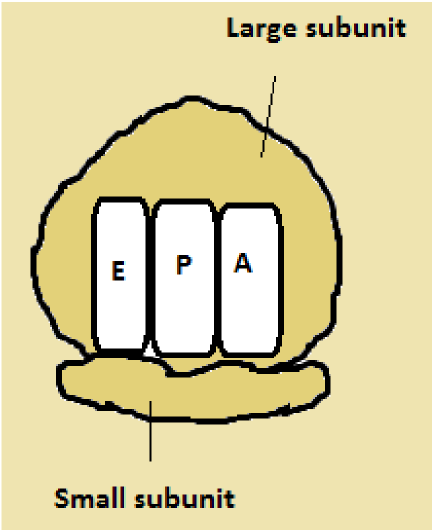
- In prokaryotes, translation starts while transcription is going on because there is no barrier between nucleoid and cytoplasm.
- In eukaryote, first introns are removed.

Process of Translation

Initiation:

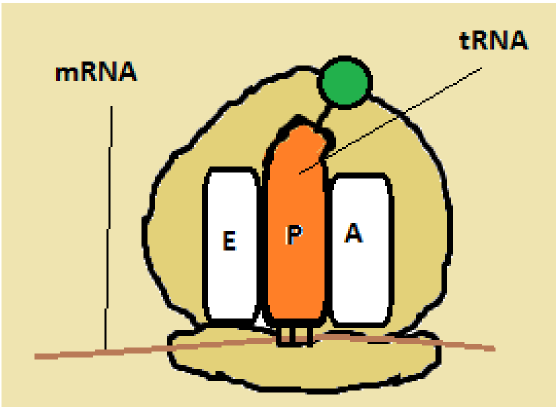
- The mRNA binds to the small unit of ribosome.
- The large ribosomal subunit has 3 binding sites called E (Exit), P (Peptidyl), and A (Aminocyl).

- When the first codon (triplet code) is aligned at the P site then the large ribosomal subunit attaches to the small subunit.



A ribosome.

- A tRNA carrying the amino acid methionine attaches to the start codon (AUG) on the messenger RNA.

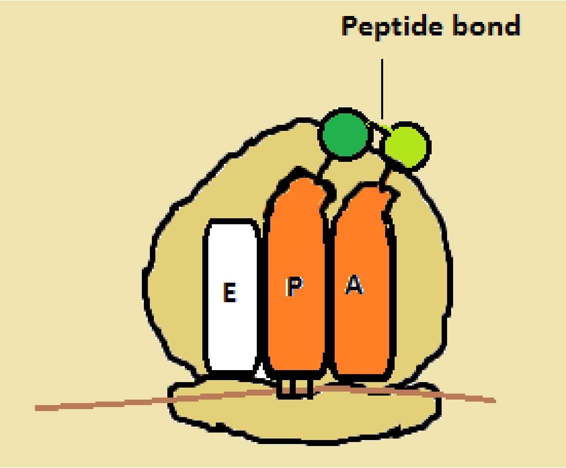


A tRNA with an amino acid on the P site.

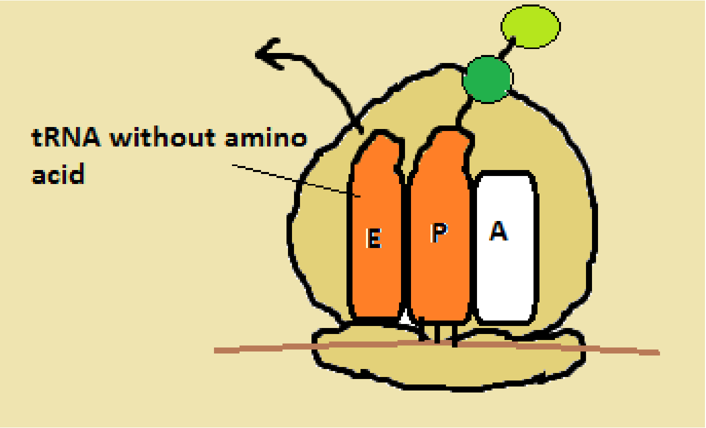
Elongation:

- A tRNA with its amino acid attaches to the A binding site.
- Peptide bond formation occurs between the methionine and the amino acid carried at the A binding site.
- Ribosome moves in the 3' direction down the messenger RNA by three bases, shifting the tRNA and polypeptide chain to the P Binding site.
- The A binding site is open and a vacant tRNA (without amino acid) is in the E binding site.

- Now, the next tRNA brings another amino acid and bind to A site.
- A peptide bond is formed between the second and this new (thirs) amino acid.
- Ribosome moves in 3' direction and the vacant tRNA is released from the E site.
- This process continues until a stop codon arrives on mRNA.
- A Releasing factor comes and binds to the A site in place of stop codon. The polypeptide chain separates from tRNA and ribosome. Then ribosomal units disassemble again. mRNA molecule also released which has been coded.



Peptide bond is formed between the amino acids brought by tRNAs present on P and A sites.



Growing polypeptide is present on P site and empty amino acid on E site. New tRNA with an amino acid will come and attach on A site.

Exercise

1. Explain the process of transcription with the help of diagram.
2. Explain the process of translation with the help of diagrams.
3. Differentiate between the transcription and translation processes of prokaryotes and eukaryotes.

Summary GSC101 lecture # 34
Biology lecture # 6

DIGESTIVE SYSTEM

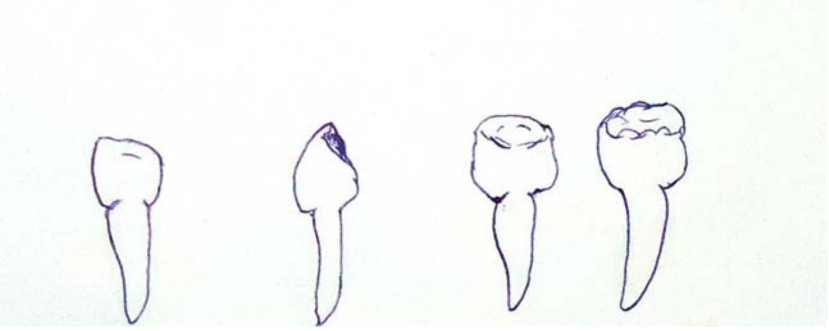
Nutrition

Acquiring energy from environment is one essential property of life. Plants acquire energy from sunlight and prepare their food. We call them producers. Animals, however, acquire energy from either plants or other animals or organic materials. We call the consumers or decomposers.

Common Modes of Nutrition in Animals

- Herbivores
  - Plant eaters, e.g. goat
- Carnivores
  - Flesh, meat eaters, e.g. lion
- Omnivores
  - Mixed food, e.g., bear, crows
- Detritivores
  - Dead organic matter, e.g. earthworms

Dentition is according to the mode of nutrition



Dentition in animals; incisor, canine, premolar and molar teeth.

Mouth Parts also are also according to the mode of nutrition

Animals have different types of tongues according to their mode of nutrition. For example, frogs have forked, inverted and sticky tongue to catch insects. Tongue of chameleon is also sticky and very long. Beaks of birds make another example. Birds have a variety of beaks; long, small, curves and many other. All of these are present in birds according to their mode of nutrition for example parrots have long curves beak for cutting and breaking nuts. Pelican have a very long and wide for catching fish from water. Snouts in mammals make another example. Mammals have different snouts according to their food.

A parrot: observe the long and curved beak.

Nutrition, Ingestion, Digestion, Absorption, Assimilation, Elimination

- After acquiring food and ingestion, animals have to digest it.
- Digestion is actually, breaking down food into small ingredients. For example, carbohydrates to glucose.
- Absorption is movement of food into blood after digestion.
- Assimilation is utilizing those broken small molecules for getting energy for organisms functions.
- Elimination is removal of the undigested matter from the body.

Nutrition and Digestion in Human beings

Humans are omnivores, i.e., we eat plants (vegetables) and meat (chicken, beef). Digestive system of humans hence is adapted accordingly.

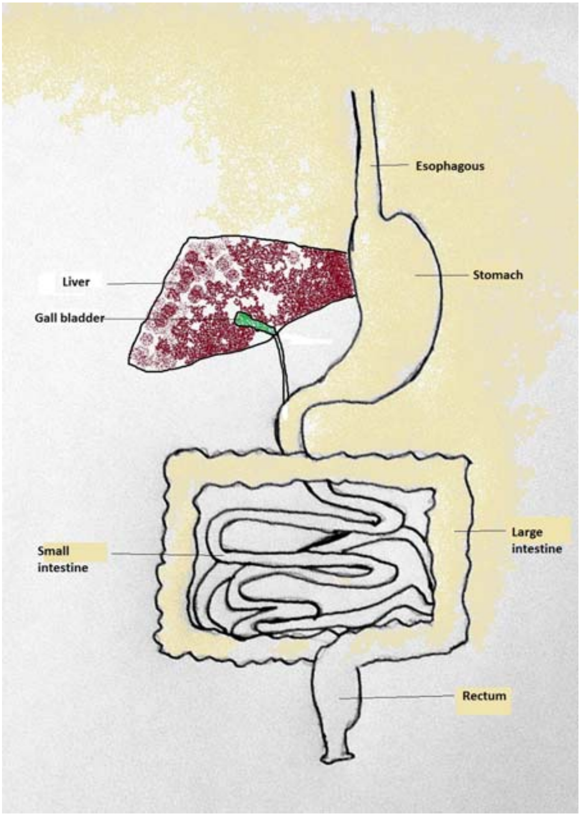
Basic Components of Human Digestive System

- Alimentary canal

- From mouth to anus

- Alimentary canal in humans consist of following parts:
  - Oral cavity
  - Pharynx
  - Esophagus
  - Stomach
  - Intestine (small and large)
    Rectum and anus

- Accessory glands
  - Liver, Pancreas



Digestive system in human beings.

Sensing the Food

We look at the food and smell when we get a food. These are called sensory qualities of food. This is the first part of food selection and foods which are improper are rejected. If the food looks inappropriate or it smells bad, it is rejected. This is a human adaptation just like other animals.

Alimentary Canal - From mouth to anus

The Oral Cavity

Food selection is one function of the oral cavity. Oral cavity has **tongue** with taste buds. Food selection takes place by taste buds if food tastes bad it is rejected. Tongue converts the ground food mass to a bolus. Grinding the food is the other important function of oral cavity. Oral cavity contains teeth for this purpose. **Dentition** is according the food types. Teeth are of four types; incisors, canine, premolars and molars. Human have all four types of teeth; few animals have others. **Lubrication** and **chemical digestion** is another function of the oral cavity. Salivary glands secrete saliva which contains amylase for digestion of starch. It also contains mucous for lubrication of food.

Pharynx

Pharynx is a part of digestive system. It lies just behind the mouth and nasal cavity and above the esophagous and larynx. Food bolus passes through pharynx to enter the esophagus. Pharynx helps swallowing by closing the trachea and nasal cavity pathways.

Esophagus

It is a long tube starts from pharynx and enters stomach. From pharynx, food enters esophagus. In esophagus, food moves down to stomach by a series of muscular contractions called "peristalsis". Bolus moves down by alternate contraction and relaxation of muscles of esophagus. Sometimes an antiparistalsis occur, i.e., movement from stomach to mouth that result in vomiting.

Stomach

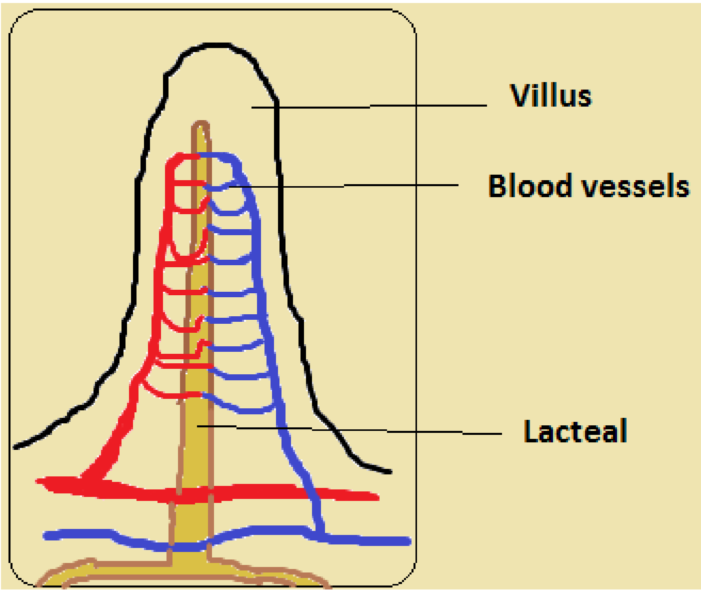
Stomach is mainly a storage organ. It also helps in digestion of proteins. Stomach has guarded openings on either side. There is a sphincter (group of muscles) which is pyloric sphincter that controls movement of food from stomach to intestine. The other sphincter is present where esophagus meets stomach. Gastric glands in stomach produces gastric juice, which contain mucus, hydrochloric acid and an enzyme called pepsinogen. Pepsinogen is converted into pepsin which is its activated form. Pepsin converts proteins to peptides. Protection of the stomach walls from the acid particularly is important, mucus secreted by the stomach walls cover the stomach lining to protect it from acidic damage.

Stomach is also designed to mix up the food with enzymes and acid. Churning movements of stomach walls thoroughly mixes the food with gastric juice. Churning converts food to chyme, small part of which enters the small intestine by pyloric sphincter.

Small Intestine

It consist of three parts; duodenum, jejunum and ilium. Duodenum (first 25 cm of intestine) is the first part where most of the digestion occurs. *Bile* enter here from liver and helps emulsification and digestion of lipids. *Pancreatic juice* from pancreas also enters here, which contains trypsin, pancreatic amaylase and lipase fordigestion of protein, carbohydrates and lipids. *Intestinal juice* is also released, which help in digestion of all foods.

Jejunum is the next 2.4 m of the small intestine; remaining digestion takes place here. Ilium is the last 3.5 m long part where absorption takes place. Its lumen is highly folded. It have extensions of the epithelium called villi and microvilli, which increases the surface area to a greater extent to increase absorption.



A single villus in smalle intestine.

Large Intestine

Undigested food comes in the large intestine. It consists of various parts including caecum, colon, and rectum. Absorption of water from the undigested matter occurs in colon. Water is returned to blood vascular system. Remaining semi solid mass is called feces that are are stored in rectum, when rectum is full it give rise to a reflex for defecation and feces are excreted out.

Intestinal Motility is an important factor. If the motility in large intestine is increased then there is less water reabsorption and result is a situation called **diarrhea**. On the other hand if motility is decreased then **constipation** is the result which means that feces will have less than normal water.

Liver and Pancreas

Liver produces a secretion called bile which helps in fat digestion and emulsification. Bile is stored in gall bladder and is released by its contraction. Liver perform various functions called deamination, converting ammonia to urea, destroys old blood cells and manufactures fibrinogen, which is blood clotting factor.

Exercise

1. Diagrammatically show various parts of human digestive system.
2. How human beings find out the quality of foods?
3. List various functions of small intestine.
4. List various functions of liver and pancreas.

Summary GSC101 lecture # 35
Biology lecture # 7

Transport System and Blood – the Circulatory Fluid

Why transport systems?

Organisms have to exchange materials with the environment. They also need to distribute nutrients, gases and metabolic products within their body.

Living organisms …

- acquire energy or food from the environment; they have to distribute energy and food within the body.
- need an intake of oxygen and removal of carbon dioxide from their bodies.
- need to remove toxic materials and waste products from their bodies.
- have to distribute hormones and other materials in the body.
- have to exchange materials with the environment

For all that, they require a Transport System.

Transport systems in organisms

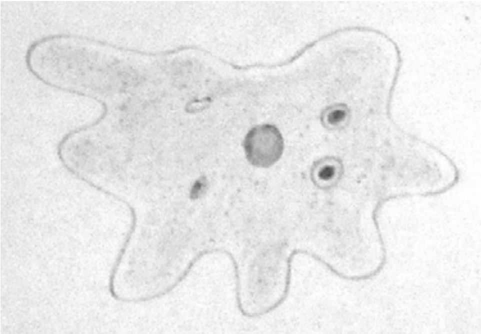
A transport system should fulfill the requirements of the organism for all of the above functions like nutrient distribution or gas exchange.

We take some examples here:

- Unicellular organisms
  - e.g. amoeba
- Simple multicellular organisms
  - Small organisms; e.g. sponges, hydra
- Plants and animals
  - Plants
  - Animals

Unicellular organisms

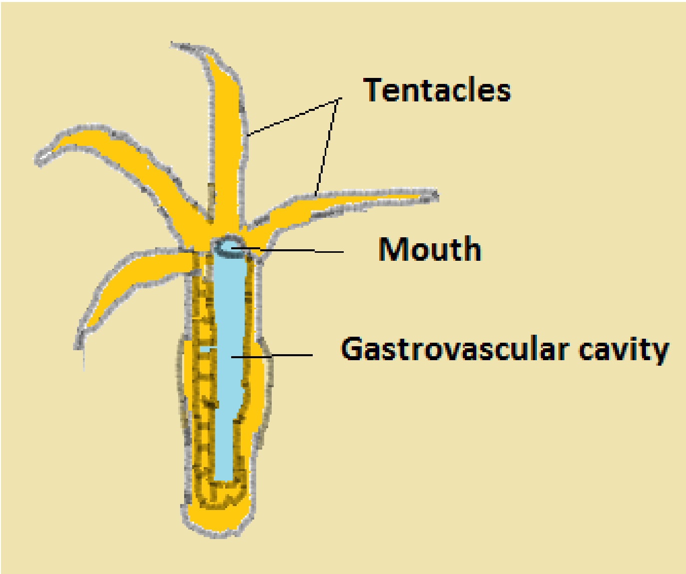
Unicellular organisms have a simple body, just one cell. Their requirements are also few. For example amoeba performs the transport via cytoplasmic streaming which is the movement of their cytoplasm and few organelles. Food vacuoles distribute the food in the body. Contractile vacuoles removes the water fro the body. Cytoskeleton helps in the movement of all the above parts.



Amoeba.

Simple multicellular organisms

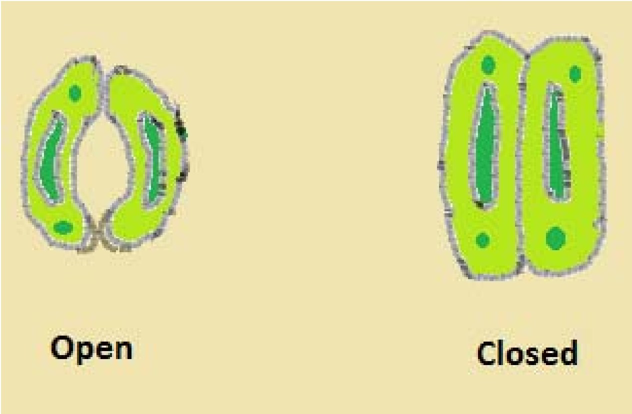
Simple multicellular organisms transport materials by simple methods. Like hydra have a mouth and a body cavity; water enters through mouth and transport of materials takes place in the body cavity. Body wall also exchange materials with the water outside as organism is aquatic. Hence, water act as a medium of transport. Few cells help in transport, which are present inside the body towards body cavity.



Hydra: transport system.

Transport in plants

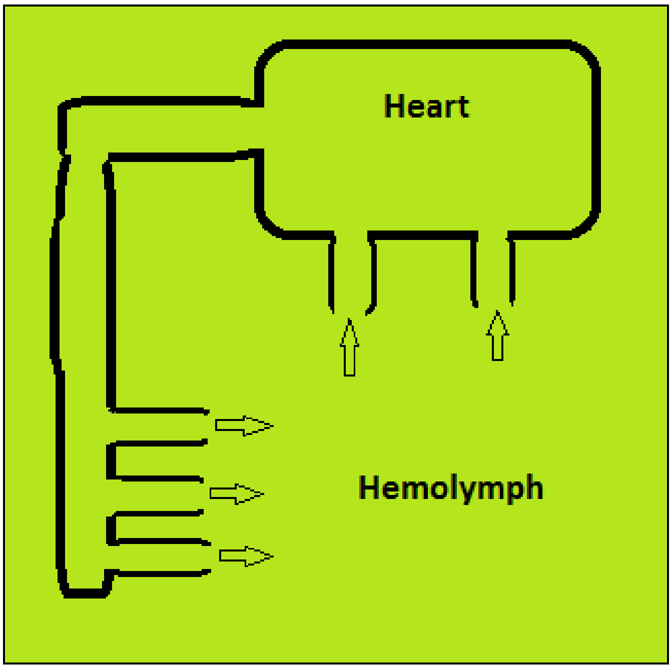
Transport in plants occurs by roots and conducting tissues called phloem and xylem. Roots absorb water and materials from soil. Plants remove water through a process of transpiration. The leave has guarded openings called stomata, which open and close to remove water.



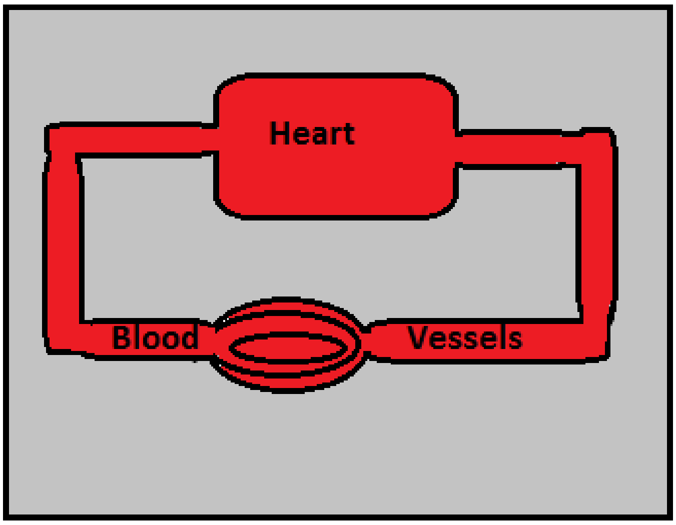
Stomata: opened and closed.

Transport in animals

Animals have a system called circulatory system for transport. There are two kinds of this system called an open circulatory system and closed circulatory system. In an **open circulatory system**, the circulatory fluid is freely moving in the body cavity bathing tissues and there is/are pumping heart/s but these only send blood to some vessels which are then connected to body cavity. In **closed circulatory system**, the blood never leaves vessels and heart and is always present inside the vessels.



Diagrammatic presentation of an open circulatory system. In this system circulatory fluid (e.g. Hemolymph moves into body cavity and from here to back to heart.



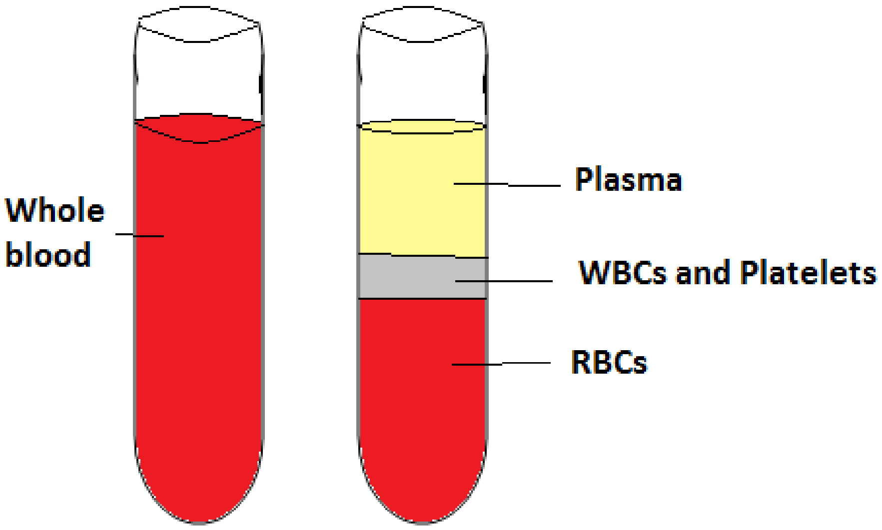
Diagrammatic presentation of closed circulatory system. I this system, blood never leaves vessels.

Basic components of human circulatory system

Blood is the circulatory fluid which is the medium for transport. Blood vessels are the tubular system for transport of blood within the body. Heart is the pumping organ that pumps the blood toward the body.

Composition of blood

Human blood consists of plasma (fluid) and cellular content (cells). Plasma is the fluid with dissolved and un-dissolved materials. It consists mainly of water, which have many inorganic and organic materials dissolved in it. Cellular content consist of Red Blood Cells (RBCs), White Blood Cells (WBCs) and Platelets. Red blood cells are also called erythrocytes and white blood cells are also called leukocytes. Plasma consists of 55% of the blood. Cells constitute 45% of the blood Average human body has about 5liters of blood.
Blood contents could be separated based upon their densities and weights by various methods including centrifugation and sedimentation.



Components of blood.

Functions of the main components of blood

Blood plasma

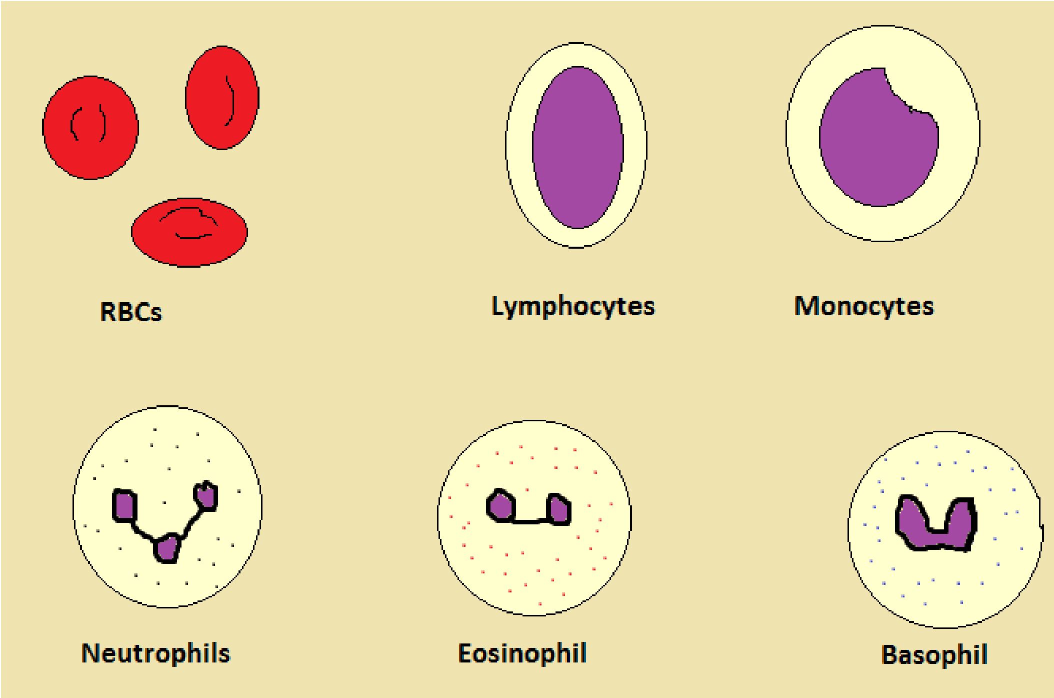
Plasma consist of 55% of the blood, It consist of 92% water. 0.9% of it consists of salts – NaCl, Mg, Zn ions etc. The salts maintain the pH of the blood. Plasma has 7-9% part consist of proteins. Important proteins include antibodies, fibrinogen and albumin. Plasma also contains digested food, nitrogenous wastes, hormones, respiratory gases etc.

Blood cells and cell-like bodies

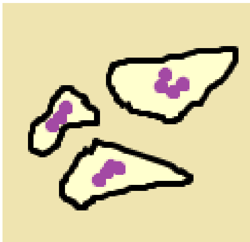
Cellular components of blood consist of erythrocytes, leucocytes, thrombocytes. Erythrocytes – Red Blood Cells carry oxygen with the help of a protein called haemoglobin. In men 5-5.5 million cells/mm^3 RBCs are present. This number is 4- 4.5 million/mm^3 in women. Men have usually larger bodies and more muscle mass, so that heir demand for oxygen is more than women.

Leukocytes – White Blood Cells are categorized in to two kinds: *Agranulocytes* and *granulocytes.* Agranulocytes are theose white blood cells which have nongranulated cytoplasm, these include monocytes and lymphocytes. Granulocytes are those WBCs, which have granulated cytoplasm. These include basophils, eosinophils and neutrophils. Platelets are the third type of cells or we can call these, cell like bodies. These are formed by fragmentation of a single cell called megakaryocyte.

Erythrocytes (RBCs) do not have a nucleus at maturity. That is why these look concave under microscope.



Blood cells include RBCs and WBCs (lymphocytes, monocytes, neutrophils, eosinophils, and basophils).


Platelets.

Blood groups in human beings and blood transfusion

Blood cells have some specific protein present on their surfaces called antigens, which are meant for the identification of the blood cells. About 29 blood groups are identified. The most important blood group systems are, however, two named as **ABO** and **Rh blood group systems**. There are four main types of blood groups present in human beings according to ABO blood group system. These blood groups are based upon presence or absence of two antigens on surface of RBCs called antigen A and antigen B (Table 1). Other important blood group is based upon presence or absence of Rh antigens on the surface of RBCs. The people have Rh antigen on the surface of their RBCs are called Rh positive and those who do not have it are called Rh negative. ABO system works with the help of Rh system. So that we talk of the blood groups based upon ABO system with Rh positive or negative. For example, A +ive means that the person have an A blood type with Rh antigens present.

Table 1: Blood groups, antigens and antibodies.

Blood Group	**Antigen A**	**Antigen B**	**Antibody A**	**Antibody B**
A	Present	Absent	Absent	Present

B	Absent	Present	Present	Absent
AB	Present	Present	Absent	Absent
O	Absent	Absent	Present	Present

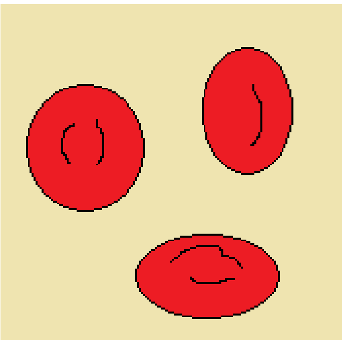
Blood transfusion

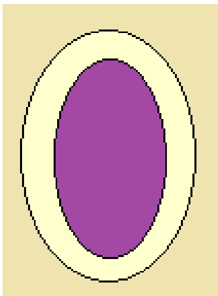
Blood transfusion is required in case of some diseases, surgery or in case of injuries. Blood groups of donor and recipient should match, otherwise could cause agglutination reactions leading to even death of the patient. Blood groups are matched using antigen antibody reactions. A blood group O -ive is called Universal donor because it has not antigens, hence, it cannot react with any of the antibodies in recipient's blood. Universal acceptor is AB+ blood group which has all antigens.

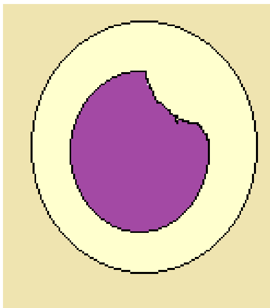
Exercise

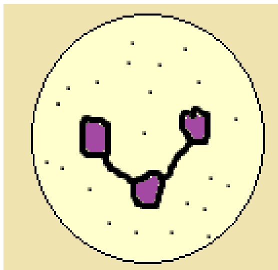
1. What are the ABO blood groups and how these are important in transfusion?
2. Describe various transportation systems in unicellular and small multicelluar organisms with the help of diagrams.
3. What are various components of blood and how can we separate them?
4. Describe important functions of white blood cells.
5. Identify the following:

Diagrams of blood cells

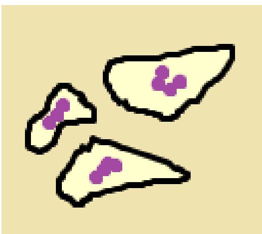


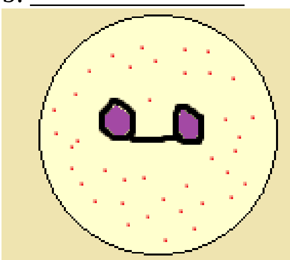


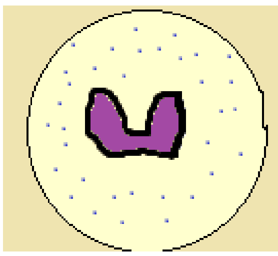




a. ________________________ b. _________________ c. _________________ d. _________________







e. _______________________ f. _____________________ g. _________________

6. List various functions of red blood cells.

Summary GSC101 lecture # 36

Biology lecture # 8

Circulatory System in Humans - Blood Vessels and Heart

Circulatory System in Humans

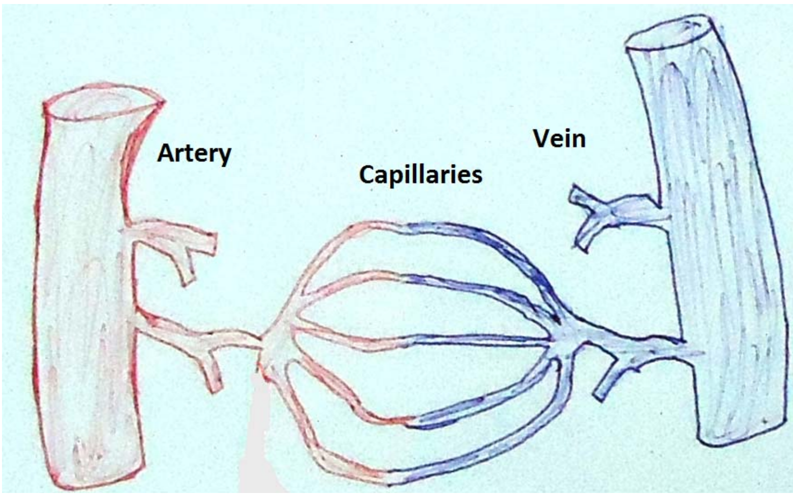
Circulatory system in humans consists of blood, vessels and heart. Blood is the circulatory fluid. We can call it a **liquid tissue**. Blood consist of plasma – the watery fluid and cells – the cellular content. **Blood** has been described in detail in last lecture. Here we talk about heart and blood vessels. **Heart** is a pumping organ and is highly muscular. Function of the heart is to pump blood with pressure towards lungs and body. **Vessels** are of three main types; arteries, veins and capillaries. Arteries carry blood from the heart to body. Veins return blood from body to heart. Capillaries connect arteries to veins. Function of the capillaries is the exchange of materials.

Structure and functions of blood vessels

Arteries and veins are elastic in their structure. These also have a layers of muscles. These consist of 3 layers:

- External layer - connective tissues layer
- Middle layer, consist of smooth muscles
- Inner layer, consist of endothelium

Lumen of both of these is meant for blood flow. Arteries have a lumen smaller in diameter and veins have large.



Artery, vein and capillaries.

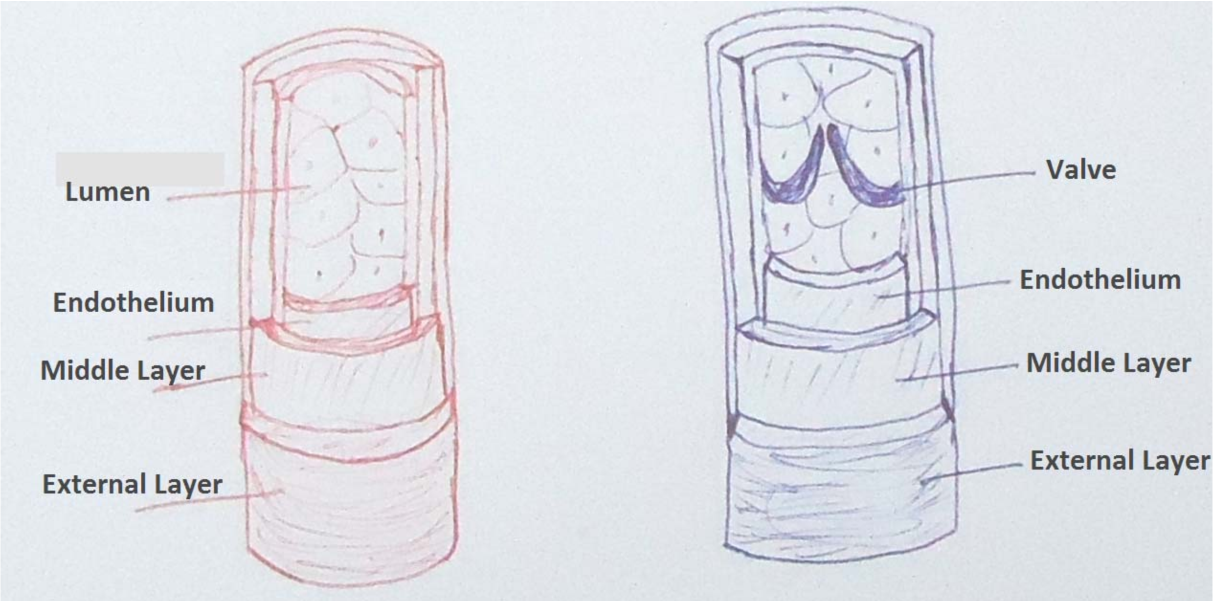
Comparison of Arteries, Veins and Capillaries

	Arteries	**Veins**	**Capillaries**
Carries blood	From heart to body; one exception pulmonary artery	From body to heart; one exception is pulmonary vein	From arteries to tissues to veins
Stat of blood	Oxygenated	Deoxygenated	Oxygenated to deoxygenated
Layers	3	3	1
Walls	Thick	Thin in comparison to arteries	Very thin; one cell thick only called endothelium
Pressure	High	Low	Medium
Valves	Absent	Present	Absent

Arteries carry blood from heart to body. These face maximum pressure. Their function is to distribute blood to all the body tissues. Blood is pumped in the arteries by the heart with very high pressure that is why arteries are thick walled to withstand high pressure.

Veins have to collect blood from the body and return it to the heart. Veins face less pressure, pressure almost negligible in major veins. Blood flow in major veins against gravitational pull and with low pressure so that veins have valves that prevent backflow of blood. In many parts of the body like arms and legs there are muscles that contract and relax to move the blood towards heart.

Capillaries have to exchange materials with tissues; these originate from arteries and pass from tissues then joins to make veins. Capillaries have to carry out exchange of materials with the tissues that is why their walls are just one celled thick. Capillaries when enters tissues makes branches, where they branch groups of muscles are present which may open or close to increase or decrease the blood flow towards tissues.



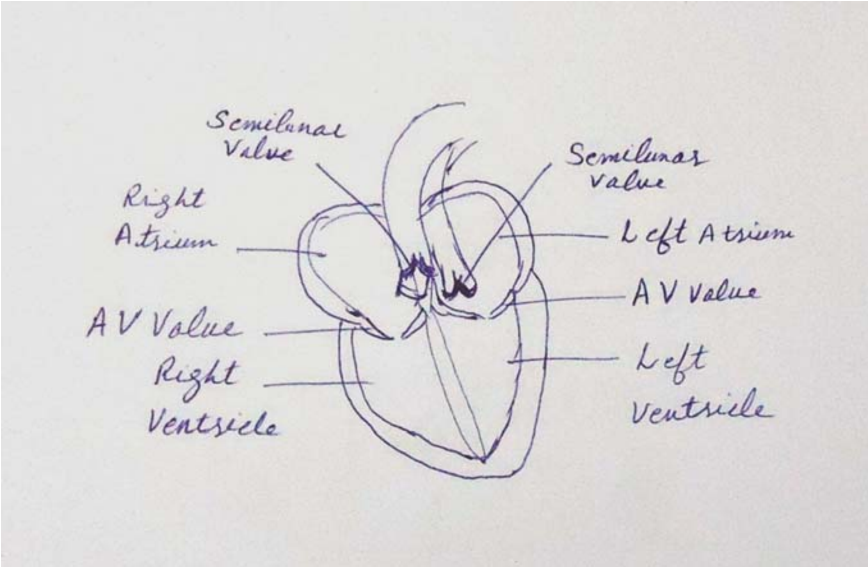
Comparison of an artery and a vein.

Main arteries and veins in human arterial and venous systems

- head, shoulders, arms
- other body organs like kidneys, gonads, liver etc.

Structure of human heart

Heart in human beings is a muscular pump to push blood towards body and lungs. Heart in humans is of the size of a clenched fist. Heart consists of four chambers including 2 atria and 2 ventricles. Atria receive blood from body and lungs. Ventricles push blood from heart to body and lungs. These chambers (atria and ventricles) are connected to each other. At their junction valves are present, which are responsible to prevent backflow of blood.
Left side of the heart, particularly ventricle is stronger because it has to push blood to the whole body in comparison to right side.



Structure of human heart.

Double pumping action of heart and role of valves

Deoxygenated blood from body enters the heart through major veins (vena cava) to right atrium. When right atrium contract, blood enters the right ventricle. There is a valve called **tricuspid valve** that prevents backflow of blood. On the other side, oxygenated blood from lungs enters the left atrium and when left atrium contract it enters the left ventricle. At the junction of left atrium and ventricle another valve is present called **bicuspid valve** that prevents backflow of blood. **Tricuspid** and **bicuspid valves** are collectively called **atrioventricular vales**.

In fact, both atria are filled at the same time and also contract at the same time to push blood in the ventricles. Both ventricles also contract at the same time to push blood toward body (left one) and lungs (right side). **Right ventricle** pushes blood in the **pulmonary artery** towards lungs. At this junction a valve is present called **pulmonary valve** that prevent backflow of blood from pulmonary arteries to right ventricle. **Left ventricle** pushes blood towards **aorta**, which is the main artery distributing blood the body. This junction is also guarded by a valve called **aortic valve**, which prevents backflow of heart from the aorta to left ventricle. **Pulmonary** and aortic **valves** are collectively called as **semilunar valves**.

Self-excitatory system of the heart

Heart has self-excitatory system. Heart has s group of muscles called **sinoatrial node** which produces impulse (electrical activity) that spread in the heart to contract its various chambers systematically. Impulse spread toward atria first and causes the atria to contract. Then it enters another node called **atrioventricular node** where its magnitude is increased and then it enters the ventricles and the ventricles contract. The self-excitatory group of muscles of the heart is called **pace maker**.

Cardiac Cycle

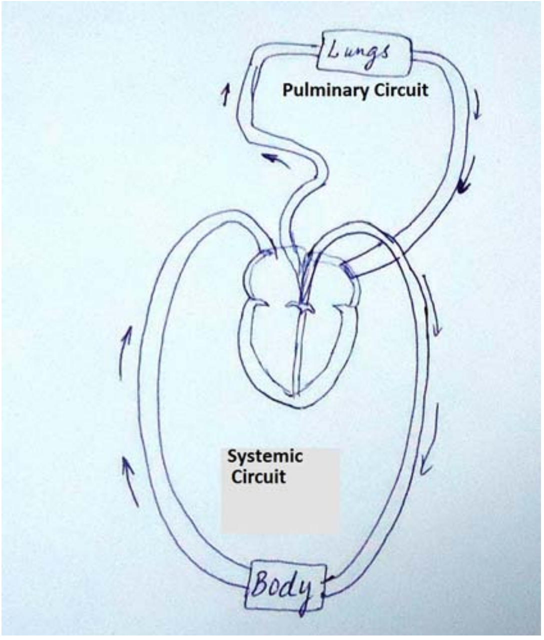
Cardiac cycle is the time period from when the blood enters the heart to the time when blood is pushed by the heart. We can also say that it is the time period from artial and ventricular diastole to ventricular systole.
Cardiac cycle consists of following steps:

1. Both atria and ventricles are relaxed. This is the time when both atria are filled with blood from body and lungs. All heart muscles are relaxed, which means that these are at diastole.
2. Then both atria contract and blood is pushed into ventricles. This is called atrial systole. At this time, both AV valves are open and both semilunar valves are closed.
3. Then the ventricles contract and push blood into aorta and pulmonary artery. This is called ventricular systole. With this, a **cardiac cycle** is complete.
4. Then again, both atria and ventricles are relaxed, i.e., come back to the initial state.

Double Circulation

Human circulatory system is called a double circulatory system because heart receives and sends blood from and to lungs (**pulmonary circuit**) and body (**systemic circuit**). Look at the diagram below for a detailed view.

- Systemic circulation
    - From heart to body and vice versa
    - Head, shoulders and arms
    - Lower body organs
- Pulmonary circulation
    - From heart to lungs and vice versa



Double circulation in humans.

Exercise

1. Draw the structural diagram of human heart.
2. Differentiate between arteries and veins using diagrams.
3. Draw the structure of a capillary. Also describe the functions of capillaries.
4. Explain the significance of valves in preventing backflow of blood in heart.

Summary GSC101 lecture # 37
Biology lecture # 9
Respiratory System

Why respiration?

- Living organisms needs energy for their activities.
- Energy is extracted by complex metabolic processes from food or photosynthesis.
- Respiration is the process of exchange of gases to produce energy in biological form.

What is respiration?

Respiration consist of processes involves exchange of gases in living organisms or metabolic reaction to produce energy. Respiration is one of the most important metabolic activities. It is of two types:

- **Organismic respiration** consists of breathing or ventilation, i.e., inhalation and exhalation movements and gas exchange.
- **Cellular respiration** consist of metabolic reactions to produce energy by utilization of oxygen, production of carbon dioxide and extracting and conserving energy from food molecules in biological form, such as ATP.

Cellular respiration

Cellular respiration is of two types:

- Aerobic, in which oxygen is utilized to produce energy.
  - Example is electron transport chain in mitochondria.

- Anaerobic, in which oxygen is not involved but energy is produced using other molecules.
  - Example is fermentation in some bacteria.

Organismic respiration

Organismic respiration is the ventilation or breathing, i.e., the movements which causes inhalation and exhalation. Air contains gases and exchange of gases occurs in the specialized organs, for example, lungs in humans.

Difference between cellular and organismic respiration

- Cellular respiration is a series of events of metabolic reactions for production of energy.

- Organismic respiration is the process of coordinated movements of body that results in inhalation and exhalation of air. *We also call it breathing or ventilation.*

Respiration in air and water

Respiration in air is easier in comparison to water because air is lighter and water is denser. Also, air is much more saturated with oxygen than water. So that gas exchange in air is easier in the water than in water.

Respiration in plants

Gas exchange in plants occurs by stomata in mesophyll cells. Stomata are openings guarded by guard cells; these are used for transpiration in plants through water vapors. Roots of land plants get the oxygen required by the plants from air present in soil. Aquatic plants acquire their oxygen from oxygen dissolved in water.

Respiration in animals

In animals, respiration occurs by means of specialized organs, for example gills in fishes and lungs in terrestrial animals. The most important property of the respiratory organs is respiratory surfaces that support and facilitate the process of repiration.

Properties of Respiratory surfaces

Properties of Respiratory surfaces include a large and moist surface area, a thin epithelium, ventilation (air availability) and a capillary network.

Respiration in some small animals

In small animals, respiration occurs by means of general body surface or specialized systems. Hydra is an aquatic organism, which have a mouth and body cavity through which water moves in and out. Cells of the inner body wall exchange gases with that water. Cells of the epidermal layer exchange gases with the water.
In some other organisms like earthworms which have a closed circulatory system the exchange of gases takes place by the capillaries, which are present in closed vicinity with the body wall.

In the arthropods, especially insects like cockroach a very special system of gas exchange exist called the **tracheal system**. Tracheal system is a system of tubes which are extensions of the body wall and makes a network of tubes called **tracheae**, **tracheoles** and **air sacs** in the body. These have openings to the exterior called **spiracles**. Air enters in through spiracles and enters the trachea and tracheoles, which are present close to the tissues. Gas exchange is easier because in trachea only air is present, which is a very lighter medium. Tracheal system is a very efficient system of respiration.

Respiration in fish, frog and birds

Fishes

Fishes are aquatic animals; these have respiratory organs called **gills**. Water enters through mouth into the gills where gas exchange occurs and then water move out from gills. Heart is fishes is called a single circuit heart, which pumps blood towards gills where gas exchange occurs and then blood moves towards body.

Frogs

Frogs are called a transition between aquatic and land animals. These live in water and land both. These have three different types of respiratory system at different stages of life. When a frog is hatched for an egg and becomes a larva, it lives in water and respires through gills. When it becomes an adult frog it respires by lungs and skin. Frog's skin has a network of blood capillaries so that gas exchange may occur there.

Birds

Birds have a very efficient system of respiration. Birds respire through lungs. They also have air sacs in their in their body and bones, which also helps in capturing air and hence efficiency of gas exchange is improved.

Respiratory organs

Land animals have their respiratory organs named lungs. In aquatic animals, gills are the organs for gas exchange.

Respiratory system in humans

Respiration in human beings occurs by lungs and associated air passageways. Human respiratory system consists of:

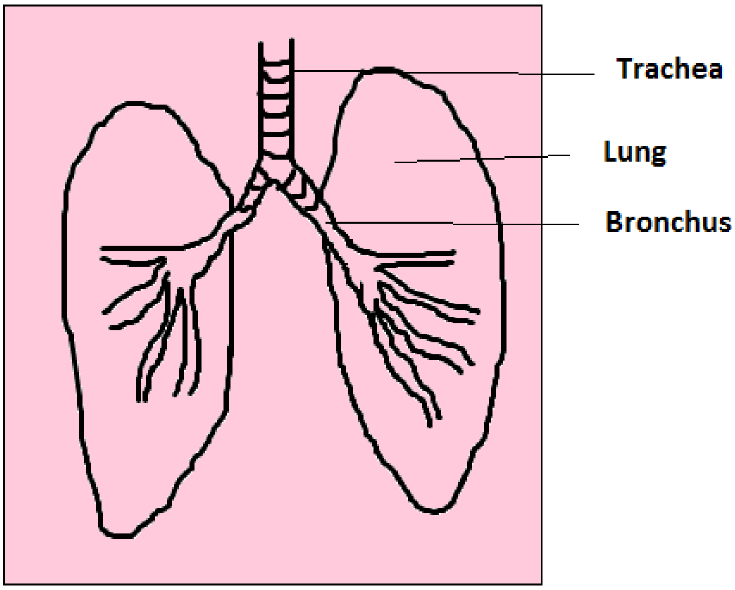
Air passageways in humans

- Nostril and nasal cavity
- Pharynx
- Larynx
- Trachea
- Bronchi
- Bronchioles

Lungs in humans

- Pleural cavity

- Body of lungs
- Alveoli – the smallest units



Lungs inhuman beings.

Structure and functions of various parts of air passageways

Nose and nasal cavity

Nose is the part for inhalation. Nose and nasal cavity is lined with ciliated epithelium and its surface is covered with mucus. The ciliated and moist surface traps dirt and other particles. The air, which enters inside is filtered, moist and warm.

Pharynx

It is a small muscular passage, which is lined with mucous membrane. Air moves down to larynx through pharynx.

Larynx: the voice box

Larynx is a complex cartilaginous structure, through which air moves down to trachea. Its opening is ciliated and covered with mucous. Mucus membrane is stretched across into thin edged fibrous bands called *vocal cords*. Vocal cords help in voice production.

Trachea (windpipe)

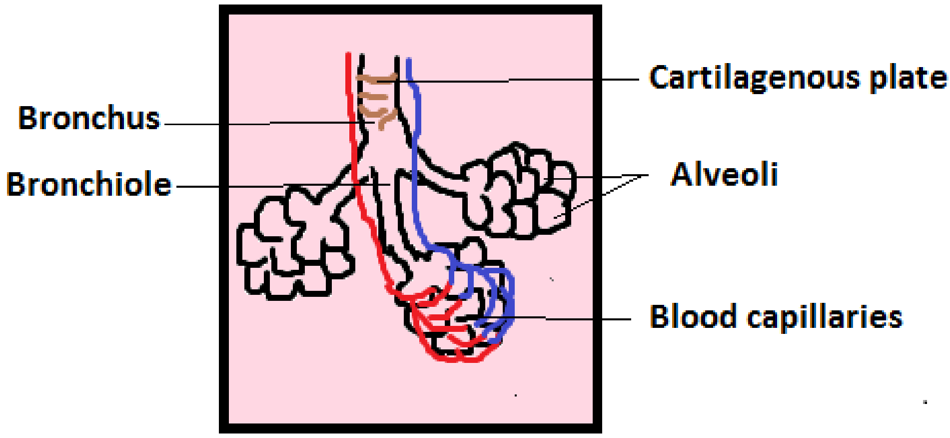
Trachea is a long tube stretched from larynx to lungs. It has a tubular structures and it lies ventral to the esphagous. It has C-shaped cartilaginous rings which are supporting structure and prevent tracheal collapse. Trachea extends through the chest cavity or thorax. In thorax, it divides into 2 tubes called *bronchi* one entering each lung.

Bronchi, bronchioles and alveoli

Trachea divides to form *bronchi* in thorax region. Bronchi enter the lungs and divide further to make *bronchioles* (when they attain a diameter of 1mm or less). Bronchi have same cartilaginous rings but these become irregularly distributed plates when reaches at the end of bronchioles.

Alveoli

Brochioles keep dividing further and enter deep into the lungs to give rise to *air sacs*. Air sac is the functional unit of lungs. Air sacs consist of several microscopic structures called *alveoli*. Alveoli and air sacs are covered by a network of capillaries. This network is the site of gas exchange.



Functional units of lungs.

Structure of lungs

There is a pair of lungs, one is right and other is left. These are present in chest cavity. Lungs are protected by ribs and pleural cavity (double membrane fluid filled cavity). Lungs are spongy in structure because of the presence of millions of alveoli. Below lungs a muscular floor of the chest is present, which is called *diaphragm*.

Breathing

Breathing is the process of inhalation and exhalation. Lungs are spongy, cannot pull or push air themselves. Breathing movements occurs with the help of pressure and movements of diaphragm. Diaphragm is dome-like structure present as the floor of chest cavity. When it is contracted, it becomes less dome-like, which results in expansion of chest and inhalation of air. When it is relaxed then it becomes more dome-like and pressure in the chest is decreased, which results in exhalation of air. When muscles between the ribs contract, the rib cage is elevated; and when relax, ribs settle down. This movement also helps in the process of breathing.

Exchange of gases in alveoli

Gases are exchanged against a pressure difference in the blood and lungs (alveoli). Blood capillaries are distributed around alveoli in very thin layers. Blood cells and alveolar air are very close for exchange of gases. Gases are exchanged at the alveoli.
Hemoglobin (Hb) in blood cells help in exchange of oxygen against the concentration difference.

$Hb + O_2 \longrightarrow HbO_2$ (reversible if pressure of gases in air is changed)

Transport of CO_2

Carbon dioxide is more soluble and dissolves in tissue fluids. From here it enters into blood capillaries. Carbon dioxide is transported in blood as:

- 20 % as carboxyhemoglobin
- 5% by few plasma proteins
- About 70 % as bicarbonate ions combined with sodium.
- CO2 + H2O –Carbonic anhydrase- H_2CO_3
- $H_2CO_3 \longrightarrow H+ + HCO^{3-}$

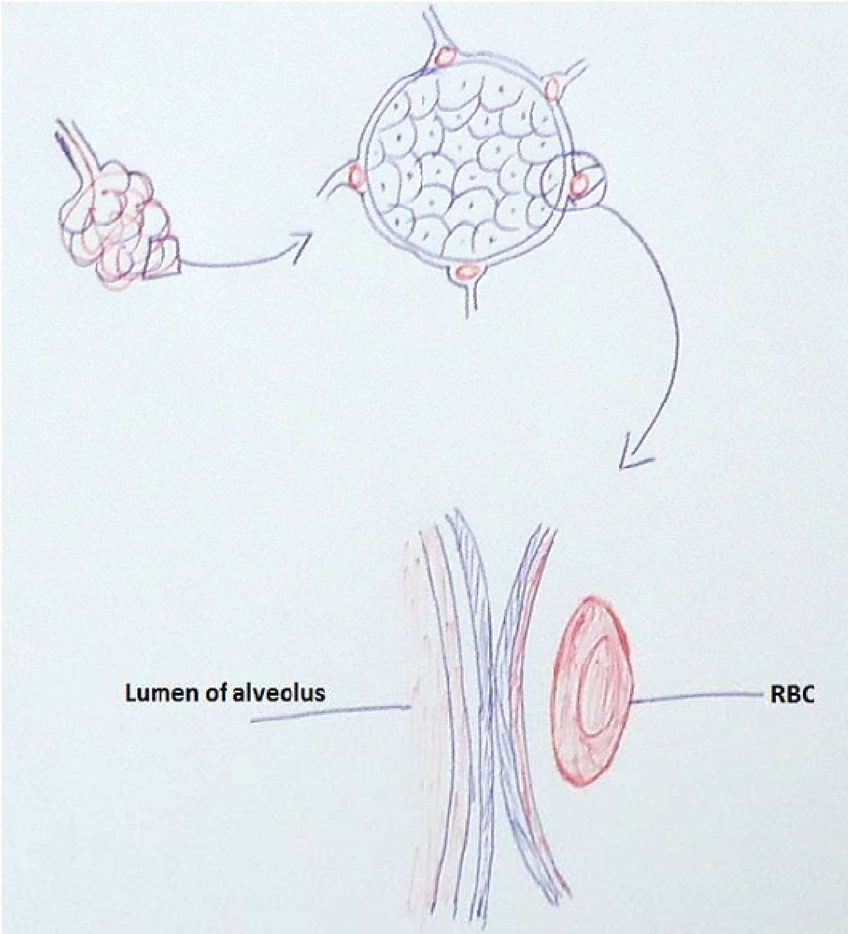


Figure showing association of the alveoli with blood capillaries in lungs.

Factors affecting gas exchange

- Carbon dioxide
  - If CO_2 increases then O_2 tension decreases. The result is that capacity of hemoglobin for O_2 is reduced.
- Temperature
  - Rise in temperature decreases the oxygen carrying capacity of hemoglobin.
- pH
  - If pH declines then oxygen carrying capacity declines.

- H+ ions bind to hemoglobin to decrease oxygen carrying capacity.

Lung capacity and effect of exercise on breathing rate

In humans, fully inflated lungs have a capacity of 5 liters. Normally, at rest or sleep exchange is half a liter. During exercise, it may increase up to 3.5 liters. It means that there is a 1.5 L residual volume that cannot be expelled. Inhalation per minute is 15-20 times; during exercise it may be up to 30 times to fulfill the needs of exercising muscles.

Changes in composition of breathed air

Gas	**Inhaled air**	**Exhaled air**
Oxygen	21 %	16%
Carbon dioxide	0.04%	4%
Nitrogen	79%	79%
Water vapors	Variable	Saturated

Exercise

1. Differentiate between cellular and organismic respiration.
2. Draw the structure of human lungs.
3. What are characteristics of a respiratory surface?
4. How exercise affects the breathing process?

Summary GSC101 lecture # 38
Biology lecture # 10

Excretory System

Introduction and need of excretion

Living organisms have to metabolize which consist of anabolism and catabolism. Anabolism consists of all reactions for formation of compounds. Catabolism is break down of various compounds including glucose, proteins and lipids for the formation of energy.

Catabolism of carbohydrates, proteins and lipids

carbohydrates + oxygen $\longrightarrow$ $CO_2 + H_2O$ + energy

proteins + oxygen $\longrightarrow$ $CO_2 + H_2O$ + NH3 + energy

lipids + oxygen $\longrightarrow$ $CO_2 + H_2O$ + energy

Metabolic wastes

We can see in the reactions above that metabolic waste products are carbon dioxide, water and ammonia. These are waste and surplus materials. These have to be removed. Ammonia is highly toxic for the tissues. Water and CO_2 are dangerous for the body if these are present in excess. Rise in CO_2 may result in decrease in pH in blood which is dangerous. Ammonia is highly toxic and has to be converted into less toxic form. But those forms also need to be removed. Changes in water concentration in tissue fluids also create problems. Higher concentration may cause *dropsy*, which is accumulation of water in tissues. Decrease in water concentration may lead to dehydration. For all of these reasons an excretory system is required.

Excretion in Vertebrates

Major waste products in vertebrates

- Carbon dioxide
- Mineral salts
- Urea
- Creatinine
- Uric acid
- Excess water

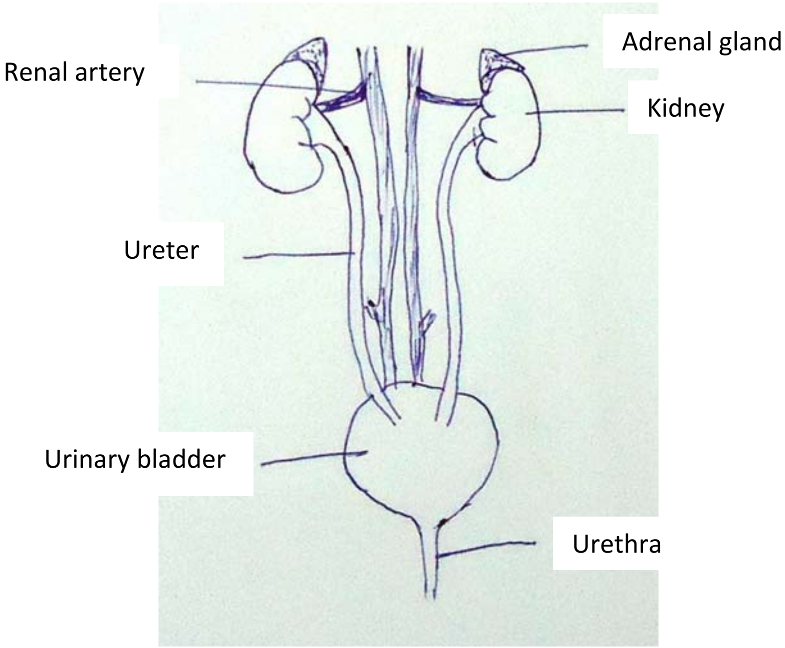
Excretion in animals

- Unicellular organisms
- Small animals
- Large animals
- Adaptations to habitat
  - water - fresh and brackish e.g. marine
  - desert
  - terrestrial

Excretory Organs

- Skin acts as excretory structure
- Salt glands are present in some marine or brackish water inhabiting organisms
- Intestine sometimes act as excretory organ
- Kidney
  - Major organ for excretion in vertebrates
  - Help also in osmoregulation
- Structure of kidney is different in organisms living in fresh and marine waters. Kidneys in fresh water organisms is modified to produce dilute urine while kidneys of marine or brackish water inhabiting animals are designed to produce concentrated urine.

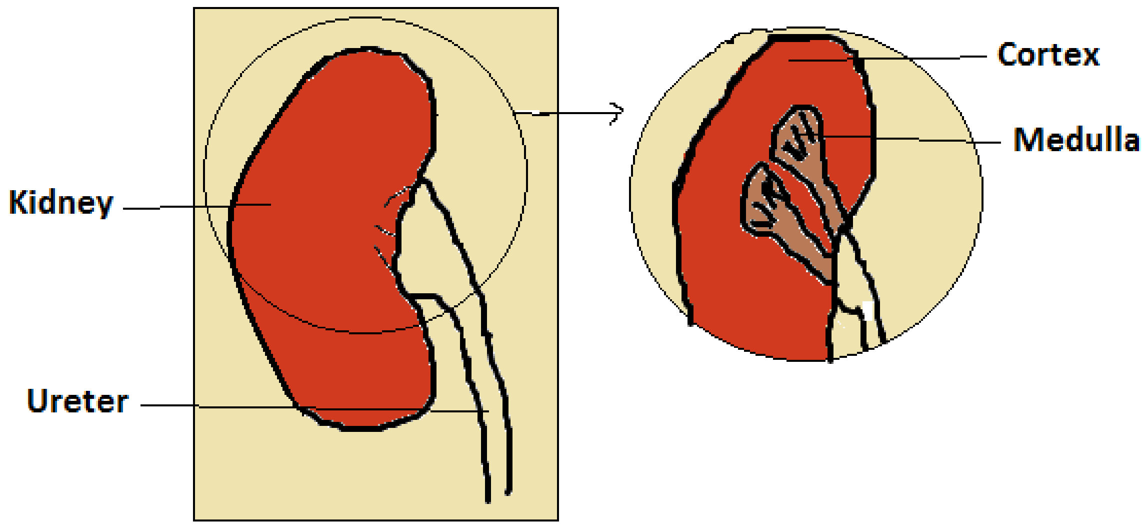
Basic components of human excretory system: kidneys and accessory parts



Various parts of human excretory system.

External and internal structure of kidney

Kidney is a bean shaped structure. A pair of kidneys is present in abdominal cavity attached to dorsal body wall. The concave part of kidney lies towards vertebral column. There is a depression present towards the vertebral column which is called *hilus*. The concave part provides space for entrance and exit of renal artery, vein and nerves. A thin tube *ureter* arises out of the concave part of kidney.



Structure of a kidney.

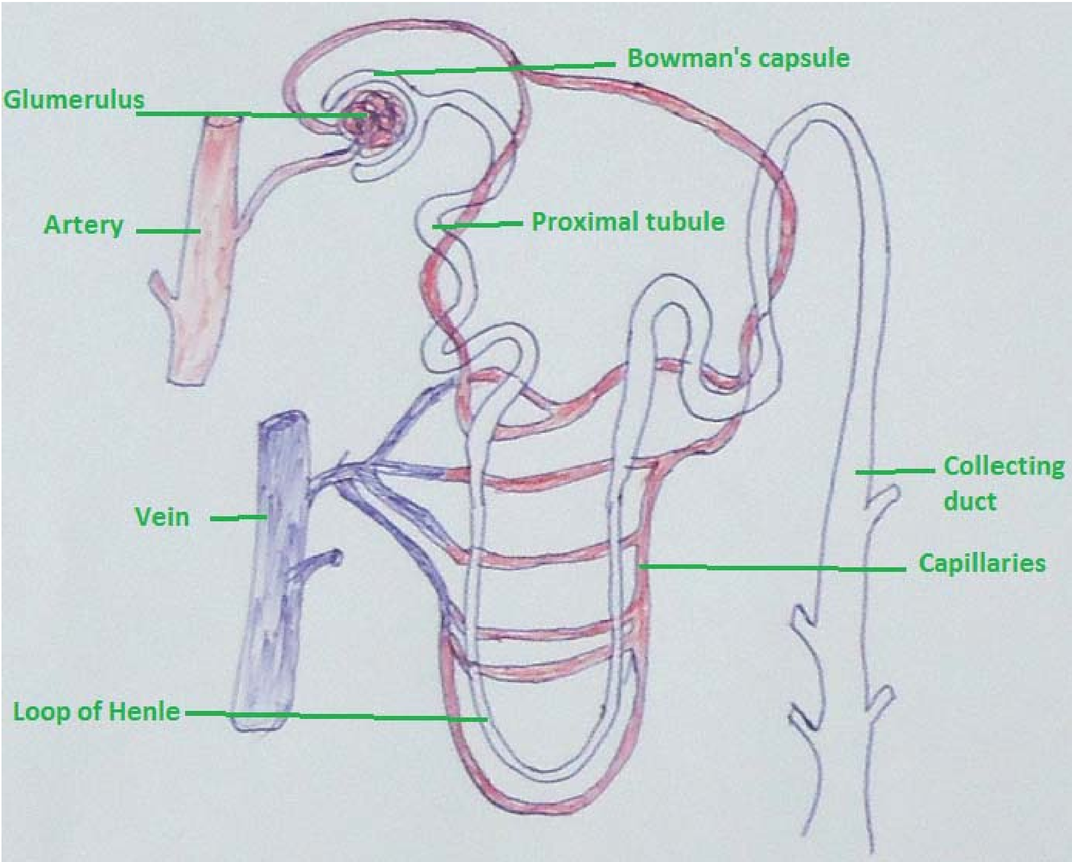
Renal cortex and renal medulla

If we look at a section of a kidney, then the outermost layer, reddish in color is called *cortex*. After cortex the second layer consists of structure like pyramids occur. This region is called *medulla.* A funnel shaped cavity is present towards inside that receives urine called *renal pelvis*.

Nephron

Nephron is the functional unit of kidney. Kidneys have many small structures present in cortex and medulla called nephrons. Function of the nephron is to produce urine. Nephron consists of following structures:

- Glomerulus, which is a capillary network.
- Bowman's capsule (Glumerular capsule) is the capsule like structure in which the glumerulus is present.
- Convoluted tubule
- Loop of Henle
- Collecting duct



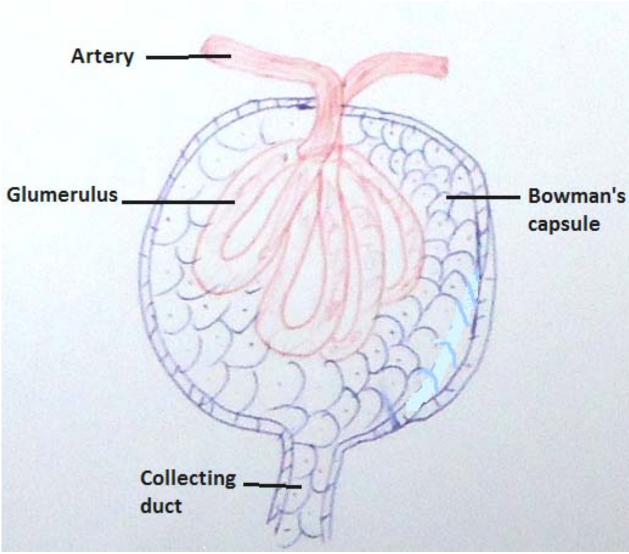
Structure of a nephron.

Functioning of the kidney: Urine formation

Function of the kidney is to produce urine. Kidney produces urine by following mechanism.

Pressure Filtration

- Pressure filtration in the renal corpuscle occurs due to blood pressure in renal artery. Molecules other than RBCs and plasma are filtered, i.e., these enter into the renal capsule.
- It is called Bowman's filtrate
- It consist of salts, glucose, urea and uric acid



Filtration apparatus: Bowman's capsule and glumerulus.

Reabsorption

The filtrate moves down the tubular system. Next step is called reabsorption. Reabsorption means that those compounds which are useful for the body return back to the blood and the remaining part of filtrate in the tubules makes urine consist of water and nitrogenous wastes. Reabsorption occurs through the network of capillaries surrounding the tubules. Reabsorption is selective process. Glucose, water and salts are reabsorbed.

In the last step, only nitrogenous wastes remain inside the urine. This urine now goes down to pelvis and uretes. Through ureters it enters the urinary bladder for temporary storage. When bladder is full, there is a reflex for urination through urethra. Urination is not under conscious control in infants. In adults, however, this is under the conscious control through a sphincter present on the junction of urinary bladder and urethera.

Osmoregulation

Kidneys help in osmoregulation. This also helps in the maintenance of blood pressure. In case of increased blood pressure dilute urine is produced to temporarily reduce the quantity of water. In case of decreased blood pressure concentrated urine is produced and water is reabsorbed to compensate for fluid loss like in case of too much perspiration. Thirst is also a reflex in response to decreased quantity of water in blood.

Exercise

1. Draw a labeled diagram of human kidney.
2. Describe the structure of human excretory system with the help of diagram.
3. Describe the process of urine formation.
4. Describe the role of kidneys in osmoregulation.

Summary GSC101 lecture # 39
Biology lecture # 11
Reproductive System

Introduction of reproduction

Reproduction is one of the basic characteristics of life. It is a biological process by which the organisms produce their young ones which are similar to their parents. This ability also allows organisms to adapt itself to the changing environment.

Types of Reproduction

There are two types of reproduction, asexual and sexual. In *asexual reproduction*, offspring are produced by simple cell division. No gametes are involved and offspring have same characteristics as their parents. In *sexual reproduction*, two organisms are involved in reproduction and offspring have characteristics which are combination of their parents and some new. Gametes are involved in this kind of reproduction. Sexual reproduction has advantage of increase in genetic variability. Gametes are formed by a process called meiosis in which alterations in genetic material takes place. As two organisms are involved, mixing of their characteristics takes place that increase more genetic variability. Genetic variability leads towards more adaptability to the environment.

Types of asexual reproduction

Asexual reproduction involves no gametes. There are many methods of asexual reproduction in organisms including:

- Binary fission
- Multiple fission
- Budding
- Regeneration
- Vegetative propagation in plants

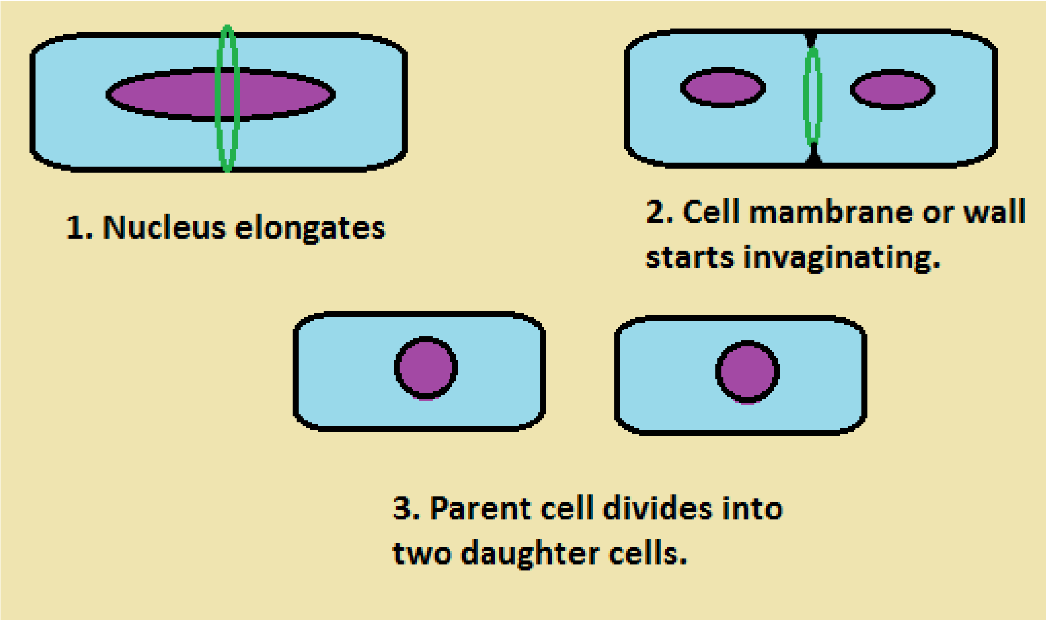
Binary fission

This is a type of asexual reproduction in which one unicellular organism divides into two by simple division. In bacteria, for example, binary fission takes place:

1. Replication of single chromosome takes place.
2. Daughter chromosomes move towards opposite poles.
3. Cell membrane invaginates and meets in the center.
4. Cell wall follows the cell membrane and cell divides into two.

Binary fission also takes place in unicellular organisms like amoeba and paramecium. In these organisms:

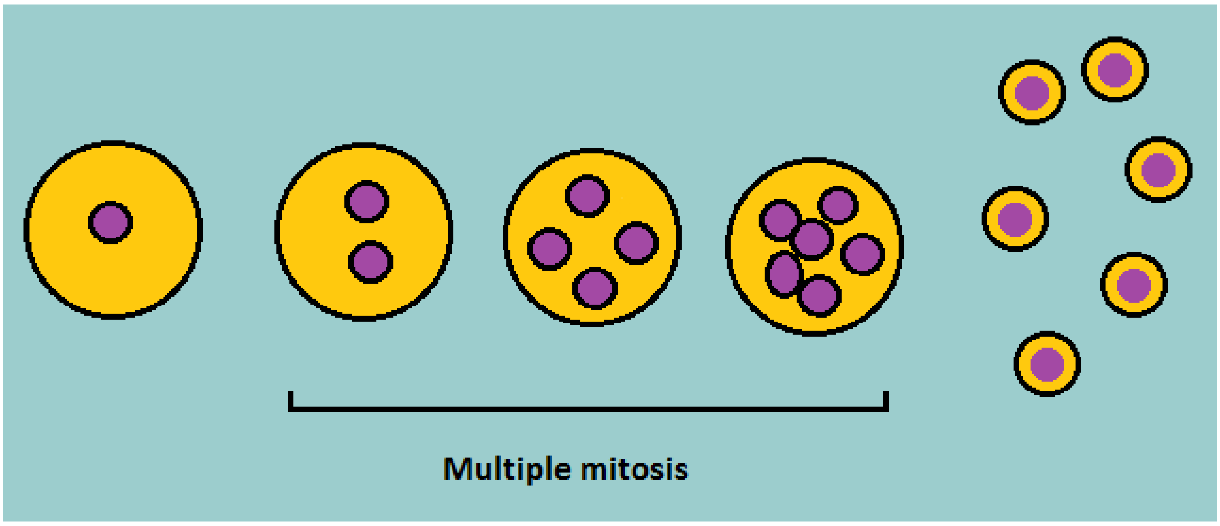
1. nucleus elongates and divide into two
2. Cytoplasm also divides and cell divides into two



Process of binary fission.

Multiple fission

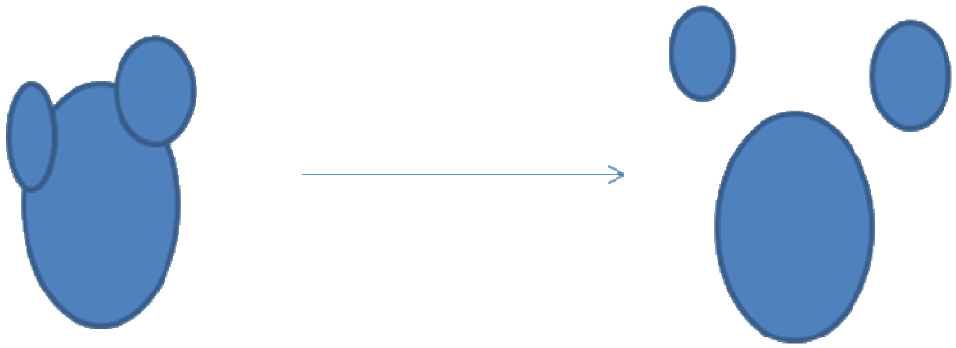
This is a process in which a single cell divides into many cells. For example amoeba makes a cyst in unfavorable conditions. Its nucleus divides into many nuclei and every part is surrounded by some cytoplasm. When favorable conditions come, the cyst split into many cells, each one a new amoeba.



Multiple Fission results in production of many daughter cells.

Budding

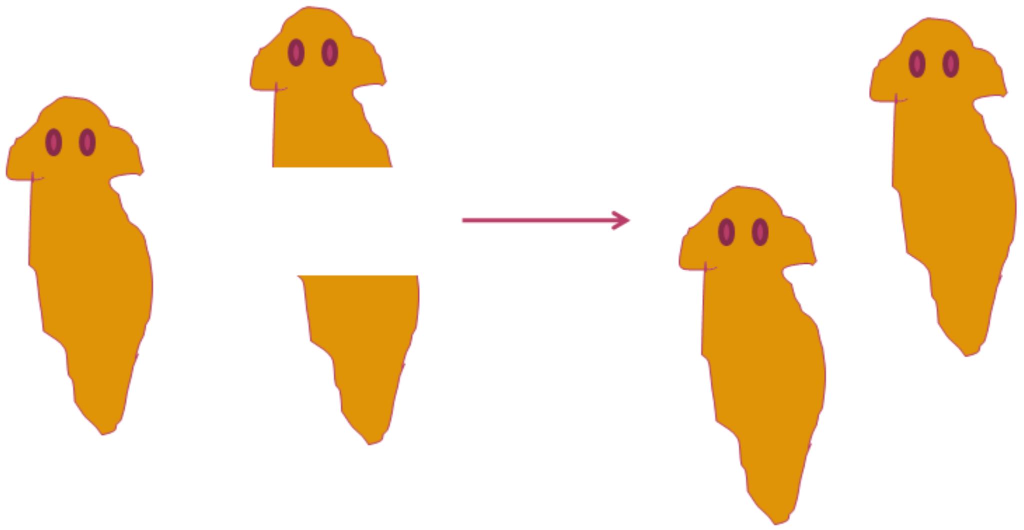
In this process an outgrowth (called bud) appears on the surface of an animal and may separate later on to develop into a new organism. Examples are yeast, hydra.



Budding in yeast

Regeneration

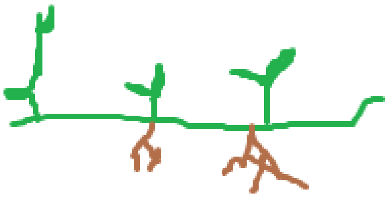
Regeneration is the formation of lost part of the body. Examples are starfish and planaria. If their one body part is lost then they have ability to grow it again. In star fish an arm is lost then the arm grows again.



Regeneration in planaira.

Vegetative propagation in plants

It is a process that involves the vegetative propagation of some plant part such as stem or leaves. Examples are runners, suckers. Runners like grasses and strawberry and suckers like banana and mint.



Adventitious roots are means of vegetative propagation.

Sexual reproduction in Plants

Flowering plants reproduce by sexual reproduction. Flowers have male and female parts called stamen and carpel. Fertilization occurs with the help of a process called pollination, i.e., transfer of pollen grains from anthers of stamen to carpel and then ovary. Pollination is of two types: self pollination and cross pollination.

Formation of seed and fruit

- Seed is formed from the zygote. It consists of embryo and its food.
- When the seed are formed then the wall of ovary becomes fleshy or scaly and forms fruit wall.
- The floral parts (sepals, petals etc.) fall off.
- The ripened ovary is called fruit.

Sexual reproduction in Animals

In animals, it occurs through fertilization of gametes (sperms and ova). Gametes are produced by meiosis which is the reduction division. These have half a number of chromosomes. Females and males are different in only one pair of chromosomes. Males have a chromosome different called a Y chromosome in one pair. So females have an XX pair while males have XY.

Example of Frogs

- Frogs carry out sexual reproduction.
- Female frog lays a large amount of ova in water and male release sperms on these.
- Sperms and ova fertilize to produce zygote.

- Zygote the divide by mitosis to develop a larva which lives in water for a specific period of time and then by a process called morphogenesis develops into adult frog.

Reproductive system in humans

Humans reproduce sexually by fertilization of gametes called sperms and ova. Gametes are produced by specialized organs called testes and ovaries. Gametes have a haploid number of chromosomes, i.e., 23 chromosomes. 22 of these pairs are alike but 23^{rd} pair is different in males and females. Females have X chromosomes in their gamete while males have an X or Y. Gender of the child is hence determined by the sperm, X or Y. Female always contribute an X in gamete. If male gamete has a Y then a male child will be produced. If sperm have an X then female child will be produced.

Basic components of male reproductive system

Human male reproductive system consists of a pair of gonads called testes, and a system of accessory tubes. (testis: sing.; testes: plural). Testes are paired which produces sperms. Testes lie outside the body in the sac called scrotum. From testes, sperms are transferred to main duct called vas deferns. Vas deferns makes a complex system of ducts called epididymis. From epididymis, sperms pass through the urinogenital tract and discharged.

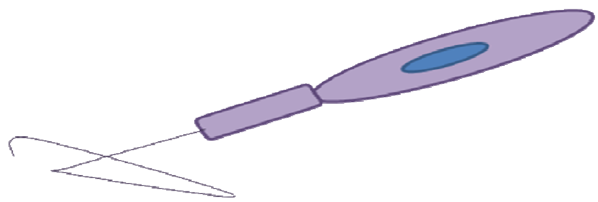
Function of testes

Function of testes is to produce sperms and the male hormone testosterone. Testis consists of a system of tubules called seminiferous tubules.

Process of Spermatogenesis

1. In the seminiferous tubules, germinal epithelium produces the cells called spermatogonia.
2. Spermatogonia divide into primary spermatocytes (2N).
3. Primary spermatocytes undergo meiosis to produce secondary spermatocytes (N).
4. Secondary spermatocytes divide further to make 4 haploid cells called spermatids.
5. Spermatids are converted to sperms by morphological changes.

Testis also has some large cells in seminiferous tubules called sertoli cells. These cells provide support and nourishment to the developing sperms.



Mature sperm

Basic components of female reproductive system

Female reproductive system consists of a pair of ovaries and an associated system of tubes. A pair of ovaries lies inside the female body cavity which produces ova. Ovaries leads to the tubes called oviducts also called fallopian tubes. Oviduct opens into uterus. Ovum is fertilized in the oviducts then it passes to the uterus where it is implanted. A placenta is established between the uterine and fetal tissues for the exchange of materials. Uterus is connected to the vagina through cervix.

Function of ovaries

Function of ovaries is to produce ova and female hormones estrogen and progesterone. Germ cells in ovary produce many cells called oogonia.

Process of Oogenesis

1. Oogonia produce primary oocyte (2N) by mitosis.
2. The primary oocyte divides by meiosis into secondary oocyte (N) and a polar body.
3. The secondary oocyte divides to form one ovum and a polar body.
4. The first polar body also divides to form 2 polar bodies.
5. Hence from secondary oocyte, one ovum and three polar bodies are produced.

Usually ovary releases one ovum at a time, this is called ovulation. Sometimes it releases more which may result into fraternal (non-identical) twins.

Exercise

1. Draw the process of spermatogenesis.
2. Draw the process of binary fission in bacteria.
3. Draw the process of multiple fission in amoeba.
4. Differentiate the process of meiosis in males and females.

Summary GSC101 lecture # 40
Biology lecture # 12

Ecology I

Ecology is the study of interactions among organisms and their environment.

Environment

The physical surroundings of an organism including air, water, soil etc. Organisms have to interact with environment. Environment provides organisms everything required to live. Environment is always changing, may be supportive or hostile. Organisms living in an environment are "best fit" for that particular environment.

Environment consist of biotic and abiotic factors

- Biotic factors
  - Animals, plants, fungi, algae, bacteria

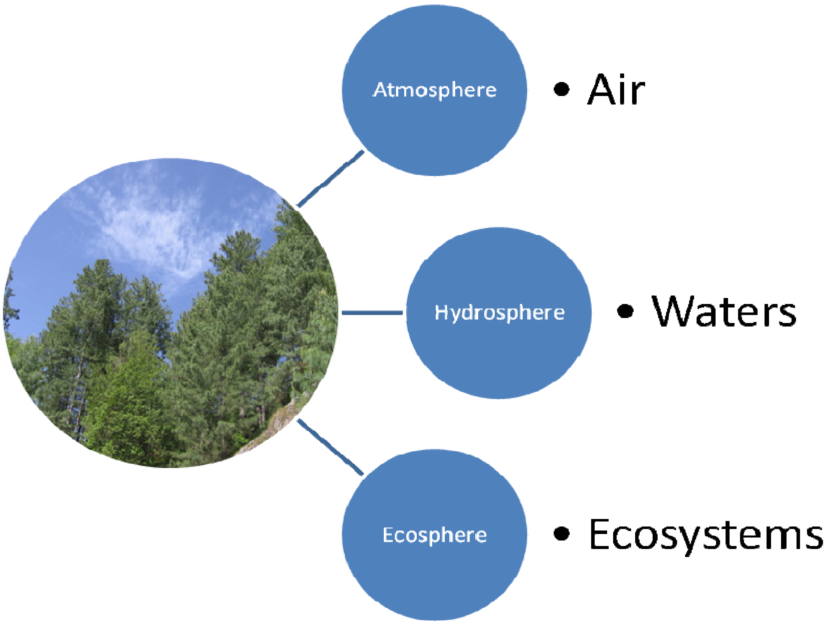
- Abiotic factors
  - Air, water, soil

What is Ecology?

- The study of interactions between organisms with each other and their environment.
- Biosphere and environment.
  - Surface of Earth's crust
  - Water bodies on Earth's surface
- Atmosphere that surrounds Earth

Soil support life.

Rain helps in water availability.



Levels of Organization in an Ecosystem

- Species
- Population
- Community
- Ecosystem

Then comes:

- Biome
- Biosphere

Species: male and female Golden Pheasants

Population is the group of organisms of same species living in an area.

Ecosystem

Ecosystem is the area where organisms live in interaction with non-living factors.

Organisms and their environment

Organisms live in specific locations or areas suitable for them. *Habitat* is the term used for physical location of organism. Another term is *niche*. Niche is defined as ecological role of organisms. Organisms interact with their surroundings; their interaction is termed as niche.

Organisms and their environment.

Biotic and Abiotic Components

- Living / Biotic Components of an Environment
  - Animals, plants; Interactions between organisms.

- Non-living / Abiotic Components of an Environment:
  - Air, water; Interactions between organisms and their environment.

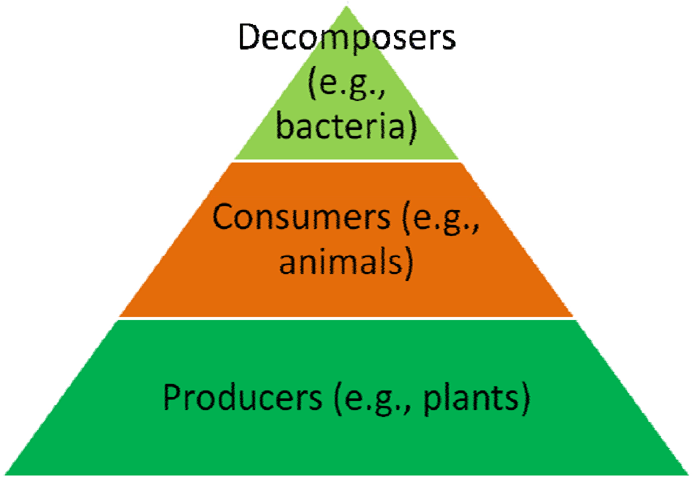
Energy Flow in Ecology

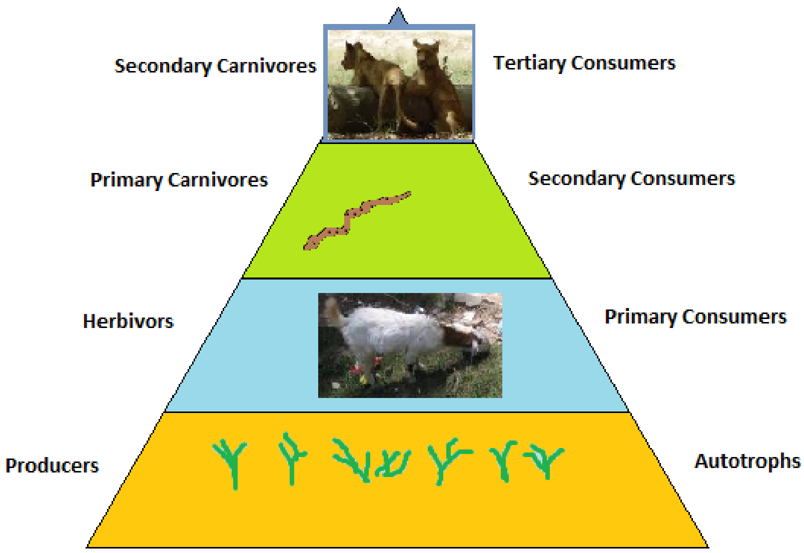
Main source of energy in an ecosystem is "Sunlight". Autotrophs (producers) are the organisms which utilize the energy stored in inorganic compounds and use sunlight to make their food. These organisms carry out "photosynthesis" and use this energy to convert "carbon dioxide and water into oxygen and glucose". The other type of autotrophs makes carbohydrates using chemical energy e.g., many bacteria. These are called chemoautotroph. Heterotrophs (consumers) are the organisms that cannot make their own food and depends upon organic source.

  - Herbivores (the organisms that eat plants, i.e., producers; also called primary consumers)
  - Carnivores (the organisms that eat herbivores or other carnivore animals)
  - Omnivores (the organisms that eat upon plants and animals both)

Pyramids in Ecology

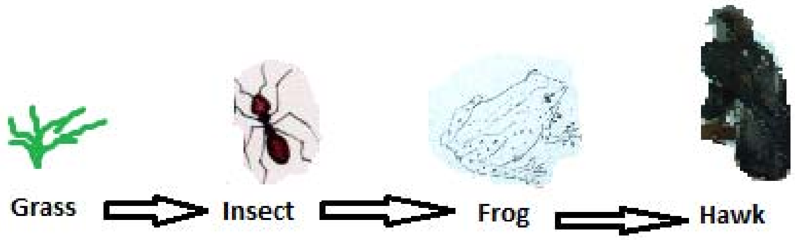
- Decomposers (these are the organisms which break down the dead organic matter)
- Consumers (the organisms which feed upon producers or other consumers)
- Producers (the organisms which makes their own food by either using sunlight or inorganic chemicasl)

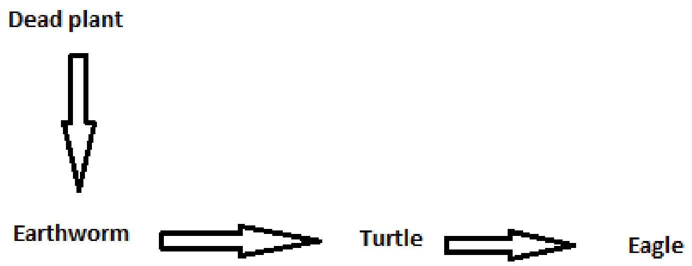




An example of ecological Pyramid.

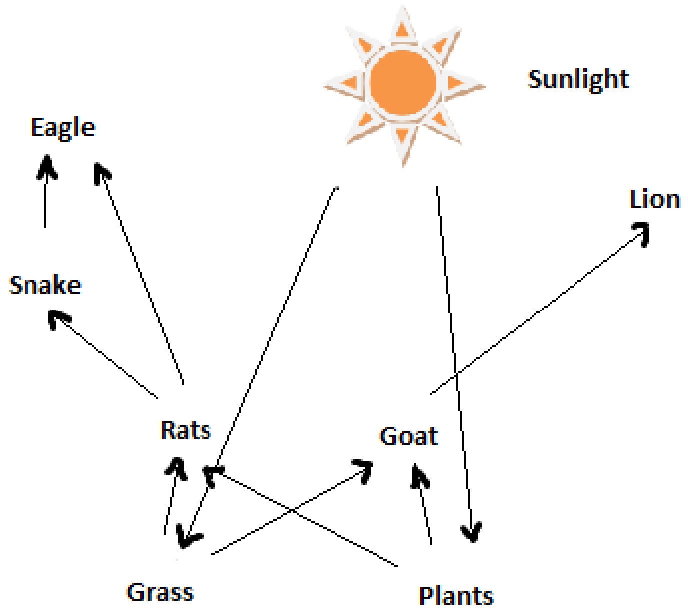
Food Chains are straight energy flow relationships in an ecosystem.





Food Webs

Food webs are complex energy flow pathways and relationships in an ecysystem.



An example of a terrestrial food web.

Introduction of the factors that affect the quality of environment

Factors that Affect Environment

- Air currents
- Temperature
- Soil
- Water
- Light

Human interference

Industrial effluents

Industrial growth results in the production of more and more effluents. Industries produce effluents which may be solid or liquid. These may contain heavy metals, toxic chemicals. These are disastrous for the biodiversity. These should be treated well. The solution is treatment plants for removal of dangerous materials.

Deforestation

Forests are cut down for wood; wood may be used in buildings, furniture etc. Forests are also cut for making towns. This result in destruction of habitats of organisms which may leads to extinction of many organisms. As organisms are related, results may be increase or decrease of number of other organisms, e.g., if sparrows are decreased then insect pests may increase and destroy crops in that area.

Human interference: littering by the tourists.

Urban spread

As populations are increasing there is an increasing need of towns and cities. Urban spread requires the cutting of forests or other type of habitat destruction.

Construction of dams, waterways

Dams and water ways etc are constructed on water bodies. These may result in habitat destruction of fish and other aquatic animals. Loss of biodiversity results in instability of ecosystem.

Agriculture

Agriculture also affect environment. In grasslands keeping too many animals may result into loss of grass and destruction of ecosystem. In crop growing fields fertilizer use and growing exhaustive crops (the crops that uses much of soil's resources) may result in damage to the ecosystem.

Natural factors

Natural disasters like floods, earthquakes etc. may lead towards total or partial habitat destruction. Both biotic and abiotic factors are affected. The whole structure of ecosystem may change.

Importance of environment for the healthy living of organisms

Organisms have to live in environment

Organisms need food, shelter and other resources. If the balance of environment is changed by extinction of an organism or some other factor then many organism in the food chain or web are disturbed. A balanced ecosystem is required for healthy living of organisms.

Exercise

1. Differentiate between niche and habitat.
2. Describe the effects of human interference on ecosystems.
3. Define the following:
    a. Population
    b. Community
    c. Ecosystem
    d. Biosphere
4. Describe some abiotic and biotic factors of an ecosystem.
5. Draw a typical water ecosystem.
6. Draw a typical example of terrestrial ecosystem.

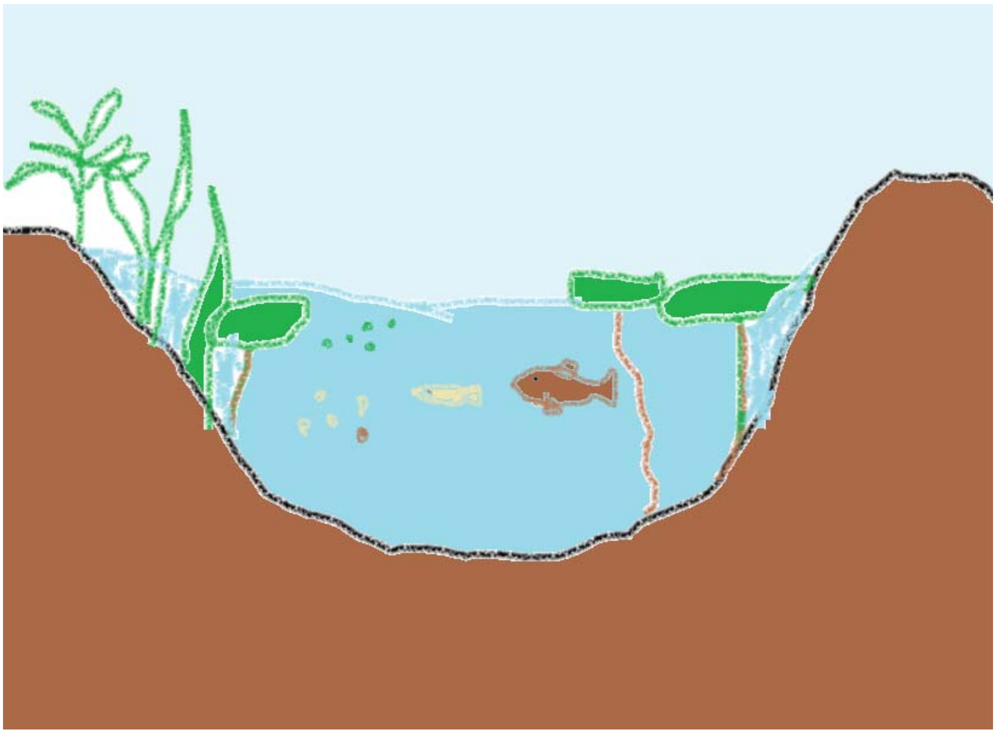
Summary GSC101 lecture # 41
Biology lecture # 13

Ecology II - Ecosystems

Ecosystems - An Introduction

Ecosystem is an area where the organisms are living in an area in interactions with each other and their physical surroundings. There are many types of ecosystems, mainly divided into two categories:

- Aquatic ecosystems (ecosystem in water)
- Terrestrial ecosystems (ecosystem on land)



An aquatic ecosystem.

Basic components of an ecosystem; and their roles / significance

Ecosystem consists of:

- Abiotic factors
    - Air, water, soil
    - Temperature, pH, humidity

- Biotic factors
    - Animals, plants, protists, bacteria

Biotic components

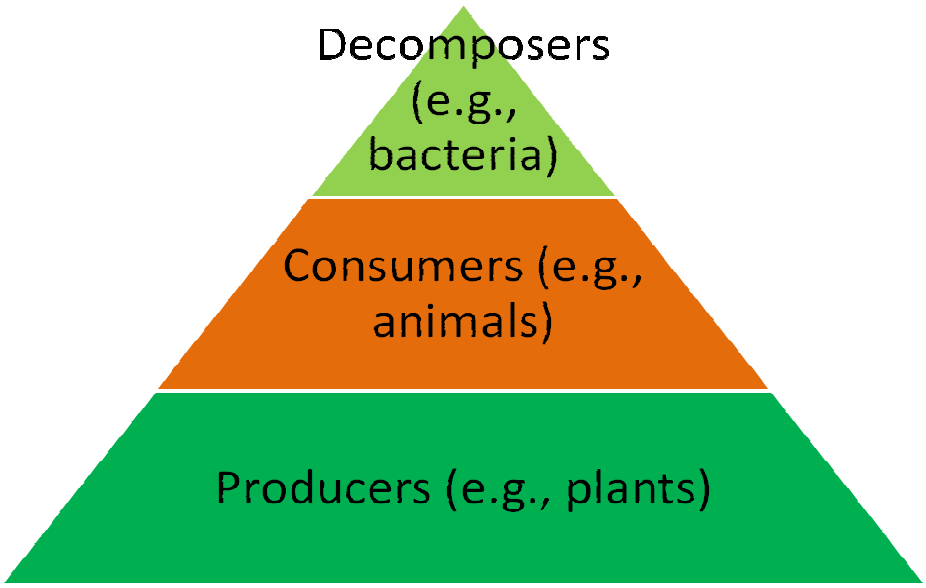
- Producers
    - Plants, algae

- Consumers
    - Animals

- Decomposers
    - Fungi, bacteria

Pyramids in Ecosystems

Ecological relationships are also shown in the form of pyramids in ecology. These are called ecological pyramids or trophic levels. On the base come producers, then consumers and then decomposers.



A pyramid.

Producers

The living organisms which make their own food are called producers. Examples include plants, bacteria and algae. They carry out photosynthesis, carbon dioxide and sunlight to water and oxygen. They synthesize carbohydrate by a process called Calvin's cycle. Entry point of energy in the ecosystem is producers.

Consumers

These are the organisms that uses organic carbon source. These use carbohydrates produced by plants. Types include primary, secondary and tertiary consumers. Consumers include herbivores, carnivores and omnivores.

Consumers

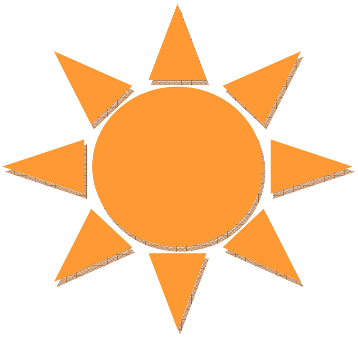
Decomposers

These organisms feed upon dead organic matter. These include fungi and bacteria.

Abiotic components of Ecosystem

Water, Light, Air and Soil

- Water is a limiting factor in an ecosystem. It is required by living organisms. Organisms have to adapt according to the availability of water.
- Sun light is the primary source of energy, e.g. zones of a lake.
- Air manages temperature and other things.
- Soil supports life.



ECOSYSTEMS – EXAMPLES

Climate and weather affect the ecosystem. There are various ecosystems in the world and in Pakistan according to the climate of the area.

Aquatic Ecosystems

Water is a liquid medium to support life. Aquatic ecosystems may be of fresh water or marine; a lake or a sea.

Water has some properties

- It changes its temperature slowly; more appropriate for life.
- It absorb considerable amount of energy (sunlight) but at depths its level decreases for photosynthesis.
- Nutrients are concentrated at bottom.
- Water is abundantly available in this ecosystem.

Fresh water lakes

- Lakes vary in nutrient, physical conditions and depths.
- Life also varies according to the conditions.
- Lakes have three zones:
  - Littoral – shallow water, photosynthesis occur, most diverse, anchored plants, submerged plants, phyto and zooplankton and fishes.
  - Limnetic – upper layer of deep water, have good light penetration, photosynthesis occur, cynobacteria – protozoans – crustaceans and fishes.

    - Profundal – bottom layer of deep part, almost no light for photosynthesis, high nutrients on bottom, bacteria – decomposers.

Human interference

Wastes comes from different areas and results in eutrophication. Excessive growth of cyanobacteria creates a scum on the surface; result is that plants and animals die. Decomposer bacteria further decompose result in more organic matter. Ultimately habitat destruction is the result.

Terrestrial Ecosystems

Plants and animals adapts to the changes from water to land habitat. Supporting tissue developed for the purpose; animals have skeleton and plants have vascular bundles to support these organisms on land. Water conservation is another adaptation to conserve water.

Types of Terrestrial Ecosystems

Divided into four main types:

    - Forest ecosystems
        - Tropical rain forests
        - Temperate deciduous forests
        - Coniferous alpine and boreal forests
    - Grassland ecosystems
    - Desert ecosystems
- Tundra ecosystems

Major ecosystems in Pakistan

- Pakistan has a variety of climate and seasons.
- Have these main ecosystems:
    - Temperate deciduous forests – Shogran and Neelum valley
    - Coniferous alpine and boreal forests – Kaghan, Malam Jabba, Dir and Chillas
    - Grassland ecosystems – Gilgit, Kashmir, Waziristan, Chitral and Kallat
    - Desert ecosystem – Mianwali, Bahawal Nagaar, Bahawalpur and more, Thal, Thar and Cholistan
    - Tundra ecosystem – mountains of Karakoram and Hindukash

Temperate deciduous forest

- Present in Southeast Asia, India, North America, China, Japan etc.
- Have moderate temperature – 4 – 30 C
- Rain fall 750 to 1500 mm
- Plants – Taxus, Pinus, Berberis, ferns, grasses, herbacious; shed their leaves in dry season
- Animals – Rehesus monkeys, leopard, black bears

- Soil - very fertile and rich in nutrients
- Humans hunt animals and cut wood

Coniferous alpine and boreal forest

- Eurasia, North America, Canada
- Low temperature – freezing to 10C
- Snow cover is present
- Harsh climate – less suitable for life
- Highly adapted species lives here, Marco polo sheep, bisons, wolf, black bear
- Plants – Pinus species grow; have long waxy needle like leaves to survive cold
- Human disturbs less because less accessible

Grassland ecosystem

- Pakistan, Eurasian countries, North America
- Two types – Prairies, Savana
- Rain fall 250-750 mm, water is a crucial factor
- Plants are grasses – tall and short, legumes, herbs, mosses, lichens
- Animals are reptiles, amphibians, mammals
- Decomposers are fungi, bacteria
- Human impact – agriculture and live stock

Desert ecosystem

- Rain fall – 25-50 mm
- Perennial plants, cacti, succulent leaves and stems
- Animals adapt to little water, kangroo rats, reptiles, birds
- Human impact – desertification

Tundra ecosystem

- Very cold, snowy
- Small perennial flowers
- Mosquitoes grow well, birds feed upon these (geese, ducks)
- White bears, foxes, snow owls are present
- Human interference can produce long lasting effects because plants grow slowly but this interference is low due to harsh weather

A monkey in Ayubia National Park.

Monkeys in Ayubia National park, you can see the solid wastes behind these.

Black bear which was once found in the Ayubia National Park

A beautiful ecosystem.

Exercise

1. What is an ecosystem? Name some areas of Pakistan that have desert ecosystems.
2. With the help of a drawing show the grassland ecosystem.
3. Describe various components of an aquatic ecosystem with the help of a diagram.
4. List some effects of human interference on ecosystems.

Summary GSC101 lecture # 42
Biology lecture # 14

Food Chains and Food Webs

Ecosystem

An area where the organisms are living in interactions with each other and their physical surroundings is called an ecosystem. There are many types of ecosystems, mainly divided into two categories:

- Aquatic ecosystems (water ecosystems)
- Terrestrial ecosystems (land ecosystems)

Ecosystem

Ecosystem consist of biotic (living) and abiotic (non living) components.

- Biotic factors:
  - Producers, Consumers, decomposers
  - Plants, animals, fungi / bacteria

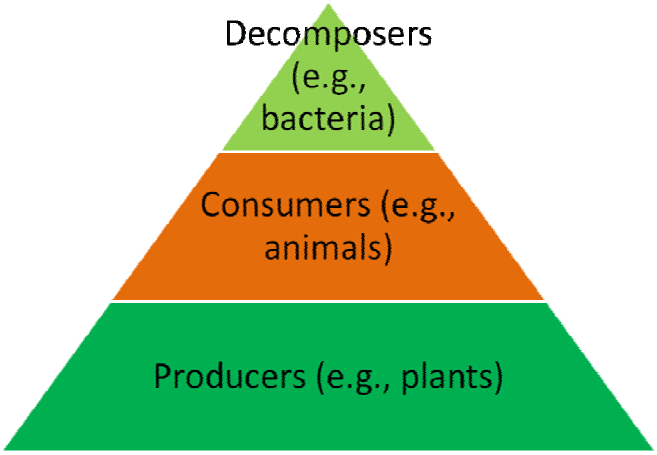
Biotic factors are in relationship with each other in an ecosystem. These also interact with abiotic factors present in their surroundings like air, water, sunlight.

Trophic levels

Trophic levels or feeding levels in an ecosystem define roles of the groups of organisms.

- Producers
  - Plants, algae
  - Consumers
  - Animals
  - Decomposers
- Decomposers
  - Fungi, bacteria

Pyramids in Ecosystems



Autotrophs – Producers

These are the organisms that make their own food using sunlight as an energy source. These convert carbon dioxide and water into carbohydrates. Producers are the only source for all organic food in the planet Earth; this is the entry point of energy. These provide food to all other life forms. Examples include plants, algae.

Chemotrophs

These are the organisms, which uses inorganic chemicals as energy source and makes carbohydrates. These lives in deep oceans, where there is no light source. Examples are some bacteria and deep sea worms.

Heterotrophs – Consumers

Organisms that do not make their own food and get food from other organisms are called *consumers*. They get energy by eating either plants or other animals. Their source of food hence is organic compounds produced by producers. Examples are small and large animals.

Types of Consumers

Consumers are divided into three classes:

- Primary consumers – herbivores (plant eaters)
  - e.g., goats, cows
- Secondary consumers – primary carnivores (meat eaters that eat herbivores)
  - e.g., frogs, snakes
- Tertiary consumers – secondary carnivores (meat eaters that eat other meat eaters)
  - e.g., eagle, hawk

Goat – herbivore

Squirrel - herbivore

Cat - carnivore

Decomposers

These are the organisms that eat dead organic matter. These feed upon animals and plants – their fallen parts or dead organisms. These recycle food in the ecosystem, convert non available organic matter into available matter for producers.

Food chains

What is a food chain?

Food chain is a one-way flow of energy in an ecosystem.
Producers to consumers to decomposers

In an ecosystem different food chains exist. This is a relationship of eating and being eaten.

Phytoplankton → Fish Herbivore → Fish Carnivore → Fish Eater Bird

Example of a food chain from land (grassland) ecosystem

Grassland ecosystem has following characteristics:

- Rain fall 250-750 mm, water is a crucial factor
- Plants are grasses – tall and short, legumes, herbs, mosses, lichens
- Animals are reptiles, amphibians, mammals
- Decomposers are fungi, bacteria

Sunlight → Grass → Primary consumer (Rat/Mole) → Secondary Consumer (snake) → Tertiary Consumer (Hawk)

A grassland ecosystem food chain.

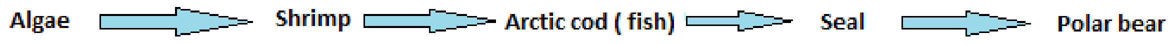
Example of a food chain from aquatic ecosystem

- Aquatic ecosystem is marked by:
  - Water, which is a liquid medium to support life.
  - May be fresh water or marine; a lake or a sea.
- Light, temperature penetration is important for biodiversity.

A Simple Food Chain in a Lake

Phytoplankton → Crustaceans → Fishes → Fishes

Arctic ecosystem



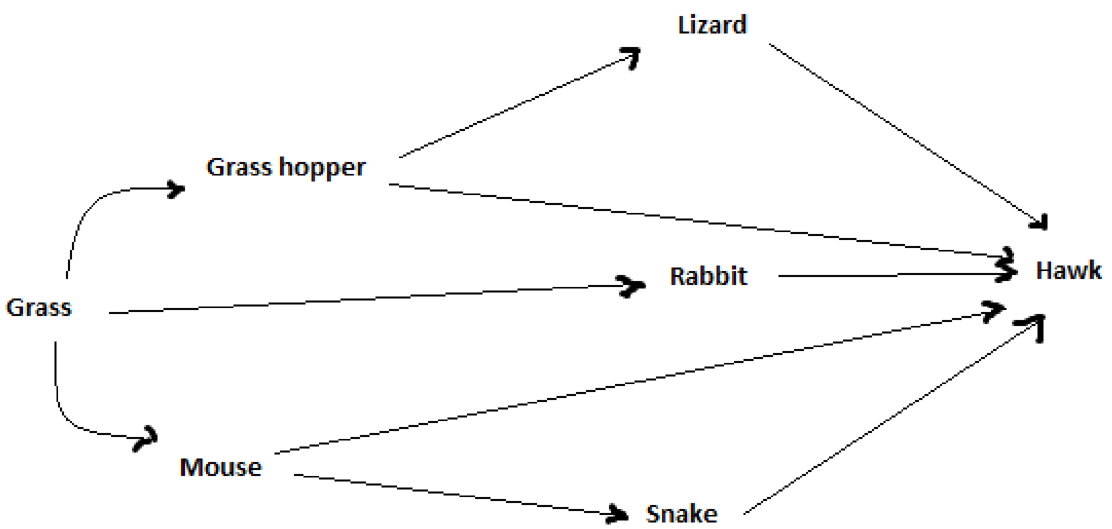
Food web

What is a food web?

- A network of eating and being eaten.
- Feeding relationships between organisms are not as simple as food chains.
- There is a diversity of organisms and one organism may be eaten by more than one other organisms.
- Example is grass is eaten by cows, buffaloes

Example of a food web from land (grassland) ecosystem

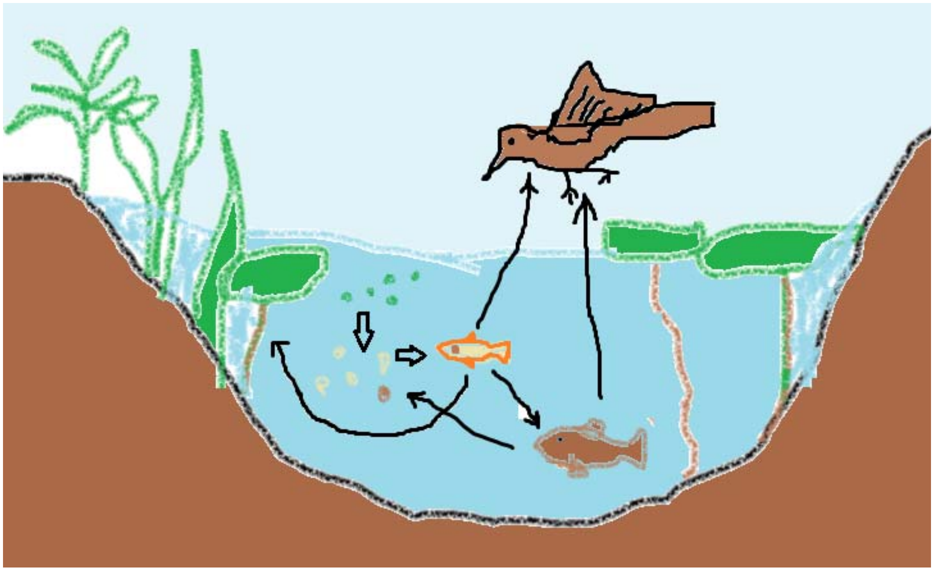
- Grassland ecosystem have small plants, reptiles, amphibians and mammals.
- Grass is eaten by most of the herbivores.
- Herbivores are eaten by more than one carnivores.



A food web of Grassland Ecosystem.

Example of a food web from aquatic ecosystem

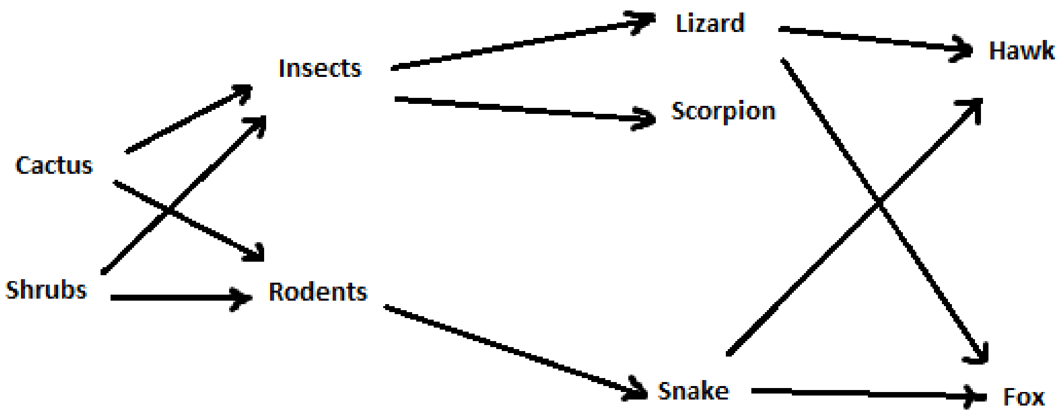
Aquatic ecosystem has phytoplanktons, zooplanktons, plants, animals and decomposers. Food webs may be simple or complex starting from producers.



A food web in an aquatic ecosystem.

Desert Ecosystem

- Dry and hot environment.
- Few specific plants.
- Well adapted animals.

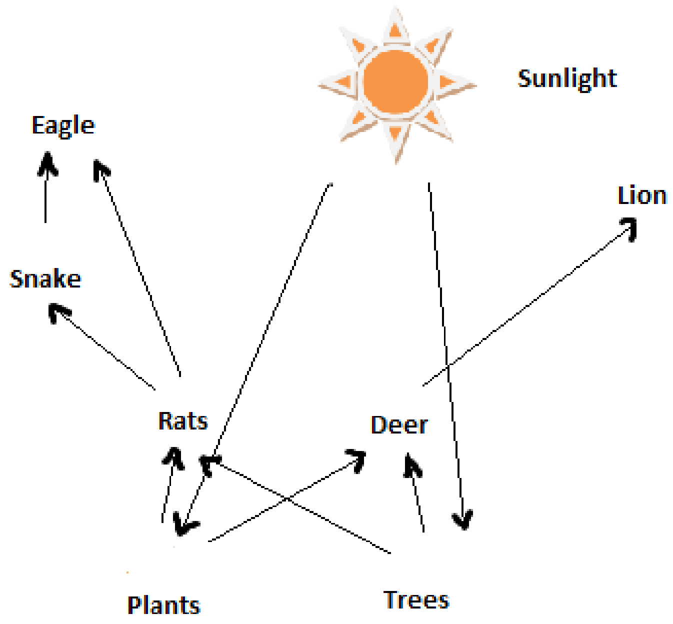


A desert food web.

Forest Ecosystem

- Dense vegetation, animal diversity is high

- Simple to complex food webs



Exercise

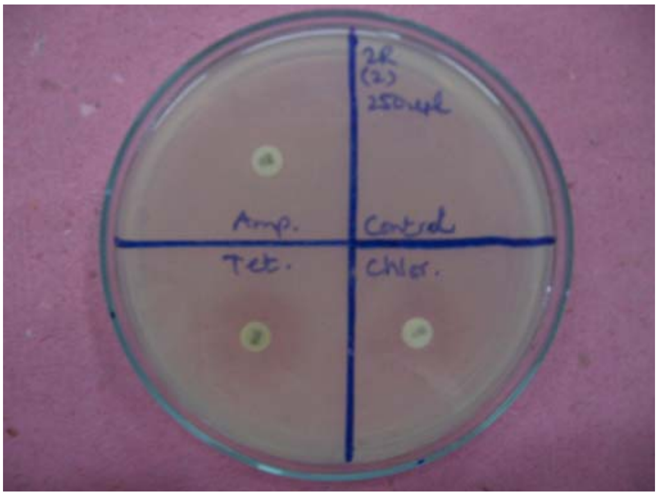
1. Draw a food chain in a grassland ecosystem.
2. Draw a food chain in an aquatic ecosystem.
3. Draw a food web in a forest ecosystem.
4. Draw a food web in a lake ecosystem.

Summary GSC101 lecture # 43
Biology lecture # 15
Algae and Fungi

Algae are:

The organisms range in size from microscopic unicellular to large sea weeds, demonstrate following characteristics:

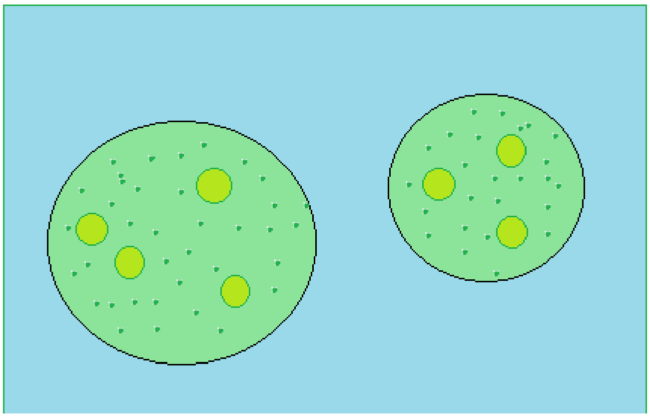
- Major producers of oxygen
- Provide food for animals in various food chains
- Source of chemicals with pharmaceutical value
- Utilize carbon dioxide to reduce the greenhouse effect
- Source of valuable materials including biofuels, food and agar (part of media for microbial growth)
- Thrived for 1.5 billion years, are an integral part of the global ecosystem



Distinguishing characteristics of algae, with examples

- Photosynthetic, autotrophic
- Eukaryotic, have cell wall consist of cellulose
- Classified by their:
  - energy storage products
  - cell walls
  - colour (due to types and abundance of pigments their plastids)
  - cellular organization
  - Reproduce both asexually and sexually
  - Asexually by mitosis
  - Sexually when there is environmental stress
  - Plus and minus gametes fuse to form zygospore which give rise to new organism e.g. chlamydomonas

- Some reproduce by conjugation like spyrogyra



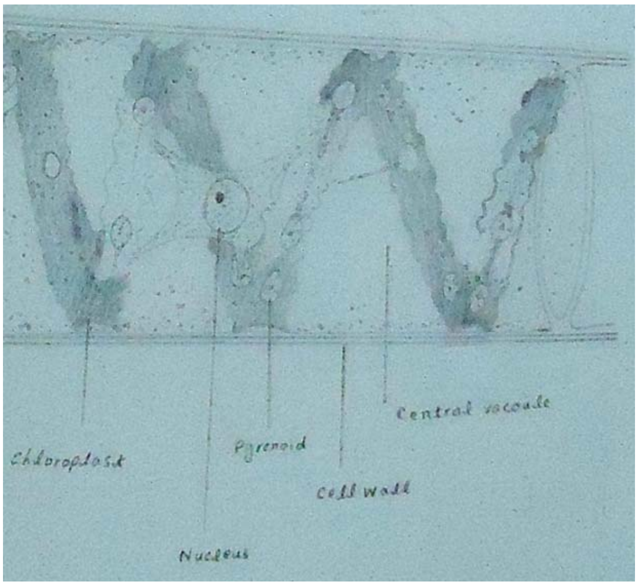
Volvox is algae consist of rounded colonies.

Types of Algae based upon the pigments

- Green algae (chlorophyll, soluble in organic solvents only, such as alcohol), 7000 species
- Red algae (have “phycobilins” water soluble pigment) 4000 species, cosmeics, gelatin etc
- Brown algae 1500 species, weeds
- Golden brown algae (formation of petroleum products)
- Carotenoids are also algal pigments soluble in organic solvents
- Euglenoids, both plant and animal like characteristics

Algae could be distinguished by cellular organization:

- **Unicellular** algae: species occur as single, unattached cells that may or may not be motile. For example, Chlamydomonas, Euglena.
- **Filamentous** algal species occur as chains of cells attached end to end. These filaments may be few to many cells long and may be unbranched or branched in various patterns. For example, Spirogyra.
- **Colonial** algae occur as groups of cells attached to each other in a nonfilamentous manner. For example, a colony may include several cells adhering to each other as a sphere, flat sheet, or other three-dimensional shape. For example, Volvox.



Spirogyra

Distribution and Significance of algae

Algae are widely distributed in various areas of the world in small to large water bodies. These are present in small ponds to huge oceans. Green algae are found almost everywhere. Red algae and brown algae are mostly marine organisms. Euglenoids are fresh water inhabitants. When algae grow a lot covering large area of water it is called algal blooms.

Important producers of the planet Earth

Algae are producers in many food chains particularly in aquatic ecosystems. These convert sunlight into energy and carbon dioxide into carbohydrates. These help in reducing the Greenhouse effect by absorbing carbon dioxide.

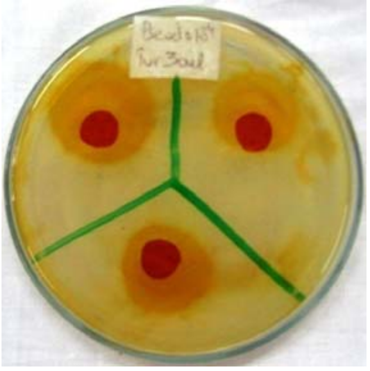
Algae as human diet alternatives

Agar is used in the place of gelatin to make gels in many foods. Weeds are part of the salads and other materials for making various kinds of salads and desserts. Some are used in making ice creams.

Production of Agar

These are also used in production of Agar which is material extracted from sea weeds and help in solidifying bacterial growth media.

- Agar is very important in scientific research
- Used to culture microorganisms on solid surface
- A plentiful and cheap source for growing microorganisms
- Used in almost all microbiology research laboratories, for example in clinical laboratory



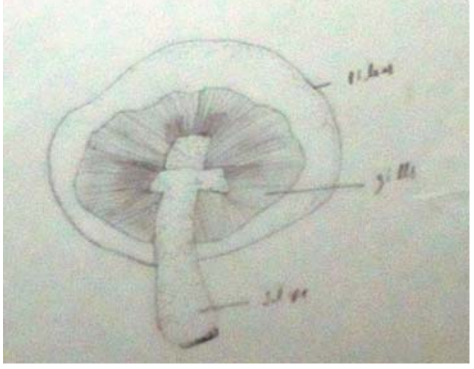
Agar medium to test bacterial growth and effect of an antibiotic on it.

Algal Biofuels

Algae can produce huge biomass. This biomass could be used to convert into fuels like ethanol. Algae are potential source of biofuels.

The Fungi

Fungi are the heterotrophs and major decomposers which feed upon decaying organic matter. These range in size from microscopic to large ones. These include heterotrophs, symbionts and parasites.



Mushroom.

Distinguishing characteristics of fungi, with examples

- Unicellular to multicellular
- Eukaryotic
- Body is made of long filaments of hyphae (singular: hypha) which form a mycelium (collection of hyphae)
- Have a cell wall, made up of chitin
- Reproduce both asexually and sexually
    - Spores
    - Mating of hyphae

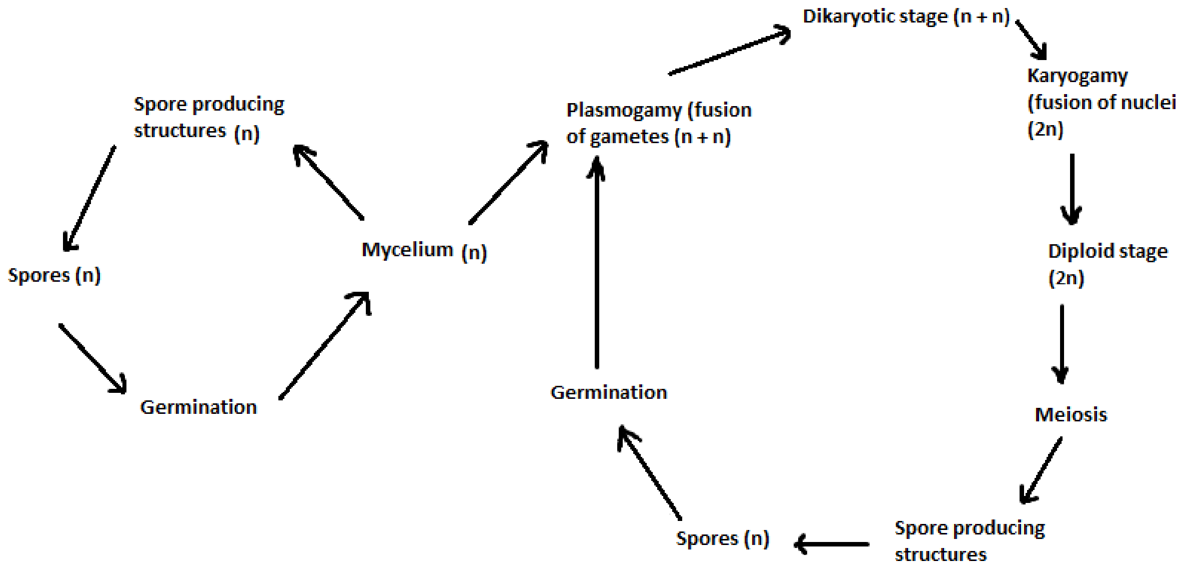
Some important groups of Fungi

Phylum Zygomycota = the Bread Molds
e.g. Rhizopus – black bread mold

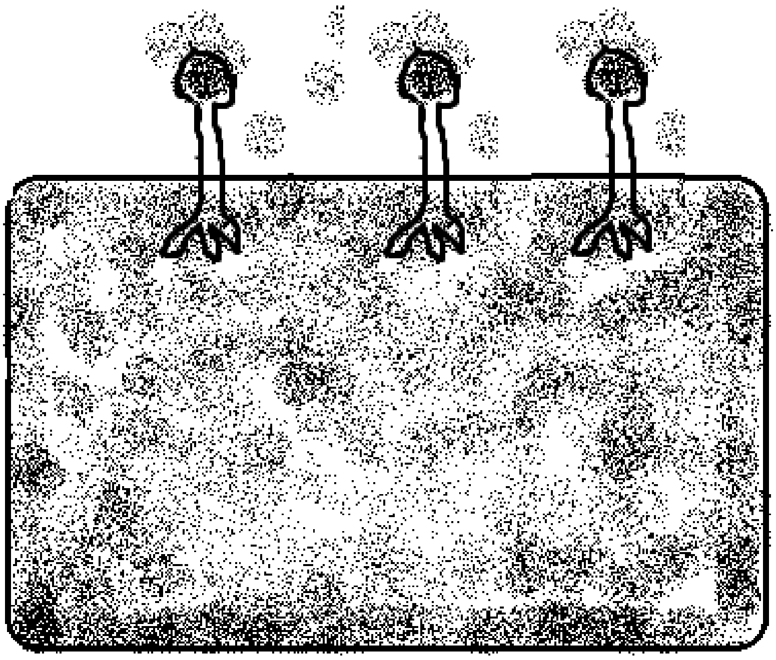
Phylum Ascomycota = the Sac Fungi
e.g. Yeast

Phylum Basidiomycota = the Club Fungi
e.g. Mushrooms, puffballs, bracket fungi, rusts, smuts

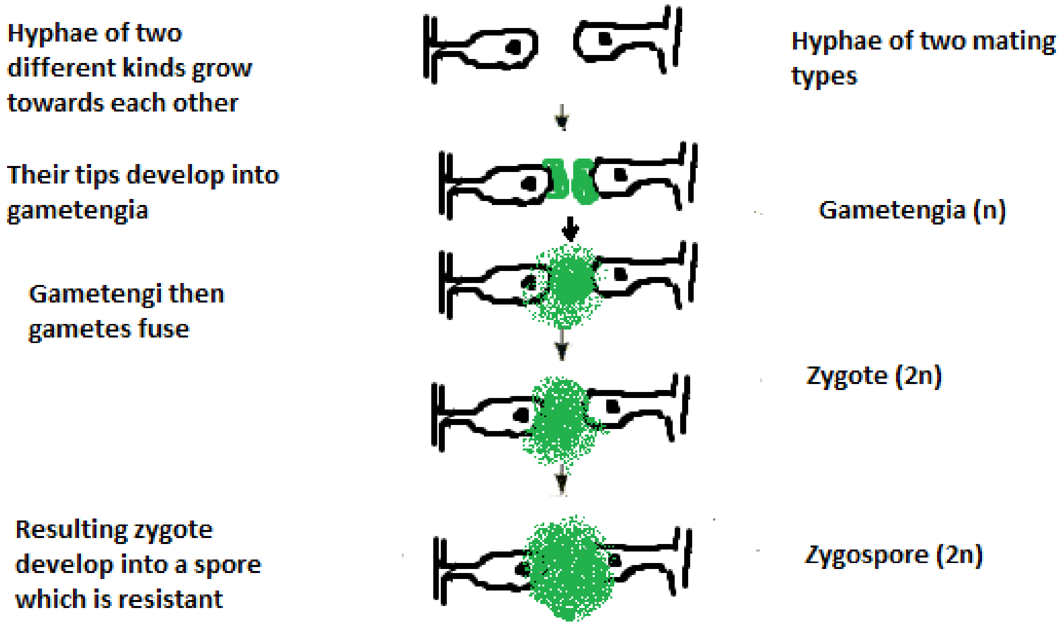
Phylum Deuteromycota = the Fungi Imperfecti
e.g. Penicillium



Life cycle of fungi.



Hyphae and mycelium; Spores on the top (fruiting bodies).



Mating in fungi.

Habitats and Significance of fungi

Fungi grow in almost every habitat imaginable, as long as there is some type of organic matter present and the environment is not too extreme. It is a diverse group; number of described species is somewhere between 69,000 to 100,000 (estimated 1.5 million species total). It is present in soil, water, or on foods. These may also live on animal or plant bodies. Mycorrhizae are the fungi associated with the roots of vascular plants. Lichens are the association between fungi and algae.

Lichens

Lichens consist of association between algae and fungi. It is a symbiotic association. These are usually the first inhabitants of a new ecosystem.

Fungi are important reducers / decomposers

- Feed on dead organic matter
- Convert it to less toxic form
- Convert into useable form for plant's use

Food source and food spoilage

Many fungi are source of food and many other spoils foods.

- Mushrooms
    - Various types
    - Poisonous to edible
    - Used as food, protein source

- Some fungi cause spoilage of foods
    - Bread molds

Sources of medicines

Some fungi are sources for medicines.

- Truffles
    - Used in medicines
    - Gorw inside soil

- Penicillium
    - Source of penicillin

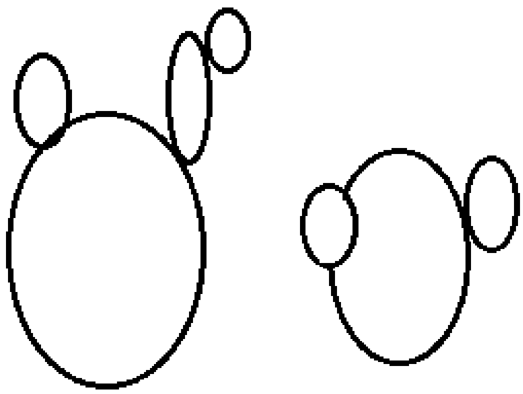
- Other drugs

Pathogenic fungi causing diseases in plants and humans

Many fungi are pathogenic and cause infections in animals, plants and human beings. These may cause skin infections, eye infections and others. Parasites can harm human beings and plant infections can damage crops.

Yeast

Yeast is a very important organism for biotechnology and food industry. It is used to make various biotechnological products. It is eukaryotic and better in making proteins in comparison to prokaryotes. It is also used in wastewater treatments because it absorbs heavy metals and converts other contaminants into less toxic form.



Structure of yeast while budding.

Exercise

1. What are important characteristics of algae?
2. What are important uses of fungi?
3. What are lichens and their significance for ecosystems?

Summary GSC101 lecture # 44
Biology lecture # 16

Animals and Their Importance

Distinguishing Characteristics of Animals, with examples

- Consist of eukaryotic cells
- Multicellular organisms, from simplest sponges to complex animals like mammals
- Highly adapted to their environments
- Widely distributed, present in all types of aquatic to terrestrial ecosystems even in air, e.g., the birds
- Important parts of food chains as consumers of different levels
- Heterotrophic, rely on organic carbon sources
- Independently living or parasitic
- Reproduce asexually or sexually
- Very important for human beings and the ecosystems

Diversity of animals

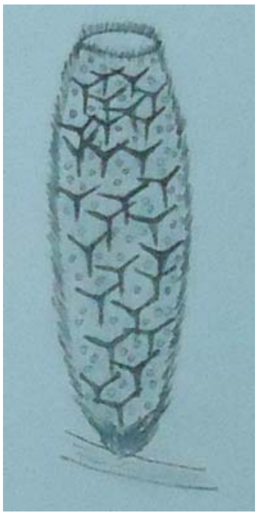
These are widely distributed and are present in almost all habitats. There are two major groups including invertebrates and vertebrates. Animals are wild if these are living in natural habitat or these are termed as domestic if these are kept for some benefit or as pets. Animals are kept in captivity or controlled habitats if there is a need in zoological gardens and safari parks.

Phyla of Invertebrates with examples

Porifera

These are simple animals with one opening as mouth and a body cavity. These are aquatic organisms.

- e.g. Sponges
- Two layered, no specific organ, porous body
- Highly specialized cells

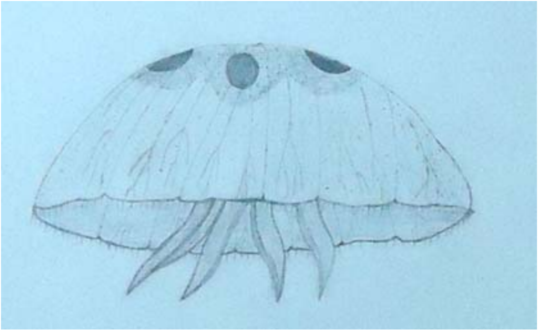


Leucosolenia.

Coelenterates

The animals with 3 body layers. These have stinging cells which have a poison to paralyze or kill the prey.

- e.g. Jelly fishes which are marine
- Have simple organs
- Have stings, mouths, tentacles

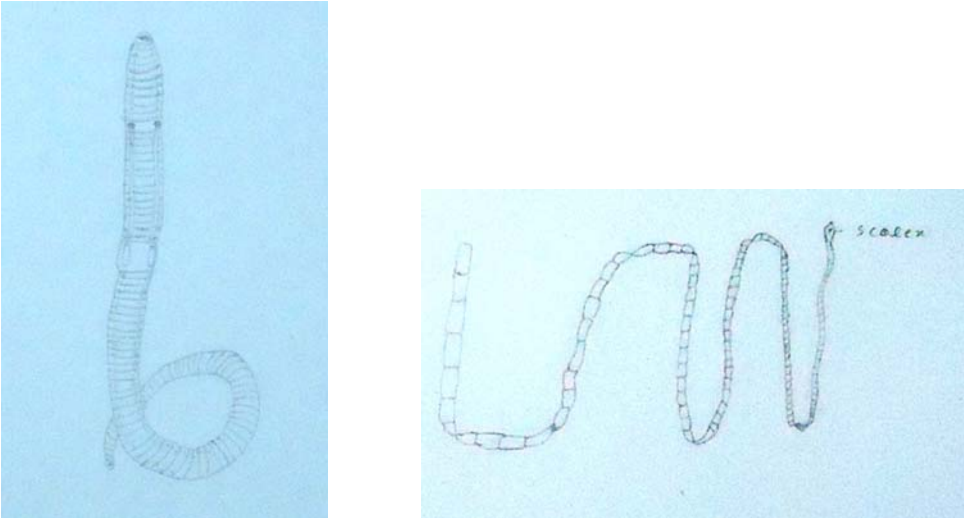


Aurelia – a jelly fish.

The worms

These are of different kinds including round worms, flat worms and earth worms.

- Regeneration: These have ability to regenerate their lost part.
- Parasites, decomposers
- Grow very long



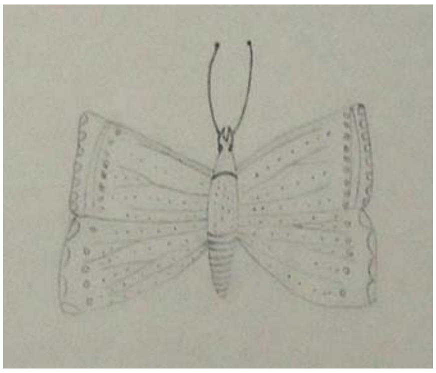
Earthworm and flat worm.

Arthropods, widely distributed

These are one of the most diverse groups of animals. These organisms have an exoskeleton.

- Four major groups
  - Arachnids (spiders)
  - Crustaceans
  - Insects
  - Millipede, centipede
- Have sense organs, are segmented, have exoskeleton

House fly.



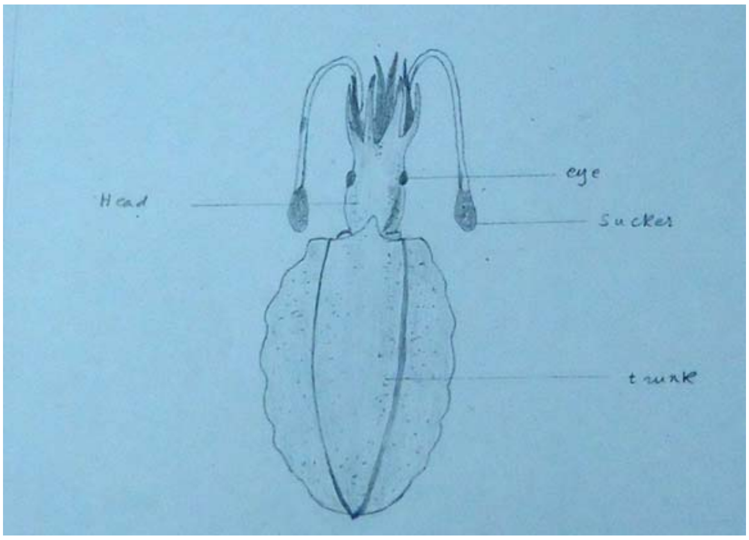
Butterfly

Molluska

These organisms are specific to have shells around their soft bodies.

- Soft bodies, hard shells
- Aquatic mostly

- Snails, lobsters
- Some of these make pearls

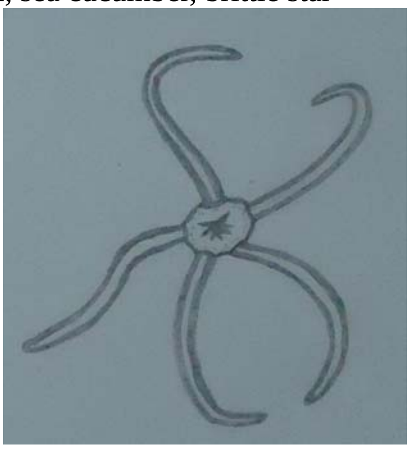


Sepia.

Echinoderms

These are the animals with spiny skins hence called echinoderms (echino-spiny).

- Exclusively marine
- Have a water vascular system for the movement
- Examples are star fish, sea cucumber, brittle star



Brittle star.

Importance of Invertebrates

- Invertebrates are very important part of lot of food chains hence important for stability of ecosystems
- For human use:
    - Sponges are used widely in sound proofing, washing

- Worms are important parasites of domestic animals and human beings
- Insects are pests of many crops, many useful insects like honey bee, lac insect
- Lobsters makes pearls, cultured for pearls

These are components of Food Webs

- Component of aquatic food webs
- Components of terrestrial food webs
- Maintain ecosystem stability, if one becomes extinct then the whole food chain or web may become disturbed.

Role in Soil Fertility

- Some invertebrates are decomposers, e.g., Earthworm
- They feed upon dead organic matter and increase soil fertility
- When animals die their bodies become part of soil and decomposed to add nutrients to soil

Parasitic Invertebrates

These could harm the humans and also harm our domestic animals and crops. There are many treatments available for these.

- Ticks, mites, lice are ectoparasites
- Worms are endoparasites
- Leeches are ectoparasits

Major Classes of Vertebrates and their Importance

Vertebrates are the organisms with a vertebral column precisely with 3 main characteristics at any stage of their life including notochord, nerve cord and pharayngeal slits.

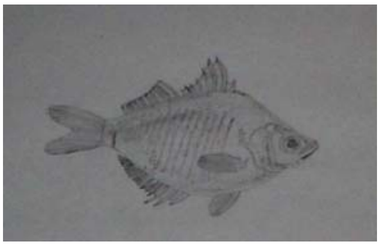
Vertebrates are divided into:

- Fishes
- Amphibians
- Reptiles
- Birds
- Mammals

Fishes

- Aquatic animals, occupies fresh water and marine habitats, widely distributed, bony or cartilaginous
- Have gills for gas exchange, 5 chambered single circuit heart
- Have streamlined and slimy body, ectotherms
- Have fins (appendages) and tail
- Cultured in ponds and caught from natural habitats, are important food source of proteins

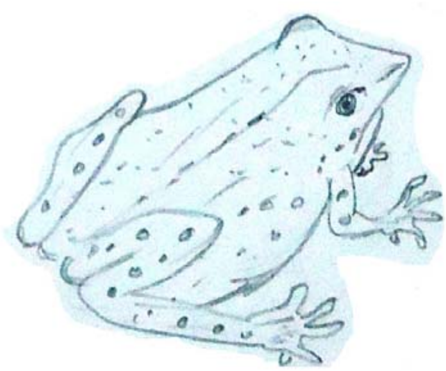
- Cultured for ornamental purposes
- Examples are Rohu, Carps, sharks, electric rays



An ornamental fish.

Amphibians

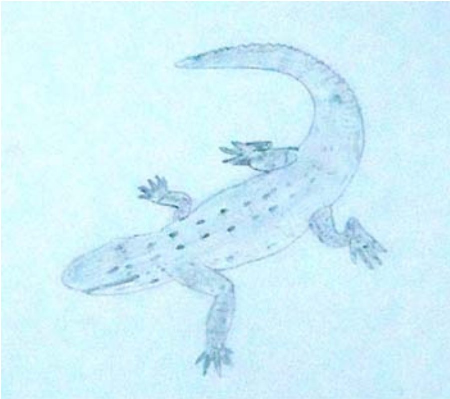
- Are transition between aquatic and land animals
- Gills, lungs and cutaneous respiration
- 5 chambered double circuit heart, mixing of blood
- Some part of the life is aquatic and some part terrestrial
- Produce large number of eggs, no parental care
- Ectotherms
- Examples are frogs, toads



A frog.

Reptiles

- Of diverse types, widely distributed, aquatic and marine
- Highly adapted for hot dry habitats such as deserts
- Terrestrial animals, ectotherms
- Scaly skin, four chambered double circuit heart
- Lungs for gas exchange
- e.g. lizards, chameleon, turtles, tortoises, crocodiles, snakes, gavials


An alligator.

Birds

- Arial mode of life, terrestrial life, fore arms modified into wings
- Endotherms, 4 chambered heart
- Lungs and air sacs for respiration
- Lays fewer eggs, provide parental care
- Bones light weight called hollow bones
- Grain eaters to omnivores
- e.g. parrots, pigeons, peacock, pelican, king fisher


A type of crane.

Mammals

- Widely distributed, most complex, endotherms
- 4 chambered heart, lungs for gas exchange
- Highly developed brains
- Young ones are born mostly, mother feed them with milk, provide parental care
- Have hairs on their body, provide insulation
- Thick skin with skin sensory receptors
- Heterotrophs, herbivores to omnivores

A rhinoceros.

Importance of Vertebrates

These are beneficial

- Important parts of food chain and webs
- Beauty and diversity of nature
- Provides protein foods to human beings, eggs, milk, meat, honey
- Furs and feathers are used for various purposes
- By products of fish industry
- Pearls, clam culture
- Lac insect and silk worm
- Snake venom for medicines

These are harmful

- Poisonous animals, e.g. frogs, snakes,
- Parasitic animals, e.g. worms, mites, ticks
- Insect pests of crops
- Other animal pests e.g. rats
- Termites damage woody structures of buildings

Exercise

1. How biology helps in dealing with parasites?
2. How can we use knowledge of biology to improve our animal keeping capability?

Summary GSC101 lecture # 45
Biology lecture # 17

Applications of Biology

Biology – Useful for Humankind and World

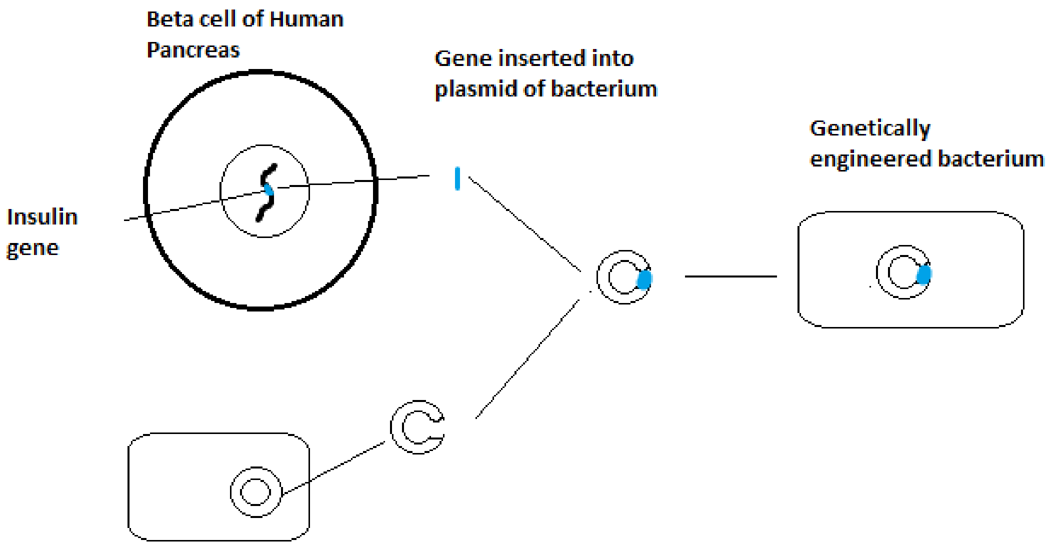
- Demands and problems are increasing with increase in population.
- Biologists investigate phenomena of nature and problem and find ways to resolve these.
- They introduced techniques and technologies to explore all biological resources to cope demands and resolve problems.

Biotechnology

- **Biotechnology** is the use and manipulation of biological processes, organisms and systems to manufacture products to improve the quality of human life.
- The term biotechnology was first used in 1970's.
- Some important applications
  - Genetic Engineering
  - Fermentation and Microorganisms

Genetic Engineering

- It is a process in which a useful gene is taken from one organism and inserted into another organism. The resulting organism is called transgenic.
- This process is carried out with the help of vectors and enzymes.
- Most common vector is bacterial plasmid.
- Most common enzymes are restriction endonucleases or restriction enzymes.



The Process of Genetic Engineering: Transgenic organisms (organisms that acquires a foreign gene)

Transgenic bacteria

- *E. coli – most commons microorganisms in biotechnology because these have many strains (types) which are non-pathogenic, i.e., these cannot produce disease.*
- *GRAS (Generally regarded as Safe) Organisms are those which are known for their non-pathogenecity.*
- Chemical industry: Acids and alcohols are produced using bacteria.
- Pharmaceutical industry
  - Formation of insulin by *E. coli* for diabetic patients
  - Formation of human growth hormone for dwarf children
  - Formation of vaccines

Transgenic Bacteria

Transgenic bacteria are used in many industries, for example:

- Food industry
  - Yogurt, Cheese, Sour creams are prepared using microorganisms
  - Breads b use of yeast
  - Beverages, drinks by yeasts or some bacteria

- Treatment of waste materials is also carried out using different form of bacteria or even yeast. The microorganisms are used to treat:

    - Solid wastes
    - Waste water
    - Oil spills
    - Nuclear wastes
- Bacteria and algae are also helpful in biofuels production (biogas, biodiesel etc).

Transgenic plants

These plants are produced to develop certain specific properties in these, for example, resistance to viruses. Some examples are following:

- Virus resistant crops (cotton)
- Insect resistant corn
- Genetically modified banana
- Pesticide resistant crops
- FOOD SAFETY AND SECURITY: This is very important in modifying food crops particularly that if we are inserting a gene of resistance or else, the plant should not develop any harmful characteristic. For this purpose, before selling any transgenic seed or other product to market, it is tested for safety. This is called *biosafety*.

Transgenic animals

- Transgenic mice as model of human disease
    - Obese rats, diabetic mice
- Genetically modified organisms to increase milk yield
- Genetically modified farm animals to produce antibodies
- FOOD SAFETY AND SECURITY: This is very important in modifying food producing animals particularly that if we are inserting a gene of interest the animal should not develop any harmful characteristic. For this purpose, before selling any transgenic product to market, it is tested for safety. This is called *biosafety*.

Fermentation Pathways

Microorganisms carryout fermentation, i.e., utilization of anaerobic pathway for production of energy. They produce many useful products for us during these pathways. These products are commercially produced by growing such organism in mass culture in very big vessels called *fermenters or bioreactors*.

Following products are obtained by this process:

- Biofuels
- Acids and alcohols
- Yogurt, cheese, sour creams
- Bread
- Beer, wine

Applications of biology in culturing Animal

Animals are traditionally cultured for their products

- Meat from fish, chicken, goats, cows
- Milk from cows, buffaloes
- Eggs from hens, ducks
- Wool from sheep
- Leather industry uses skins
- Honey from Honey bee
- Silk from silk worm

Poultry farms provide us with meat and eggs.

<u>Common types of animal cultures</u>

- Aquaculture
- Ornamental fish
- Seri culture (Silk worm)
- Dairy and Poultry
- Apiculture (honey bee)
- Biological pest control

We discuss these one by one briefly.

Aquaculture

Culturing animals in water is called aquaculture for example fish farming.

- Fish farming, Prawn culture
- Pearl oyster culture
- Other aquacultures (clams, lobsters etc.)

- Byproducts of fishing industry include many cosmetics and some animal diets.

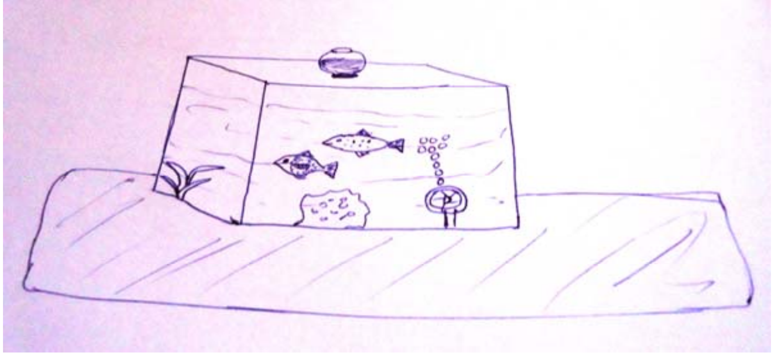
Biology helps in improvement of fish varieties and also extraction of various products from these, for example:

- Selection of fishes in a fish pond (herbivores, carnivores)
- Feed for fishes which may increase their production
- Diseases and their treatment: biology help in finding causes of diseases and their treatments.

Aquaculture for Ornamental Fish

Ornamental fishes are the beautiful usually small fishes kept in small aquaria in houses or other places like hotels. *Biology helps in:*

- Feed: which is good for their maintenance
- Diseases: how can we handle diseases
- Requirements for healthy culture in small to large aquaria



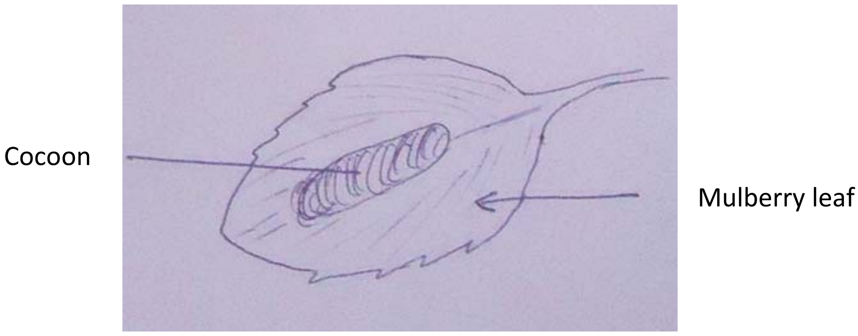
We keep aquaria at home.

Sericulture

Culture of silk moth for making silk on mulberry leaves is called *sericulture*. It is a popular home industry in many parts of the world

Biology helps in improvement of this culture:

- Process of making silk
- Diseases in moth or larvae can result in huge loss
- Biology helps in making new varieties, e.g., wingless variety, varieties which completes 5-6 cycles in a year



Sericulture, a cocoon on the leaf of mulberry.

Dairy and poultry

Biology plays very important roles in dairy and poultry industries. Biology helps in many ways for example:

- Improved breeding techniques and cross breeds (more vigorous and resistant).
- Improved quality and quantity yield of meat, milk, wool and eggs.
- Diagnosis and cure for diseases in farm animals.
- Biological knowledge is also helping in providing balanced food for best yield.

Apiculture (honey bee)

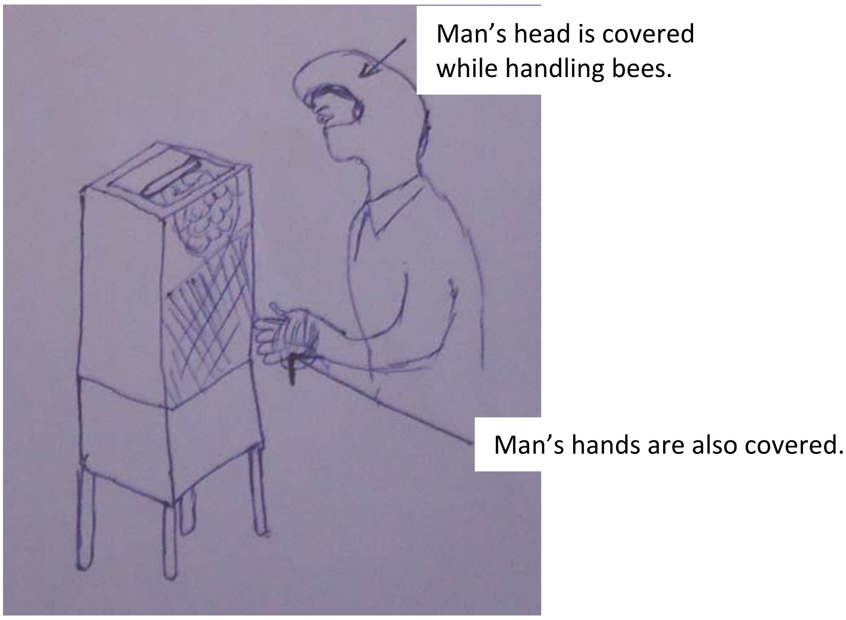
Keeping the honey bee for honey production is called Apiculture (Bee keeping). Biologists explore the phenomena behind Honey production, like knowledge of biology tells us that:

- Honey bee is a social insect and lives in large colonies
- Queen bee, drones and workers

Biology helps in understanding how this system works and can help in production of better varieties and improved system for culturing these animals to increase yield of honey.

Honey bee (small sized).

Honey bee (large sized).



A unit of honey bee keeping farm.

Biological pest control

A large number of organisms damage the useful plants or animals and can cause huge losses. These are called pests, e.g., many insects damage crops.

There are few ways to control pests:

- Primary or cultural control
    - Crop rotation rather than monoculture, i.e., different crops are grown at different seasons.
- Chemical control
    - Various chemicals are used to kill insects but insects may develop resistance and chemicals are dangerous for health

- *Biological control* means that the pests are controlled or killed by living organisms.

    - This is the most promising method of pest control
    - The natural enemies and predators of the pests are used to kill the pests
    - Lady beetles for citrus fruits
    - *Bacillus thuringienesis for cotton*

Selection of biological control agent needs care. These should be ecologically safe. For example if we introduce a sparrow for eating an insect and that sparrow also start eating some plants. This will be even more harmful for crops and environment.

Advantages of biological pest control

- They do not pollute the environment.

- They do not disturb the natural ecosystem.
- A more permanent control because pest usually do not develop resistance

Applications of Biology in agriculture and plant growth

Plants are in many ways useful

- Parts of ecosystems, producers
- Food crops: crops, which makes our food like wheat, rice, vegetables.
- Many useful products like perfumes, medicines, furniture
- Beauty of the nature, ornamental plants

Biology helps in:

- Understanding the life cycles and methods of spread
- Better varieties by cross breeding or genetic engineering
- Disease mechanisms and control
- Appropriate soil, fertilizers and water availability

Exercise

1. Discuss the role of biology in apiculture.
2. Describe the process of sericulture.
3. What are important advantages of biocontrol?