"क्या पढ़ना है क्या छोड़ना है, सफलता के लिए अभ्यर्थी / प्रतिभागी को यह जानना आना चाहिए"

EVERYDAY SCIENCE

CHEMISTRY: SOAPS AND DETERGENTS

- **Soaps are anionic surfactants used for washing and cleaning.** Surfactants are wetting agents that lower the surface tension of a liquid
- **Soaps consist of sodium or potassium salts of fatty acids.**
- They are obtained by reacting common oils or fats with a strong alkaline solution
- The earliest recorded evidence for use of soap is from Babylon c. 2800 BC

Mode of action

- Soap molecules have both a hydrophilic end and a hydrophobic end
- **The hydrophilic end dissolves in water, while the hydrophobic end dissolves dirt and oil molecules**
- As a result, although water and oil don't mix, **soaps allow oil to dissolve in water, allowing them to be rinsed away**
- Thus, soaps allow water to remove normally insoluble matter by emulsification

Detergents

- **Detergents are surfactants other than soap**
- Detergents are commonly used as industrial soaps, due to their heavy duty grease removal capabilities
- Soaps differs from detergents in that in the case of former, excess of fat is used to consume the alkali and the glycerine is not removed, leaving a naturally moisturising soap
- In general detergents are substances that have cleaning properties. By definition,**even water is a detergent**

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BIOLOGY: NUTRITION

Overview

- Nutrition is the supply to cells and organisms, of the materials necessary to support life
- Many common health problems can be prevented by a healthy diet
- A poor diet can have injurious impact on health, leading to problems such as scurvy, beriberi and kwashiorkor
- A healthy diet can also significantly prevent and mitigate systemic diseases like cardiovascular disease, diabetes and osteoporosis
- Eating a wide variety of **fresh, unprocessed food has proven favourable** compared to monotonous diets of processed food
- Consumption of **whole plant foods slows digestion, allows better absorption and a more favourable balance of nutrients**

Nutrients:

- **There are six major classes of nutrients: carbohydrates, fats, minerals, proteins, vitamins and water**
- These can be classified into
    - **Macronutrients: nutrients needed in large quantities.** These include carbohydrates, fats, proteins and water. Fibre is another macronutrient whose functions have not been fully understood
    - **Micronutrients: nutrients needed in smaller quantities.** These include minerals and vitamins. Antioxidants and phytochemicals are micronutrients as well, but their functions are not well understood
- Most foods contain a mixture of nutrients
- Some nutrients may be stored internally (eg. Fat soluble Vitamins) while others are required more or less continuously

Carbohydrates

- Carbohydrates are sugars, and are classified as monosaccharides, disaccharides or polysaccharides depending on the number of monomer (sugar) units they contain

- Carbohydrates constitute a large part of foods such as rice, noodles, bread and other grain based products
- **In general, simple saccharides are easier to digest and absorb than polysaccharides**
- **Since they are absorbed more quickly, simple carbohydrates lead to elevated levels of blood glucose**

Fibre

- **Dietary fibre is a carbohydrate (polysaccharide) that is incompletely absorbed in humans and some animals**
- Like all carbohydrates, when metabolised it produces energy
- However, **it does not contribute much energy due to limitations on its absorbability and digestion**
- **Dietary fibre consists mainly of cellulose,** a polysaccharide that is indigestible in humans
- Whole grains, fruits and vegetables are good sources of fibre
- **Fibre provides bulk to intestinal contents and stimulates peristalsis** – the rhythmic muscular contractions of the intestines that moves digesta along the digestive tract
- For these reasons, fibre is important for digestive health. **It helps alleviate constipation and diarrhoea and is said to reduce colon cancer**

Fats

- **Fat consists of fatty acids bonded to glycerol.** Fatty acids are carboxylic acids that contain long chains of carbon and hydrogen atoms
- They are typically found as triglycerides
- Fats are classified as
    - **Saturated fats: have all the carbon atoms in the fatty acid chains bonded to hydrogen atoms**
    - **Unsaturated fats: have some carbon atoms double bonded to themselves, thereby have fewer hydrogen atoms**
- **Studies have shown that unsaturated fats are preferable to saturated fats in terms of health effects**

- Saturated fats are usually solids at room temperature (eg butter) while unsaturated fats are liquids at room temperature (eg olive oil)
- Trans fats are a type of unsaturated fat with trans-isomer bonds. These are rare in nature and usually created by an industrial process called hydrogenation. **Trans fats are harmful to health (coronary heart disease) and their use is to be avoided**

Proteins

- Proteins are the basis of many animal body structures and form enzymes that control chemical reactions in the body
- Proteins are composed of amino acids, which contain nitrogen atoms
- The body requires amino acids to produce new proteins and replace damaged proteins
- **Since the body cannot store protein, amino acids must be present in the daily diet**
- Diet with adequate proteins is especially important during early development and maturation, pregnancy, lactation or injury
- **A complete protein source is one that contains all essential amino acids**
- Sources of protein include meat, tofu, soy, eggs, grains, legumes and dairy products
- A few amino acids can be converted into glucose for energy (called *gluconeogenesis).*This process mainly happens only during starvation

Minerals

- Dietary minerals are the chemical components required by living organisms other than the four elements carbon, oxygen, nitrogen, hydrogen that are present in nearly all organic molecules
- Dietary minerals include some metals as well (sodium, potassium) which are usually found in ionic state
- Minerals are recommended to be supplied in the daily diet
- **Most famous dietary mineral is iodine (added to salt) which prevents goitre**
- Macrominerals (required more than 200 mg/day) include

  - **Calcium:** electrolyte, also needed for structural growth (teeth, bones)
  - **Chlorine:** electrolyte
  - **Magnesium:** required for processing ATP (energy)
  - **Phosphorous:** required component of bones, essential for energy processing
  - **Potassium:** electrolyte (heart and nerve health)
  - **Sodium:** common electrolyte, needed in large quantities. Most common source is common salt. Excess sodium depletes calcium and magnesium leading to high BP an osteoporosis
  - **Sulphur:** essential for certain amino acids and proteins
- In addition to the macrominerals, many other minerals are required in trace amounts. These include cobalt, copper, chromium, iodine, iron, manganese, molybdenum, nickel, selenium, vanadium, zinc

Vitamins

- A vitamin is an organic compound required as a nutrient in tiny amounts by an organism
- **A compound is called a vitamin when it cannot be synthesised in sufficient amounts by an organism, and must be obtained from the diet**
- Thus, the term "vitamin" is conditional both on the circumstance and the organism. For instance ascorbic acid is termed Vitamin C for some organisms but not for others, and Vitamins D and K are required in the human diet only under certain circumstances
- **Vitamins must be supplied in the diet (except Vitamin D, which can be synthesised by the skin in the presence of UV radiation)**
- Fresh fruits and vegetables are good sources of vitamins
- Vitamin deficiencies may results in diseases like goitre, scurvy, osteoporosis, impaired immune system etc
- Excess of some vitamins can also be dangerous: excess Vitamin A can cause jaundice, nausea, blurry vision, vomiting, muscle pain etc

Water

- **About 70% of non-fat mass of the body is water**

- To function properly, the body requires between one and seven litres of water every day
- It is recommended that daily water intake for an adult male be 3.7 l and for females be 2.7. However, these requirements vary with climate, activity level and other factor
- Too little water can lead to dehydration
- **Too much water can lead to water intoxication, a potentially fatal disturbance to the brain.** However, this is very rare in normal humans and usually only occurs during water drinking contests or intense bouts of exercises when electrolytes are not replenished

Malnutrition

Nutrients	Deficiency	Excess
Carbohydrates	Low energy	Diabetes, obesity
Fats	None	Cardiovascular disease, obesity
Cholesterol	none	Cardiovascular disease
Protein	Kwashiorkor (edema, anorexia, inadequate growth)	Rabbit starvation (diarrhoea, headache, low BP, low heart rate Discomfort/hunger that can only be satisfied by eating fats and carbohydrates
Sodium	Hyponatremia (electrolyte imbalance)	Hypernatremia, hypertension
Iron	Anaemia	Cirrhosis (chronic liver disease), heart disease
Iodine	Goitre, hypothyroidism	Iodine toxicity
Vitamin A	Night blindness, xeropthalmia (dry eyes)	Hypervitaminosis A (birth defects, liver problems, osteoporosis)
Vitamin B1	Beri-beri	
Vitamin B2	Cracking of skin	
Vitamin B12	Pernicious anaemia	
Niacin (Vitamin B3)	Pellagra (diarrhoea, dermatitis, dementia, death)	Dyspepsia (indigestion), cardiac arrhythmias
Vitamin C	Scurvy	Diarrhoea
Vitamin D	Rickets	Hypervitaminosis D (dehydration, vomiting, constipation)
Vitamin E	Nervous disorders	Hypervitaminosis E (anticoagulant)
Vitamin K	Haemorrhage	
Calcium	Osteoporosis	Fatigue, vomiting, depression, cardiac arrhythmias
Magnesium	Hypertension	Weakness, nausea, vomiting
Potassium	Hypokalaemia, cardiac arrhythmias	Hyperkalaemia, palpitations

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BIOLOGY: VACCINES

Overview

- A vaccine is a biological preparation that improves immunity to a particular disease
- **Vaccines were first used by Edward Jenner (England) in the 1770s** to inoculate against small pox using the cow pox microbe
- **Vaccines have resulted in the eradication of small pox**, one of the most contagious and deadly diseases known to man
- Other diseases like polio, measles, mumps, typhoid etc are have been significantly reduced. **Currently, polio is prevalent in only four countries: Afghanistan, Pakistan, Nigeria and India**

Mechanism of action

- **A vaccine is usually made from a weakened or dead form of the microbe that it is intended to fight**
- It stimulates the body's immune system to recognise the microbe as foreign, and destroy it and remember it
- When the same microbe re-appears later, the immune system easily recognises and destroys it
- When the body recognises the virulent microbe attack, it
    - Neutralises the target microbe before it can enter body cells
    - Destroys infected cells before the microbe can spread to other cells and multiply

Types of vaccines

- **Killed vaccines:** these are vaccines that contain micro-organisms that have been killed using chemicals or heat. Eg: influenza, cholera, bubonic plague, polio, hepatitis A
- **Attenuated vaccines:** these contain live attenuated (numerous) micro-organisms. These are usually live viruses that have been cultivated under conditions which disable their virulent properties, or use closely-related by less dangerous micro-organisms.**These vaccines provide more durable immune response and are preferred type for healthy adults.** Eg: yellow fever, measles, rubella, mumps, typhoid

- **Toxoid vaccines:** inactivated toxic compounds that cause illness. Eg: tetanus, diphtheria
- **Subunit vaccines:** these use protein subunits instead of the entire micro-organism as a vaccine. Eg: Hepatitis B vaccine (which uses only surface proteins), Human Papilloma Virus (HPV) vaccine (which uses subunits of influenza virus)

Effectiveness of vaccines

- Vaccines do not guarantee complete protection from a disease
- This could be due to
    - Host's immune system may not respond adequately
    - Host may have lowered immunity (such as due to diabetes, HIV, steroid use etc)
    - Host may not have a B cell capable of producing antibodies to that particular antigen
- The efficacy of a vaccine depends on a number of factors
    - The disease itself
    - The strain of vaccine
    - Following the schedule of vaccinations
    - Individual host factors
    - Genetic and ethnic predisposition
- Most vaccines use adjuvants to boost immune system response. **Adjuvants are compounds added to the vaccine that increase the immune response,** without having any specific antigenic effect by themselves.
- **Aluminum salts like aluminium phosphate and aluminium hydroxide are the most common adjuvants used**

List of important vaccines

Vaccine	Disease	Type	Notes
Anthrax vaccine	Anthrax	Protein subunit	
Bacillus Calmette-Guerin (BCG)	Tuberculosis	Live bacteria	
DTP	Diphtheria Pertussis		

	(whoopoing cough) Tetanus		
Gardasil (Human Papilloma Virus (HPV))	Cervical cancer	Protein subunit	
Polio vaccine	Polio	Killed/inactivated	Polio is prevalent only in humans Currently polio has been eradicated from all countries except Afghanistan, Pakistan, Nigeria and India
MMR	Measles Mumps Rubella		
Meningococcal vaccine	Meningococcus		
Rabies vaccine	Rabies	Attenuated	
Yellow fever vaccine	Yellow fever	Attenuated	

CHEMISTRY: MEDICINAL CHEMISTRY

- Medicinal chemistry involves the design, synthesis and development of pharmaceutical drugs
- **Compounds used as medicines are overwhelmingly organic compounds** including small molecules and biopolymers. However, some inorganic compounds and metals have been found to have medicinal properties as well

Classes of drugs

Class of drug	Application	Example	Notes
Antipyretics	Reduce body temperature	Aspirin, paracetamol (acetaminophen)	Antipyretics cause the hypothalamus to override an increase in temperature

			Taking antipyretics in empty stomach can cause ulcer
Analgesics	Pain relief	Paracetamol Non steroidal anti inflammatory drugs (NSAIDS) Morphine	Some antipyretics act as analgesics as well Some narcotics (heroin, morphine, marijuana) can also act as analgesics
Tranquilizers	Induce sedation	Barbiturates, antihistamines	Sedatives cause sleep, poor judgement, slow reflexes Excessive use can cause unconsciousness and even death
Antiseptics	Reduce possibility of infection	Boric acid, hydrogen peroxide, iodine	Antiseptics are applied externally to living tissues Antiseptics also reduce body odour caused due to bacterial decomposition They are used in breath freshners and deodorants
Antibiotics	Kill bacteria	Penicillin, gramicidin, amoxicillin, streptomycin	An antibiotic is defined as a substance produced by a microorganism that kills other microorganisms Antibiotics are considered life-saving drugs
Diuretics	Increases rate of urination	Amiloride, triamterene	
Vasodilators	Widen blood vessels	Histamine, nitric oxide	Decrease blood pressure Increase blood flow
Vasoconstrictors	Narrow blood vessels Staunch blood loss due to haemorrhage	Antihistamines, cocaine, LSD, caffeine	Increase blood pressure Decrease blood flow Make skin look paler because less blood reaches the skin
Anaesthetics	Cause loss of sensation	Cocaine, nitrous oxide, halothane	General anaesthetics cause a loss of consciousness Local anaesthetics cause loss of sensation in a specific part of the body
Antifungals	Fungal diseases like ringworm, athlete's foot, meningitis	Ketoconazole, benzoic acid, neem seed oil, tea tree oil	Since both fungi and human cells are eukaryotes, the possibility of side effects is higher than in anti-bacterial drugs (like antibiotics)
Antivirals (Antiretrovirals)	Inhibit growth of virus	Zedovudine, lamivudine	Unlike antibiotics, antiviral drugs do not destroy target microbes but only inhibit their

	growth Designing antiviral drugs is difficult because virus use host's cells to replicate Some virus, like influenza and HIV, mutate rapidly which means they can be treated with antivirals only and not be prevented by vaccines Antiretrovirals are a subclass of antivirals that treat retroviruses such as HIV

Some important common drugs

Drug	Classification	Application	Notes
Penicillin	Antibiotic	Syphilis, staphylococcal infections (food poisoning)	Narrow spectrum antibiotic (treats only a narrow range of diseases)
Zedovudine	Antiviral	HIV	
Lamivudine	Antiviral	Hepatitis B	
Streptomycin	Antibiotic	Tuberculosis	
Erythromycin	Antibiotic	Respiratory tract infections	
Ciprofloxacin	Antibiotic	Urinary tract infections, common pneumonia, myoplasmal infections	Broad spectrum antibiotic
Amoxicillin	Antibiotic	Wide range of infections	Broad spectrum
Tetracycline	Antibiotic	Cholera	
Chloroquine	Antibiotic	Malaria	
Aspirin	Analgesic, Antipyretic	Fever, pain	One of the most widely used medications in the world
Paracetamol (Acetaminophen)	Analgesic, antipyretic	Fever, pain	

BIOLOGY: STEM CELLS

Overview

- **Stem cells are cells that can renew themselves.**
- Stem cells renew themselves through mitotic cell division and can differentiate into a diverse range of specialised cell types
- Stem cells are found in most multi-cellular organisms

- There are two types of stem cells in mammals
  - Embryonic stem cells
  - Adult stem cells
- **Stem cells are mainly found in blood from the umbilical cord and the bone marrow**
- Due to their self-renewing nature, stem cells are very important for treatment of diseases

Importance of stem cells

- For a cell to be characterised as a stem cell, it must exhibit the following properties
  - **Self renewal:** the ability to go through numerous cycles of cell division while maintaining the undifferentiated state
  - **Potency:** the capacity to differentiate into specialised cell types
- **In developing embryos, stem cells can differentiate into all of the specialised embryonic tissues**
- **In adult organisms, stem cells act as a repair system for the body, replenishing specialised cells**
- Stem cells also maintain the normal turnover of regenerative organs such as blood, skin or tissues
- Stem cells can be grown and transformed into specialised cells of various tissues such as muscles and nerves using cell culture
- **Stem cell treatment holds the potential of transforming human medicine,** wherein stem cells introduce new cells into damaged tissue in order to treat a disease or injury
- **The ability of stem cells to self renew and differentiate offers the potential to replace diseased and damaged tissue without the risk of rejection or side effects**

Current stem cell treatments

- **Currently, stem cell treatment is available to treat the side effects of chemotherapy on cancer patients, such as leukaemia or lymphoma**
- During chemotherapy most growing cells are killed by cytotoxic agents
- These agents kill not only the leukaemia cells but also healthy haematopoietic stem cells in adjacent bone marrows.
- Using stem cell therapy, healthy bone marrow stem cells are used to reintroduce healthy stem cells to replace those lost in the treatment

Potential stem cell treatments

- Stem cells can be potentially used to treat a number of serious diseases. These include
  - Brain diseases such as Parkinson's and Alzheimer's
  - Cancers
  - Spinal cord injury
  - Heart damage
  - Haematopoiesis (blood cell formation)
  - Baldness, missing teeth
  - Blindness, deafness
  - Diabetes
  - Neural damage
- Almost all these treatments are still in the research stage
- **In Jan 2009, the US Food and Drug Administration (FDA) gave clearance to Geron Corporation for the first clinical trials of an embryonic stem cell therapy on humans.** The trial will evaluate the efficacy of the drug GRNOPC1 on patients with spinal cord injury

Important milestones in stem cell research

- 1963: Ernest McCullogh (Canada) and James Till (Canada) illustrate the presence of self renewing cells in the bone marrow
- 1968: Bone marrow transplant between two siblings successfully treats Severe Combined Immunodeficiency (SCID)
- 1978: haematopoietic stem cells discovered in human blood
- **1998: James Thomson (USA) derives the first human embryonic stem cell line**
- 2001: Scientists at Advanced Cell Technology (USA) clone first early human embryos for the purpose of generating embryonic stem cells
- 2006: Scientists at Newcastle University (England) create first every artificial liver cells using umbilical cord blood cells
- **2008: Robert Lanza and colleagues at ACT create first human embryonic stem cells without destruction of the embryo**

BIOLOGY: CLONING

Overview

- Cloning is the process by which genetically identical individuals are produced
- Cloning happens in nature by the biological mechanisms of asexual reproduction in bacteria, insects and plants
- Cloning can also be performed artificially by copying fragments of DNA (molecular cloning) or cells (cell cloning) or organisms
- **Mammals, which reproduce sexually, cannot clone naturally.** Mammals inherit genetic material half each from both parents, meaning that the progeny is never an identical replica of the parent. **Natural clones in mammals are confined to the production of identical twins**
- **The first vertebrate to be cloned was a tadpole by Robert Briggs (USA) and Thomas King (USA) in 1952**

Cloning in plants

- Plants have been clone for a long time.
- **Grafting is a form of plant cloning**

- Many horticulture plants are cloned, having been derived from a single individual
- Examples of plant cloning include carrots, tobacco, potato, banana

Cloning in animals

- Cloning of animals is based on a technique known as "somatic cell nuclear transfer".
- Nuclear transfer involves fusing two cells together – a donor cell containing all its DNA, and egg cell with all its DNA removed
- The two cells are fused with an electric pulse and the resulting enucleated egg is implanted in the mother

Dolly the Sheep

- Dolly, a Finn Dorset ewe, was the first mammal to be successfully cloned from an adult cell
- **Dolly was cloned by Ian Wilmut and Keith Campbell at the Roslin Institute in Edinburgh (Scotland)**
- Dolly was born in 1996 and lived for six years
- **The donor cell for Dolly was taken from a mammary gland.**
- Production of a healthy clone proved that a cell from a specific part of the body could recreate a whole individual

Some animals that have been cloned

See here for the full list cloned animals.

Cloned animal	When	Where	By whom	Notes
Tadpole	1952	USA	Robert Briggs, Thomas King	
Carp (fish)	1963	China	Tong Dizhou	

Mice (first cloned mammal)	1986	Soviet Union	Chaylakhyan, Veprencev, Sviridova, Nikitin	First cloned mammal
Sheep (first cloned mammal from adult cell)	1996	Britain	Ian WIlmut, Keith Campbell	First cloned mammal from adult cell
Rhesus monkey (named Tetra)	2000			It was named Tetra
Gaur (Asian Ox)	2001	USA	Jonathan Hill, Philip Damiani	Named Noah First endangered species to be cloned
Cat	2001 (Copycat) 2004 (Little Nicky)	USA		Copycat was the first cloned pet Little Nicky was the commercially produced cat clone
Mule (named Idaho Gem)	2003	USA	Gordon Woods, Dirk Vanderwall	First clone in horse family
Horse (named Prometea)	2003	Italy	Cesare Galli	First cloned horse First animal to be born from and carried by its cloning mother
Water buffalo (called Samrupa)	2009	India	S K Singla and others at Karnal National Dairy Research Institute	First cloned buffalo Died 5 days after birth due to lung infection
Camel (called Injaz)	2009	Dubai	Nisar Ahmad Wani	First cloned camel

CHEMISTRY: ENVIRONMENTAL CHEMISTRY

Overview

- Environmental chemistry is the study of chemical and biochemical phenomena that occur in natural places
- Environmental chemistry is used to detect and identify the nature and source of pollutants, including
    - **Heavy metal contamination of land by industry.** These can transported to water bodies and taken up ingested by living organisms
    - **Nutrients leaching from agricultural land into water sources**
    - **Urban pollutants runoff.** Typical pollutants include petrol and other fuel, metals, nutrients and sediments
- Common environmental phenomena arising out of contamination include acid rain, soil salination and ocean acidification

WATER QUALITY PARAMETERS

- **Dissolved Oxygen (Oxygen Saturation)**
    - It is a relative measure of the amount of oxygen dissolved in water.
    - **Supersaturation (excess of oxygen) can be harmful to organisms and also cause decompression sickness**
    - It is expressed in mg/l
- **Chemical Oxygen Demand (COD)**
    - COD is used to indirectly measure the amount of organic compounds in water
    - It is expressed in mg/l, which indicates the amount of oxygen consumed per litre of water
- **Biochemical Oxygen Demand (BOD)**
    - BOD measures the rate of uptake of oxygen by microorganisms in water
    - BOD is measured at a temperature of 20 C and over a period of 5 days in the dark
    - **BOD is widely used to determine the threshold at which treated wastewater can be re-introduced into the environment**

  - **Pristine rivers have a BOD of below 1 mg/l. Municipal sewage treated effectively by a three-stage process would have BOD of 20 mg/l or less**
- **Total Dissolved Solids (TDS)**
  - TDS is a measure of combined content of all inorganic and organic substances contained in a liquid
  - TDS is generally not considered a primary pollutant, but is used to indicate the aesthetic characteristics of drinking water
  - **High TDS levels generally indicate hard water**
  - **Drinking water is expected to have a TDS of 100 mg/l or less**
  - **TDS is different from TSS (Total Suspended Solids).** The former are those solids that are small enough to pass through a filter of size 2 um, while the latter are those solids that cannot pass through

ENVIRONMENTAL POLLUTION PHENOMENA

Acid rain

- Acid rain is form of rain that is unusually acidic i.e. has low pH
- **Acid rain is mostly caused by emission of sulphur, nitrogen and carbon** which react with water molecules in the atmosphere to produce acids
- The biggest human activity causes of acid rain include coal-based power plants, factories and automobile emissions
- It can also be caused by natural phenomena such as
  - **lightning strikes** (which splits nitrogen compounds)
  - **volcanic eruptions** (which release large quantities of sulphur dioxide)
- **Natural (unpolluted) rain is slightly acidic with pH of 5.2** due to the reaction of carbon dioxide with water to produce carbonic acid
- **Acid rain has many adverse effects including**
  - Damage to aquatic animals
  - Damage to soil chemistry by killing off essential microbes
  - Loss of forests and vegetation
  - Human illnesses such as cancer, asthma and other diseases
  - Damage to buildings and historical monuments (esp. those made of limestone and marble)

Ocean acidification

- Ocean acidification is the continuing phenomenon of decreasing pH in the world's oceans
- **Between 1751 and 1994, ocean pH is estimated to have decreased from 8.179 to 8.104** (decrease of 0.075). Ocean pH is expected to decrease by a further 0.3-0.5 by 2100
- **This acidification is mainly the result of uptake of carbon dioxide from the atmosphere.** The world's oceans naturally absorb carbon dioxide from the atmosphere, indirectly mitigating climate change
- **Ocean acidification adversely affects marine organisms especially calcifying organisms** like corals, crustaceans and molluscs, and also affects other organisms by entering the food chain

Soli salination

- Salt affected soils are caused by excess accumulation of salts at the soil surface
- Salt can be transported to the soil surface by capillary action from salt-laden water tables, or by human activity
- Increasing soil salinity adversely affects soil quality and vegetation
- Human activities that increase soil salinity include
    - **Land clearing**
    - **Aquaculture activities** (shrimp farms etc)
    - **Irrigation** (over a period time causes deposition of salts)
- The adverse effects of salination include
    - **loss of soil fertility**
    - **damage to infrastructure (such as roads etc)**
    - **damage to plant growth and yield**
    - **deterioration of underground water quality**
    - **soil erosion**

COMMON ENVIRONMENTAL TOXINS:

1. **Chlorofluorocarbons**
    1. They are organic compounds that contain carbon, chlorine and fluorine
    2. **Examples of CFCs include Freon, Teflon**

3. **CFCs have been widely used as refrigerants, propellants (in aerosols) and solvents**
4. **The use of CFCs has been banned under the Montreal Protocol** due to their adverse effect on the ozone layer

2. **Endocrine disruptors**
    1. Endocrine disruptors are substances that affect the function of natural hormones in the body
    2. Food is the main source of exposure to endocrine disruptors
    3. There are five main types of endocrine disruptors:
        1. DDT
        2. Polychlorinated biphenyls
        3. Bisphenol A
        4. Polybrominated diphenyl ethers
        5. Pthalates
3. **DDT**
    1. **Dichlorodiphenyltrichloroethane (DDT) is one of the most well-known synthetic pesticides**
    2. DDT is one of the most effective and simple to deploy pesticides, especially to fight mosquitoes that cause malaria and typhus
    3. **DDT has significant adverse effect on aquatic life, insects and humans** (esp. diabetes and reproductive disorders)
    4. **It is a significant reproductive toxicant for certain bird species, and is a major reason for the decline of the bald eagle, brown pelican peregrine falcon and osprey.** This is the main reason DDT use has been banned
    5. **The use of DDT for agricultural use has been banned under the Stockholm Convention,** however it can still be used for disease vector control (mosquito eradication)
4. **Polychlorinated biphenyls (PCBs)**
    1. PCBs are a class of industrial compounds
    2. **They are used mainly as industrial coolants and lubricants**
    3. **Exposure to PCBs increases the risk of skin cancer, brain cancer and liver cancer.** Additionally it also increases childhood obesity and the risk of developing diabetes
    4. **The use of PCBs was banned in 1977**
5. **Bisphenol A (BPA)**
    1. BPA is an organic compound with two functional phenol groups

2. **BPA is used as a building block of several important plastics and plastic additives**
3. It is found commonly in water bottles, plastic food containers and the lining of infant formula cans
4. **The use of BPA has been linked to diabetes, mammary and prostrate cancers, reproductive problems, obesity and neurological disorders**
5. BPA use has not been banned

6. **Polybrominated diphenyl ethers (PBDE)**
    1. **PBDEs are a class of compounds used as flame retardants**
    2. They are used commonly in televisions, computers, electronics, carpets, bedding, clothing car components etc
    3. **PBDEs have the potential to affect thyroid balance, and contribute to a variety of neurological and developmental disorders** including learning disabilities and low intelligence
    4. **Many of the most common PBDEs were banned by the European Union in 2006**
7. **Phthalates**
    1. Phthalates are esters of phthalic acid
    2. **They are mainly used as plasticisers to soften polyvinyl chloride (PVC)**
    3. Phthalates are found in soft toys, flooring, medical equipment, cosmetics and air fresheners
    4. **Phthalates have been shown to have adverse effects on the male reproductive system**
    5. **The EU and the US have begun phasing out widespread use of phthalates**
8. **Dioxins**
    1. Polychlorinated dibenzodioxins (PCDDs) are a group of polyhalogenatated compounds
    2. The main sources of Dioxins include
        1. **By-products in the manufacture of organochlorides**
        2. **in the incineration of chlorine containing substances (like PVC)**
        3. **bleaching of paper**
        4. **natural sources like volcanoes and forest fires**

3. **Dioxins accumulate and build up in the food chain (bioaccumulation)**
4. **Health effects of dioxins include**
    1. Severe form of acne called chloracne
    2. Abnormalities in teeth enamel of children
    3. Nervous system pathology
    4. Thyroid disorders
    5. Diabetes
    6. Damage to immune system
5. **Exposure to dioxins has been shown to affect the ratio of male to female births,** such that more females are born than males

"क्या पढ़ना है क्या छोड़ना है, सफलता के लिए अभ्यर्थी / प्रतिभागी को यह जानना आना चाहिए"

PHYSICS: NON-INVASIVE IMAGING

Overview

- Medical imaging is the technique and process used to create images of the human body for medical purposes
- Non-invasive imaging is the method of producing images of internal tissues without surgical procedures
- Non invasive imaging techniques can be used to produce anatomical assessment of tissues (such as X-rays) as well as functional assessments (such as MRI)
- As a discipline, it includes radiology, nuclear medicine, endoscopy, thermography etc
- **Non-invasive imaging is a vast field with differing technologies such as X-rays, tomography, MRI etc**
- Non-invasive imaging provide highly valuable diagnostic tools for diagnosing and treating varied ailments such as cancer, fractures, etc
- Imaging technologies can be broadly classified into two categories
    - **Anatomical imaging modalities:** these imaging techniques provide information on the anatomy i.e. the physical structure of the organ/tissue under study
    - **Functional imaging modalities:** these imaging techniques provide information on the physiological functioning of the organ/tissue under study

X-RAYS

- **X-rays were discovered by Wilhem Conrad Rontgen (Germany) in 1895.** He won the Nobel in Physics 1901
- **Radiography is the imaging process that uses X-rays to capture images**
- In conventional radiography, X-rays from a X-ray tube pass through the patient and are captured by an X-ray sensitive film screen

- Nowadays, digital radiography (DR) is becoming popular, in which x-rays strike an array of sensors that convert the signal to digital mode and displays the images on a computer screen
- **X-rays are the preferred diagnostic tool for studying lungs, heart and skeleton**(including fractures) due to their simplicity, available and low cost
- **X-rays is an anatomical imaging technology**

Fluoroscopy

- Fluoroscopy is used to obtain real time moving images of the internal structures
- Fluoroscope systems consist of an X-ray source and a fluorescent screen connected to a closed circuit TV. The patient is position between the source and the screen
- Fluoroscopes use low x-ray radiation doses
- **Fluoroscopy also involves use of radiocontrast agents that increase the contrast of a specific tissue w.r.t. surrounding tissues** by strongly absorbing or scattering the x-rays
- **The radiocontrast agents enable visualization of dynamic processes** such as peristalsis in the digestive tract of blood flow in arteries and veins
- **Commonly used contrast agents include Barium and Iodine.** These may be administered orally or rectally or injected into the blood stream
- **Used mainly for investigating gastrointestinal functions, orthopaedic surgery and urological surgery**
- **Fluoroscopy is a functional imaging technology**

Computed Tomography (CT)

- Computed Tomography uses X-rays in conjunction with software algorithms to image the body
- **CT generates a three-dimensional image of an object using a large series of X-ray images** taken around a single axis of rotation
- CT produces a volume data which can be manipulated in order to demonstrate various body functions

- Compared to traditional radiography, CT produces 3d information and has much higher contrast and resolution, but also uses much higher doses of radiation
- **CT scanners were first developed by Sir Godfrey Hounsfield (Britain) in 1972.** He won Nobel in Medicine in 1979
- **CT is used primarily for detecting cerebral haemorrhage, pulmonary embolism, aortic dissection, appendicitis and kidney stones**
- **CT is an anatomical imaging technology**

Ultrasound

- **Ultrasound was first developed for medical use by John Wild (Britain) in 1949**
- Ultrasonography uses ultrasound (high frequency sound waves) to visualize soft tissues in the body in real time
- **Ultrasound does not involve any ionizing radiation,** hence it considered safer than X-rays or CT and is used for obstetrical imaging
- Ultrasound is limited by its inability to image through air or bone, and by the skill of the examiner
- **Ultrasound is used primarily to study the development of foetus**
- A variant of ultrasound, the colour flow Doppler ultrasound is used in cardiology for diagnosing peripheral vascular disease
- **Ultrasound is a functional imaging technology**

Magnetic Resonance Imaging (MRI)

- **MRI was invented by Paul Lauterbur (USA) and Sir Peter Mansfield (Britain) in the 1970s.** They won Nobel in Medicine in 2003
- MRI uses strong magnetic fields to align atomic nuclei within body tissues, and then uses a radio signal to disturb this alignment and observes the signals generated as the atoms return to their original states
- **The working principle of MRI is called Nuclear Magnetic Resonance (NMR)**

- **MRI scans give the best soft tissue contrast of all imaging modalities**
- **MRI does not use any ionizing radiation.** However, it does use powerful magnetic fields
- A variant of MRI called Functional MRI measures signal changes in the brain due to neural activity
- **MRI is used primarily for neurological (brain), musculoskeletal, cardiovascular and oncological (cancer) imaging**
- **MRI is an anatomical imaging technology**

Nuclear medicine

- **Nuclear medicine uses radioactive isotopes and the principle of radioactive decay to study body functions**
- Nuclear medicine involves the administration into the patients of radio-pharmaceuticals.
  Radio-pharmaceuticals are substances with affinity for certain body tissues that have been labelled with radioactive tracers (called radio-nuclides)
- The radio-pharmaceuticals administered into the body emit radiation which is detected and converted into images.
- **The radio-pharmaceuticals, once administered, localise (i.e. attach) to specific organs or cell receptors,** meaning those particular organs or cells can be studied in isolation
- Commonly used tracers include Technetium, iodine, gallium and thalium
- **Nuclear medicine is used mainly to study the heart, lungs, thyroid, liver and gallbladder**
- Nuclear medicine mainly provides information about the physiological function of these tissues
- Since the radio isotopes decay over a period a time, they do not pose a significant threat to normal human functioning
- **Nuclear medicine is a functional imaging technology**

Positron Emission Tomography (PET)

- **PET uses nuclear medicines to produce three dimensional images**
- The PET system detects gamma rays emitted by positron emitting radio-nuclides. Images of the nuclide concentration are reconstructed in 3d by computer algorithms
- **PET is a functional imaging technology**
- PET is often combined with CT and MRI scans, enabling both anatomical and functional imaging simultaneously
- **PET was first developed by David Kuhl (USA) and Roy Edwards (USA) in the 1950s**
- **PET is mainly used in oncology (cancer) and neurology (especially dementias)**
- **A variant of PET, called Single Positron Emission Computed Tomography (SPECT) detects gamma rays emitted directly by the radio-nuclides**

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PHYSICS: MAGNETISM

Overview

- The term magnetism describes how materials respond to an applied magnetic field
- **All materials are influenced to a greater or lesser extent by the presence of a magnetic field.** Some are attracted (paramagnetism) while some are repulsed (diamagnetism)
- Substances that are negligibly attracted by magnetic fields are called non-magnetic materials. Eg: copper, aluminium, water, glass
- The magnetic state of a material depends on its temperature, with the result that a substance may exhibit different magnetic characteristics depending on its temperature
- Magnetism can arise from either intrinsic magnetic moments contained in particles, or by electric currents applied to the substance
- Magnet is a material that produces a magnetic field
- **Permanent magnet is a material that retain its magnetic field**

Types of magnetism

- **Diamagnetism**
  - Diamagnetism is the tendency of a material to oppose a magnetic field
  - **It appears in all materials.** However, in a material with paramagnetic properties, the paramagnetic behaviour dominates
  - Diamagnetic materials do not have unpaired electrons
  - Superconductors are diamagnetic materials
- **Paramagnetism**
  - Paramagnetism is the tendency of a material to be attracted to an applied magnetic field

- **Paramagnetism only occurs in the presence of an externally applied magnetic field.** When the external field is removed, the magnetisation will drop to zero
- Paramagnetic materials have one unpaired electron, allowing it to orient in the direction of the magnetic field
- Oxygen, myoglobin are examples of paramagnets

- **Ferromagnetism**
  - **Ferromagnetism is the only type of magnetism that can produce forces strong enough to be felt, and is responsible for the magnetic phenomena in everyday life**
  - Ferromagnetic materials have unpaired electron, but unlike paramagnets, they remain oriented even after the external magnetic field has been removed
  - **Ferromagnetic materials remain magnetized even after the external applied magnetic field has been removed**
  - **All permanent magnets are either ferromagnets or ferrimagnets**
  - Eg: refrigerator magnets
- **Antiferromagnetism**
  - Magnetic moments of electrons point in opposite directions
  - **Anitferromagnets have zero net magnetic field**
  - They are not very common and usually occur only low temperatures
  - **Antiferromagnetism disappears above the Neel Temperature and the material becomes paramagnetic**
  - Examples include hematite, chromium, iron manganese
- **Ferrimagnetism**
  - Neighbouring pairs of electrons point in opposite direction
  - **However, ferromagnetic materials retain their magnetisation in the absence of the magnetic field**
  - Example is magnetite

Electromagnets

- Electromagnet is a magnet whose magnetic field is produced by the flow of electric current
- The magnetic field disappears when the current ceases
- The electromagnet was invented by William Sturgeon (Britain) in 1824
- Electromagnets are widely used in electrical devices such as motors, generators, loudspeakers, particle accelerators
- Magnetic Levitation (MAGLEV) trains run on electromagnetic suspension produced by electromagnets

Earth's magnetic field

- The Earth's magnetic field, which extends several tens of thousands of km into space is called the magnetosphere
- **The earth's magnetic field is explained by dynamo theory.** The theory explains the mechanism by which celestial bodies like the earth, or a star generate magnetic fields. According to the theory, earth's magnetic field is produced by electric currents in the liquid outer core
- **The magnetic north pole of the Earth is located near the geographic south pole, and the magnetic south pole is located near the geographic north pole.** This can be explained by understanding that the north pole of a suspended magnet points towards the north, indicating that the geographic north pole should have south polarity
- **The earth's magnetic poles move with time due to magnetic changes in the earth's core.** Currently, the magnetic north pole lies near Ellesmore Island in northern Canada, while the south pole is near Wilkes Land, Antarctica. The north pole is moving northwest by about 64 km/year and the south pole is moving northwest by 10-15 km/year

CHEMISTRY: PROPELLANTS

Overview

- A propellant is a material that is used to propel an object
- The object is usually expelled by the pressure created by a gas
- This pressure may be created by a compressed gas or by a gas produced by a chemical reaction
- Propellants may be solids, liquids, gases or plasmas
- Common chemical propellants consist of a fuel and an oxidiser

Types of propellants

- **Aerosol sprays**
  - Aerosol spray is a dispensing system that creates an aerosol (fine) mist of liquid particles
  - In aerosol sprays, the propellant is simply a pressurised gas in equilibrium with its liquid form
  - As some gas escapes to expel the payload, more liquid evaporates thereby maintaining an even pressure
  - **The aerosol spray can was invented by Erik Rotheim (Norway) in 1927**
  - Aerosol sprays are typically used to dispense insecticides, deodorants and paints
- **Propellants used for propulsion**
  - **Rockets typically use *bipropellants*, which contain a combination of a fuel and an oxidiser.** *Tripropellants,* which are not used commonly, use liquid hydrogen as a third component to provide additional efficiency
  - **Propellants are usually made from low explosives, which deflagrate (burn) rather than detonate (explode)**
  - The controlled burning of the propellants produces thrust by gas pressure which is then used to accelerate a rocket, projectile or other vehicles
  - **Propellants are commonly used in rockets, firearms and artillery**

Solid propellants

- Solid propellants are used for rockets, firearms and artillery
- Examples of solid propellants include gunpowder (sulphur + charcoal + potassium nitrate), nitrocellulose and cordite
- **Single based propellants:** They have nitrocellulose as its chief ingredient. Stabilizers and other chemicals may be added for chemical stability
- **Double based propellants:** they contain nitrocellulose with nitroglycerin or other liquid nitrate explosives added. Nitroglycerin reduces smoke and increases energy output. Used in small arms, cannons, mortars and rockets
- **Triple based propellants:** consist of nitrocellulose, nitroquanidine, and nitroglycerin or other nitrate explosives. Used in cannons
- **Composite propellants**: consist of a fuel such as metallic aluminium, a binder such as synthetic rubber and an oxidiser such as ammonium perchlorate. **Used in large rocket motors such as spacecraft**
- Solid propellants have been used since the 11th century to power rockets based on gunpowder
- **Solid fuel rockets offer ease of handling, reliability and long storage periods**
- **Solid fuel rockets are used for missiles** due to their long storage periods and reliability of launch on short notice
- **Currently, solid fuel rockets are not used for space explorations, but are commonly used as booster rockets to launch spacecraft**

Liquid propellants

- Liquid propellants are usually used in combinations of fuel and oxidiser
- Common liquid propellant combinations include

  - Liquid oxygen and liquid hydrogen
  - Liquid oxygen and kerosene
  - Nitrogen tetraoxide and kerosene
- **Liquid fuel rockets are desirable because they offer higher energy output, they can be throttled and shut down and can be reused**
- **Liquid fuel rockets are used to power space shuttles**
- **A variant of liquid fuel engine is cryogenic fuel engine – these are engines that use gases which are super-cooled into their liquid forms**

Propellants used in the PSLV

- **The Polar Satellite Launch Vehicle (PSLV) has a four stage propulsion system, using solid and liquid propellants alternately**
- First stage: solid – Hydroxyl terminated polybutadiene (HTPB)
- Second stage: liquid – unsymmetrical di-methyl hydrazine (UDMH) as fuel and nitrogen tetraoxide as oxidiser
- Third stage: solid – HTPB
- Fourth stage: solid – mono methyl hydrazine as fuel and mixed oxides of nitrogen as oxidiser

Propellants used in the GSLV

- **The Geosynchronous Satellite Launch Vehicle (GSLV) is a three stage launch vehicle using solid, liquid and cryogenic propellants**
- First stage – solid – HTPB
- Second stage – liquid – UDMH as fuel and nitrogen tetraoxide as oxidiser
- Third stage – cryogenic – liquid hydrogen and liquid oxygen

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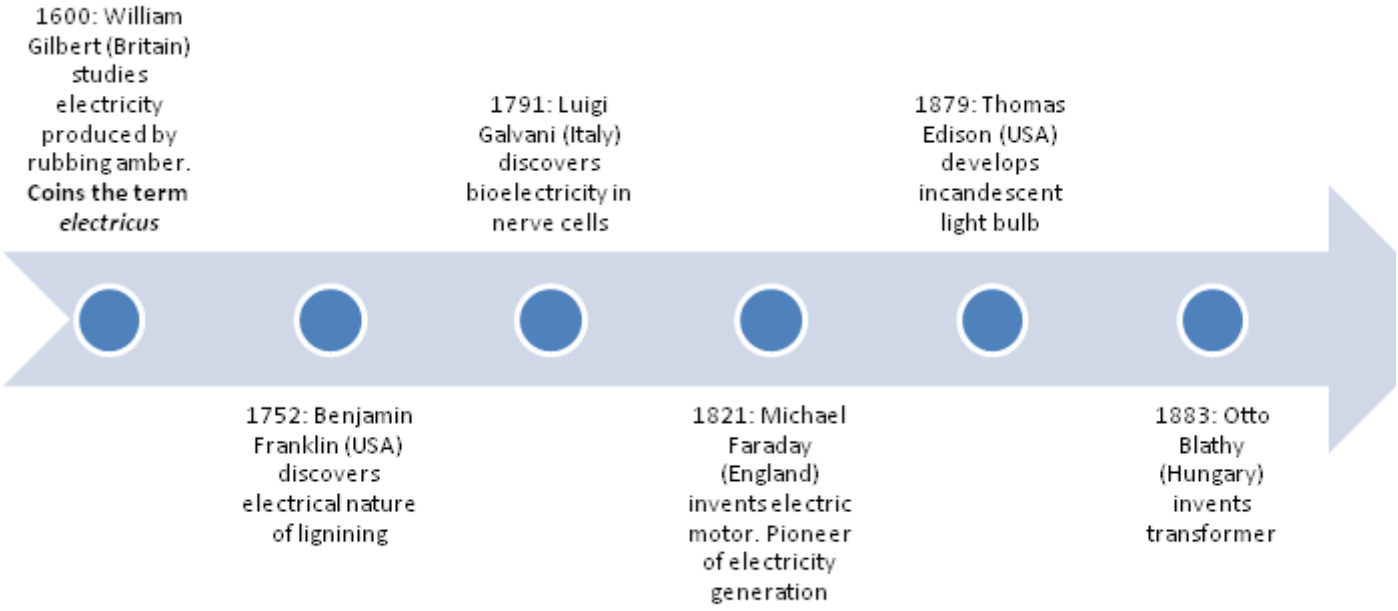
PHYSICS: ELECTRICITY

Overview

- Electricity is an extraordinarily versatile source of energy
- Electricity is the backbone of modern industrial society
- The phenomenon of electricity includes concepts such as
    - Electric charge: a property of subatomic particles that determines their electromagnetic interactions
    - Electric current: a movement or flow of charged particles
    - Electric field: influence of charged particles on other charged particles in the vicinity
    - Electric potential: capacity of an electric field to do work
    - Electromagnetism: interaction between electric and magnetic fields

TIMELINE OF EARLY DISCOVERIES/INVENTIONS



BASIC ELECTRICAL COMPONENTS

1. **Resistors**

1. Resistors are materials that resist the flow of current through them
2. They dissipate energy in the form of heat
3. **Ohmic materials are those materials whose resistance remains constant over a range of temperatures and currents.** Non-ohmic materials have resistances that change
4. The unit of resistance is Ohm

2. **Capacitors**
    1. Capacitors are devices that store electric energy in the form of electric charge
    2. They usually consist of two conducting plates separated by a thin insulating layer
    3. **Capacitors block steady state current i.e. DC current**
    4. The unit of capacitance is Farad
3. **Inductors**
    1. Inductors are conductors that store energy in a magnetic field, which is produced in response to an electrical current
    2. Inductors allow steady current, but oppose rapidly changing currents
    3. The unit of inductance is Henry
4. **Transformers**
    1. A transformer is a device that transfers electrical energy from one circuit into another
    2. This transfer occurs through inductively coupled conductors, where varying current in one circuit creates a varying magnetic field (and hence voltage) in the other circuit
    3. Transformers can be used to step-up or step-down voltages from high voltage transmission lines to appliances in homes

ELECTRICITY IN NATURE

1. **Electric shock**
    1. **A voltage applied to the human body causes an electric current through the tissues**
    2. In general, greater the voltage applied, greater the current passed through the tissues

3. **Voltages 100-250 V can be lethal in humans,** although as low 32V has been lethal sometimes. Lethality increases dramatically beyond 250V
4. **If the current is sufficiently high, it can cause muscle contractions, fibrillation of the heart and tissue burns**
5. DC tends to cause continuous muscle contractions making the victim hold on to a live conductor, thereby increasing risk of tissue burn
6. AC tends to interfere with heart function, increasing risk of cardiac arrest
7. AC at high frequencies, causes current to travel on the surface due to skin effect. This results in severe burn but is usually not fatal

2. **Electrical phenomena**
    1. Touch, friction and chemical bonding are all due to interactions between electrical fields on the atomic scale
    2. **The Earth's magnetic arises from a natural dynamo of circulating currents in the planet's core**
    3. Piezoelectric crystals like quartz and sugar generate electric current when subject to mechanical pressure
    4. **Electric eels detect and stun their prey via high voltages (500 V) generated from muscle cells called electrocytes**
    5. **Electrical currents, called Action Potential, are used for nervous system communication in all animals, including humans**

CHEMISTRY: EXPLOSIVES

Overview

- An explosive is a substance that contains a great deal of stored energy that can produce an explosion, usually accompanied by the production of light, heat and pressure
- The energy stored in an explosive material may be
    - Chemical energy such as nitroglycerine
    - Pressurised compressed gas such as a gas cylinder or aerosol can
    - Nuclear energy such as Uranium and plutonium

CHEMICAL REACTIONS IN EXPLOSIVES

1. **Deflagration**
    1. **Deflagration is a term that describes subsonic combustion that propagates through thermal conductivity**
    2. Deflagration is easier to control and so is used when the goal is to move an object with the force of expanding gas
    3. Examples of deflagration include gas stove, internal combustion engine, gunpowder, pyrotechnics etc
2. **Detonation**
    1. Detonation is a combustion process in which a supersonic shock wave through the body of a material
    2. In detonation, a supersonic shock wave originating at the point of ignition compresses the surrounding material, thus increasing its temperature to the point of ignition
    3. Because detonations generate high pressures, they are much more destructive than deflagrations
    4. Detonations are difficult to control and are used primarily for demolition and in warfare.
    5. Examples of detonation includes high explosives, oxygen-methane mixture

CLASSIFICATION OF EXPLOSIVES

1. **High explosives**

    - **Materials that explode faster than the speed of sound are called high explosives**
    - This type of explosion is known as detonation
    - Used in mining, demolition and military applications

1. **Low explosives**
    1. **Materials that explode slower than the speed of sound are called low explosives.**
    2. This type of explosion is known as deflagration

3. Used as propellants, gun powder, pyrotechnics (such as flares and fireworks)

2. **Primary explosives**
    1. **A primary explosive is an explosive that is extremely sensitive to stimuli.** These stimuli include impact, friction, heat, static electricity and electromagnetic radiation
    2. For primary explosives, a relatively small amount of energy is required for initiation of explosion
    3. **In general, primary explosives are considered to be those explosives that are more sensitive than PETN**
    4. Used in detonators to trigger larger charges of more stable secondary explosives
    5. E.g.: Mercury fulminate, Nitrogen trichloride, acetone peroxide, ammonium permanganate
3. **Secondary explosives**
    1. **Secondary explosives are less sensitive than primary explosives and require more energy to be initiated**
    2. They are safer to handle and store
    3. In general, secondary explosives are considered to be those explosives that are less sensitive than PETN
    4. Secondary explosives are usually used in large quantities and are initiated by small amounts of primary explosives
    5. E.g.: TNT, RDX

SOME COMMON EXPLOSIVES

1. **Trinitrotoluene (TNT)**
    1. TNT is a useful explosive material with convenient handling properties. TNT is sometimes also used as a reagent in chemical synthesis
    2. **TNT was first prepared by Joseph Wilbrand (GermanY) in 1863**
    3. **The explosive yield of TNT is considered to be the standard measure of strength of bombs and other explosives**
    4. Sulphitation is a process used in the manufacture of TNT, specifically to stabilize the explosive

5. TNT is one of the most commonly used explosives for industrial and military applications
6. **It is insensitive to shock and friction, reducing the occurrence of accidental detonation.** TNT melts without exploding (allowing it to be combined with other explosives), does not absorb or dissolve in water (allowing use in wet environments) and is stable compared to other explosive
7. **TNT contains energy of 4.6 Mega Joules per kilogram (MJ/kg).** By comparison gun powder contains 3 MJ/kg, dynamite contains 7.5 MJ/kg and gasoline contains 47.2 MJ/kg
8. TNT is used as a reference for other explosives. Nuclear weapons have energy content measured in kilotonnes (kT) or megatonnes (MT) of TNT equivalent.
9. TNT is usually used in mixture with other substances. E.g.: Amatol (TNT + ammonium nitrate)

2. **RDX**
    1. RDX, chemically cyclotrimethylnetrinitramine, is also known as cyclonite and T4
    2. RDX is usually used in mixture with other explosives and plasticizers
    3. **RDX is stable in storage and is considered one of the most powerful of military explosives**
    4. **RDX was discovered in 1898 by Goerg Friedrich Henning (Germany)**
3. **Pentaerythritol tetranitrate (PETN)**
    1. **PETN is one of the most powerful high explosives known**
    2. **It is more difficult to detonate than primary explosives, but less stable than secondary explosives**
    3. It is more sensitive than other high explosives, and is rarely used alone
    4. Usually used in small calibre ammunition, detonators of land mines
    5. **PETN is an effective underwater explosive**
    6. **PETN is a major ingredient of Semtex (plastic explosive)**
    7. **PETN was first synthesised by Bernhard Tollens (Germany) in 1891**
4. **Dynamite**
    1. **Dynamite is based on nitroglycerine**

2. **It was invented by Alfred Nobel (Sweden) in 1867**
3. Used mainly for mining, quarrying, construction
4. **Dynamite was the first safely manageable explosive stronger than black powder**

5. **Plastic explosive**
    1. Plastic explosives are explosives that are soft and can be moulded by hand
    2. **Common plastic explosives include Semtex (Czech Republic) and C-4 (USA)**
    3. Used mainly for demolition, also used by terrorists
    4. **The first plastic explosive was Gelignite, invented by Alfred Nobel (Sweden) in 1875**
    5. C-4 (composition 4) is made of RDX while Semtex is made from RDX and PETN
    6. Semtex became notoriously popular with terrorists because it is difficult to detect. Semtex was invented by Stanislav Berbera (Czech R.) in the 1950s

PHYSICS: PARTICLE PHYSICS

Overview

- **The atom was discovered by John Dalton in 1802**
- However, even more fundamental particles were discovered in the 20th century
- Particle physics focuses on subatomic particles including electrons, protons and neutrons
- Many fundamental particles do not occur in nature but can be created in high energy collisions of other particles

Standard Model of particle physics

- **The Standard Model describes the current classification of elementary particles**

- It describes strong, weak and electromagnetic forces using gauge bosons
- The Standard Model does not include gravitation, dark matter and dark energy
- **The Standard Model was developed by Sheldon Glashow, Steven Weinberg and Abdus Salam in the 1960s. They won Nobel in Physics in 1979**
- The Model contains 24 fundamental particles
- **It predicts the existence of the *Higgs Boson*, which is yet to discovered**
- All particles of the Standard Model have been observed in experiments, except the Higgs Boson

Elementary particles

- **All elementary particles are either fermions or bosons**
- Fermions are particles associated with matter, while bosons are particles associated with force
- Fermions can be divided into Quarks and Leptons
- Bosons can be divided into Gauge Bosons and Other Bosons (including Higgs Boson)
- **Protons and neutrons are examples of Hadrons, which are composites of Quarks**
- **Electrons are elementary particles by themselves**

Important particle physics labs

Facility	Location	Established	Famous for
Brookhaven National Lab	New York	1947	World's first heavy ion collider World's only polarized proton collider
Budker Institute of Nuclear Physics	Novosibirsk (Russia)	1959	World's first particle accelerator
European Organization for Nuclear Research	Geneva	1954	World's largest particle physics lab

			Birthplace of World Wide Web Large Hadron Collider (LHC)
German Electron Synchrotron (DESY)	Hamburg	1959	
Fermilab	Chicago	1967	Tevatron – world's second largest particle accelerator
High Energy Accelerator Research Organization (KEK)	Tsukuba (Japan)		
SLAC National Accelerator Lab	Stanford University	1962	Longest linear accelerator in the world

CHEMISTRY: CERAMICS

Overview

- A ceramic is an inorganic, non-metallic solid prepared by the action of heating and subsequent cooling
- The earliest ceramic materials were pottery made from clay
- Ceramics are resistant to chemical erosion and high temperatures (up to 1600C)

PROPERTIES OF CERAMICS

- **Mechanical properties**
  - Ceramic materials are usually formed by ionic or covalent bonds
  - These materials tend to not be elastic and fracture easily
  - Ceramics are also porous
  - In general ceramics have poor toughness and have low tensile strength
- **Electrical properties**
  - Some ceramics are semiconductors
  - Semiconducting ceramics are made using zinc oxide

  - Under extremely low temperatures, some ceramics exhibit superconductivity
  - Most ceramics exhibit piezoelectricity i.e. the conversion of mechanical stress to electrical signals. This effect is commonly used in quartz watches
- **Optical properties**
  - Ceramics (esp. those based on aluminium oxide) can be made translucent
  - This has immediate applications in sodium-vapour lamps and dental restorations
  - Ceramics can be made transparent with applications in laser technology

TYPES OF CERAMICS

1. Structural ceramics such as bricks, pipes, floor, roof tiles etc
2. Refractory ceramics such as kiln lining, steel and glass making crucibles
3. Whitewares such as tableware, wall tiles, pottery, sanitary products
4. Technical ceramics such as jet engine turbine blades, ballistic protection etc

MANUFACTURE OF CERAMICS

1. **Milling**
   1. Process by which materials are reduced in size
   2. Involves breaking of cemented material or pulverization
   3. Techniques used include ball mill, roll crusher, jaw crusher, wet attrition mills
2. **Batching**
   1. Is the process of weighing the oxides according to recipes and preparing them for further processing
3. **Mixing**
   1. Involves mixing the various components in the appropriate proportions
   2. Uses ribbon mixers, Mueller mixers and pug mills

4. **Forming**
    1. This is the process of the making the mixed materials into desired shapes such as toilet bowls, spark plugs etc
    2. Forming techniques include extrusion, pressing and slip casting
5. **Drying**
    1. Controlled heat is applied to dry the materials and obtain rigid shape
6. **Firing**
    1. Dried parts are processed through a controlled heating process and oxides are chemically changed to cause sintering and bonding

BIO-CERAMICS

- Bacteria, plants and animals exhibit a tendency to form crystalline materials composed of silicon
- These bioceramics show exceptional physical properties such as strength, fracture resistance etc
- Bio-ceramics are usually made of proteins such as keratin, elastin, chitin and collagen
- **The mother-of-pearl portion of marine shells exhibit the strongest mechanical strength and fracture toughness of any non-metallic substance known**

APPLICATIONS OF CERAMICS

Application	Ceramic components	Notes
Armoured vests	Alumina, boron carbide	Protects against high-calibre rifle fire
Dental implants, synthetic bone	Artificial hydroxyapatite (natural mineral of bone)	
Ball bearings	Silicon nitride	Harder, more resistant to heat than metal bearings
Earthenware	Kaolin, boll, flint	Opaque Used to make cups, saucers etc
Chinaware	Leached granite (to remove	Translucent

	quartz and mica)	Resists scratching
Porcelain	Kaolin, feldspar, quartz	White, semi-opaque Highly resistant to scratching Stronger than glass
Stoneware	Kaolin, feldspar, quartz	Similar to porcelain but from poor grade raw materials Hard, infusible
Space shuttles	Extremely pure Silica	Used on the outer surface of shuttles to withstand heating during atmospheric re-entry Space shuttle Colombia burnt up on re-entry due to damage to ceramic tiles

BIOLOGY: GENETIC ENGINEERING

Overview

- Genetic engineering refers to the *direct* manipulation of an organism's genes
- Genetic engineering is also referred to as recombinant DNA technology, genetic modification and gene splicing
- Genetic engineering uses cloning and transformation of molecules to alter the structure and characteristics of genes
- Examples of genetic engineering include improved crop technologies, synthetic hormones, and creation of experimental mice

Process of genetic engineering

The process of genetic engineering has five main steps:

1. Isolation of the genes of interest
2. Insertion of the genes into a transfer vector
3. Transfer of the vector to the organism to be modified
4. Transformation of the cells of the organism
5. Selection of the genetically modified organisms from those that have not been successfully modified

Applications of genetic engineering

- **The first genetically engineered medicine was synthetic insulin**
- Genetic engineering has been used to produce vaccines for hepatitis B
- **Creation of genetically modified foods such as soybean, corn, canola and cotton seed oil.** GM foods have higher resistance to pests, bacterial/fungal infections, higher yield and higher nutritional value
- **Gene therapy using viruses to treat severe combined immunodeficiency (SCID)**
- Using genetically modified virus to construct environment friendly lithium-ion battery
- Using human eggs from a second mother to allow infertile women with genetic defects in their mitochondria to have children
- **Artificial DNA, called Synthetic Organism (SO-1), with unknown functions has been created**

Milestones in genetic engineering

- **1953: James Watson (USA) and Francis Crick (Britain) discover structure of DNA. They win Nobel in Physiology or Medicine in 1979**
- 1973: Stanley Cohen (USA) and Herbert Boyer (USA) develop a technique to clone segments of DNA molecules
- 1976: Genentech, the first company dedicated to producing genetically engineered products is established in San Francisco. It was founded by Herbert Boyer and Robert Swanson
- **1979: Genetic engineering used to synthesize insulin**
- 1981: scientists at Ohio university transfer genes from other organisms into mice
- 1990: Human Genome Project launched

- **1990: first gene therapy experiment performed on a four-year old girl with adenosine deaminase deficiency. Developed by French Anderson**
- 1996: a yeast known as *Saccharomyces cerevisiae* is the first eukaryotic genome to be sequenced by more than 100 labs collaboratively around the world
- **2003: Human Genome Project announces complete mapping of human genome**

GENETICALLY MODIFIED FOODS

1. **BT-Cotton**
    1. **BT-Cotton is a genetically modified variety of cotton into which *Cryiae gene*from the *bacillus thuriegenois* bacteria have been introduced**
    2. This gene produces a toxin called BT-Toxin in every part of the plant thereby destroying the dreaded cotton pest Bollworm
    3. This technology was developed by US seed company Monsanto
    4. However, concerns include evolution of super-pests with higher levels of resistance, destruction of agriculturally beneficial organisms like bees, soil microflora etc
2. **Terminator gene**
    1. Terminator gene is a seed variety developed using genetic engineering
    2. **It causes the seed to self-destruct after it has been used to raise the first generation of crops**
    3. This is done in order to prevent farmers from raising subsequent generations of crops without paying royalties
    4. Concerns include this self-destruct gene may be transferred to other plants by cross-pollination leading to extinction of traditional agricultural production
    5. **It is also known as Genetic Use Restriction Technology (GURT) and was developed by the US Department of**

Agriculture in conjunction with the Delta and Pine Land Co.

3. **Golden rice**
    1. Type of rice crop provided with a gene to develop Beta-Carotene
    2. This helps production of vitamin A in the body
    3. **This helps fight vitamin A deficiency, the primary cause of childhood blindness**
    4. Beta-carotene gives rice a yellow colour and hence is called Golden Rice
    5. **Created by Swiss Federal Institute of Technology**
4. **GM Cabbage**
    1. Cabbage that will resistant to attack of Diamond Back Moth
    2. **Developed by Indian Agricultural Research Institute (New Delhi)**

PHYSICS: NUCLEAR PHYSICS

Nuclear Fission

- Nuclear fission is a reaction in which the nucleus of an atom splits into smaller parts
- Nuclear fission can either release energy or absorb energy: **for nuclei lighter than iron fission absorbs energy, while for nuclei heavier than iron it releases energy**
- Energy released can be in the form of electromagnetic radiation or kinetic energy
- The amount of free energy contained in nuclear fuel is about a million times that contained in a similar mass of chemical fuel (like petrol)
- The atom bomb or fission bomb is based on nuclear fission
- Example: fission of Uranium-235 to give Barium, Krypton and neutrons

Nuclear Fusion

- Nuclear fusion is the process by which multiple nuclei join together to form a heavier nucleus
- Nuclear fusion can result in either the release or absorption of energy: **for nuclei lighter than iron fusion releases energy, while for nuclei heavier than iron it absorbs energy**
- Nuclear fusion is the source of energy of stars.
- Nuclear fusion is responsible for the production of all but the lightest elements in the universe. **This process is called nucleosynthesis**
- Controlled nuclear fusion can result in a thermonuclear explosion – the concept behind the hydrogen bomb
- The energy density of nuclear fusion is much greater than that of nuclear fission
- **Only direct conversion of mass into energy (collision of matter and anti matter) is more energetic than nuclear fusion**
- Example: fusion of hydrogen nuclei to form helium

PIONEERS OF NUCLEAR PHYSICS RESEARCH

Scientist	Nationality	Discovery	Recognition
J J Thomson	Britain	Electron (1897)	Nobel in Physics (1906)
Henri Becquerel	Belgium	Radioactivity (1896)	Nobel in Physics (1903)
Ernest Rutherford	New Zealand	Structure of atom (1907)	Nobel in Chemistry (1908) He is regarded as the father of nuclear physics
Franco Rasetti	Italy/USA	Nuclear spin (1929)	
James Chadwick	Britain	Neutron (1932)	Nobel in Physics (1935)
Enrico Fermi	Italy/USA	Nuclear chain reaction (1942) Neutron irradiation	Nobel in Physics (1938)
Hideki Yukawa	Japan	Strong nuclear force (1935)	Nobel in Physics (1949)
Hans Bethe	Germany/USA	Nuclear fusion (1939)	Nobel in Physics (1967)

APPLICATIONS OF NUCLEAR PHYSICS

Application	Developed by	Working principle	Use
Nuclear power	Enrico Fermi (Italy, 1934)	Nuclear fission	Power generation
Nuclear weapons	Enrico Fermi (Italy, 1934) Edward Teller (USA, 1952)	Nuclear fission Nuclear fusion	Weapons
Radioactive pharmaceuticals	Sam Seidlin (USA, 1946)	Radioactive decay	Cancer, endocrine tumours, bone treatment
Medical imaging	David Kuhl, Roy Edwards (USA, 1950s)	Nuclear magnetic resonance (for MRI) Positron emission (for PET)	MRI: Musculosketal, cardiovascular, brain, cancer imaging PET: cancer, brain diseases

			imaging
Radiocarbon dating	Willard Libby (USA, 1949)	Radioactive decay of carbon-14	Archaeology

IMPORTANT NUCLEAR RESEARCH FACILITIES

Nuclear research facilities in the world

Facility	Location	Established	Famous for
Brookhaven National Lab	New York	1947	Until 2008 world's largest heavy-ion collider
European Organization for Nuclear Research (CERN)	**Geneva**	**1954**	**World's largest particle physics lab** **Birthplace of the World Wide Web** **Large Hadron Collider (LHC)**
Fermilab	Chicago	1967	Tevatron – world's second largest particle accelerator
ISIS	Oxfordshire (England)	1985	Neutron research
Joint Institute for Nuclear Research	Dubna, Russia	1956	Collaboration of 18 nations including former Soviet states, China, Cuba
Lawrence Berkeley National Lab	California	1931	Discovery of multiple elements including astatine, and plutonium
Lawrence Livermore National Lab	California	1952	
Los Alamos National Lab	**New Mexico, USA**	**1943**	**The Manhattan Project**
National Superconducting Cyclotron lab	Michigan	1963	Rare isotope research
Oak Ridge National Lab	**Tennessee**	**1943**	**World's fastest supercomputer**

"क्या पढ़ना है क्या छोड़ना है, सफलता के लिए अभ्यर्थी / प्रतिभागी को यह जानना आना चाहिए"

– Jaguar

Sudbury Neutrino Lab	Ontario	1999	Located 2 km underground Studies solar neutrinos
TRIUMF (Tri University Meson Facility)	**Vancouver**	**1974**	**World's largest cyclotron**
Yongbyon Nuclear Scientific Research Centre	Yongbyon, North Korea	1980	North Korea's main nuclear facility
Sandia National Lab	New Mexico, USA	1948	Z Machine (largest X-ray generator in the world)
Institute of Nuclear Medicine, Oncology and Radiotherapy (INOR)	Abbottabad, NWFP (Pakistan)		
Pakistan Institute of Nuclear Science and Technology (PINSTECH)	Islamabad	1965	

Nuclear research facilities in India

Facility	Location	Established	Famous for
Bhabha Atomic Research Centre	Bombay	1954	India's primary nuclear research centre India's first reactor Apsara
Variable Energy Cyclotron Centre (VECC)	Calcutta	1977	First cyclotron in India
Institute for Plasma Research (IPR)	Gandhinagar	1982	Plasma physics
Indira Gandhi Centre for Atomic Research (IGCAR)	Kalpakkam	1971	Fast breeder test reactor (FBTR) KAMINI (Kalapakkam Mini) light water reactor Built the reactor for Advanced Technology Vessel (ATV)

Saha Institute for Nuclear Physics	Calcutta	1949
Tata Institute for Fundamental Research (TIFR)	Bombay	1945

CHEMISTRY: POLYMERS

Overview

- A polymer is a large molecule consisting of repeating structural units
- The repeating units are usually connected by covalent chemical bonds
- Polymers can be of two types
    - Natural polymers: shellac, amber, rubber, proteins etc
    - Synthetic polymers: nylon, polyethylene, neoprene, synthetic rubber etc
- Synthetic polymers are commonly referred to as plastics
- **The first plastic based on a synthetic polymer to be created was Bakelite,** by Leo Baekeland(Belgium/USA) in 1906
- **Vulcanization of rubber was invented by Charles Goodyear (USA) in 1839.**Vulcanization is the process of making rubber more durable by addition of sulphur
- **The first plastic to be created was Parkesine** (aka celluloid) invented by Alexander Parkes (England) in 1855

Synthesis of polymers

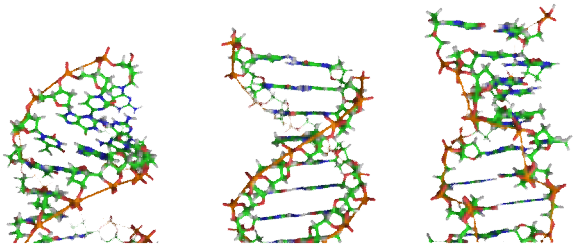
- The synthesis of polymers – both natural and synthetic – involves the step called polymerization
- Polymerization is the process of combining many small molecules (monomers) into a covalently bonded chain (polymer)
- Synthetic polymers are created using of two techniques
    - **Step growth polymerization**: chains of monomers are combined directly
    - **Chain growth polymerization**: monomers are added to the chain one at a time

- Natural polymers are usually created by **enzyme-mediated processes**, such as the synthesis of proteins from amino acids using DNA and RNA

Categories of polymers

- **Organic polymers** are polymers that are based on the element carbon. Eg: polyethylene, cellulose etc
- **Inorganic polymers** are polymers that are not based on carbon. Eg: silicone, which uses silicon and oxygen
- **Copolymer** is one that is derived from two or more monomeric units. Eg: ABS plastic
- **Fluoropolymers** are polymers based on fluorocarbons. They have high resistance to solvents, acids and bases. Eg: teflon

TYPES OF BIOPOLYMERS



DNA as a biopolymer

1. **Structural proteins**
    1. Structural proteins are proteins that provide structural support to tissues
    2. They are usually used to construct connective tissues, tendons, bone matrix, muscle fibre
    3. Examples include collagen, keratin, elastin
2. **Functional proteins**
    1. Proteins that perform a chemical function in organisms

2. Usually used for initiate or sustain chemical reactions
3. Examples include hormones, enzymes

3. **Structural polysaccharides**
    1. They are carbohydrates that provide structural support to cells and tissues
    2. Examples include cellulose, chitin
4. **Storage polysaccharides**
    1. Carbohydrates that are used for storing energy
    2. Eg: starch, glycogen
5. **Nucleic acids**
    1. Nucleic acids are macromolecules composed of chains of nucleotides
    2. Nucleic acids are universal in living beings, as they are found in all plant and animal cells
    3. Eg: DNA, RNA

TYPES OF SYNTHETIC POLYMERS

1. **Thermoplastics**
    1. Thermoplastics are plastics that turn into liquids upon heating
    2. Also known as thermosoftening plastic
    3. **Thermoplastics can be remelted and remoulded**
    4. Eg: polyethylene, Teflon, nylon
    5. **Recyclable bottles (such as Coke/Pepsi) are made from thermoplastics**
2. **Thermosetting plastics**
    1. Thermosettings plastics are plastics that do not turn into liquid upon heating
    2. **Thermosetting plastics, once cured, cannot be remoulded**
    3. They are stronger, more suitable for high-temperature applications, but cannot be easily recycled
    4. Eg: vulcanized rubber, bakelite, Kevlar
3. **Elastomers**
    1. Elastomers are polymers that are elastic
    2. Elastomers are relatively soft and deformable
    3. Eg: natural rubber, synthetic polyisoprene

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IMPORTANT NATURAL POLYMERS AND THEIR APPLICATIONS

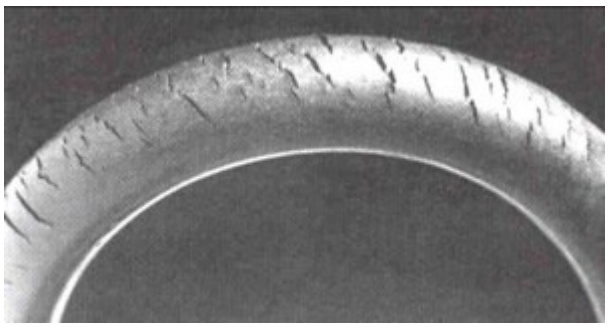
Polymer	Application	Notes
Collagen	Connective tissue Gelatine (food)	Most abundant protein in mammals
Keratin	Hair, nails, claw etc	
Enzymes	Catalysis	
Hormones	Cell signalling	
Cellulose	Cell wall of plants Cardboard, paper	Most common organic compound on Earth
Chitin	Cell wall of fungi, insects	
Starch	Energy storage in plants	Most important carbohydrate in human diet
Glycogen	Energy storage in animals	
DNA	Genetic information	
RNA	Protein synthesis	

IMPORTANT SYNTHETIC POLYMERS AND THEIR APPLICATIONS

Polymer	Developed by	Constituent elements	Application	Notes
Parkesine	Alexander Parkes (Britain, 1855)	Cellulose	Plastic moulding	First man-made polymer
Bakelite	Leo Baekeland (USA, 1906)	Phenol and formaldehyde	Radios, telephones, clocks	First polymer made completely synthetically
Polyvinylchloride (PVC)	Henri Regnault (France, 1835)	Vinyl groups and chlorine	Construction material	Third most widely used plastic

Styrofoam	Ray McIntre (USA, 1941)	Phenyl group	Thermal insulation	Brand name for polystyrene
Nylon	Wallace Carothers (USA, 1935)	Amides	Fabric, toothbrush, rope etc	Family of polyamides First commercially successful synthetic polymer
Synthetic rubber	Fritz Hoffman (Germany, 1909)	Isoprene	Tyres, textile printing, rocket fuel	
Vulcanized rubber	Charles Goodyear (USA, 1839)	Rubber, sulphur	Tyres	Vulcanized rubber is much stronger than natural rubber
Polypropylene	Karl Rehn and Guilio Natta (Italy, 1954)	Propene	Textiles, stationary, automotive components	Second most widely used synthetic polymer
Polyethylene	Hans von Pechmann (Germany, 1898)	Ethylene	Packaging (shopping bags)	Most widely used synthetic polymer
Teflon	Roy Plunkett (USA, 1938)	Ethylene	Cookware, construction, lubricant	Brand name for polytetrafluoroehtylene (PTFE) Very low friction, non-reactive

DEGRADATION OF POLYMERS



Ozone cracking in natural rubber tubing

- Degradation of polymers can be desirable as well undesirable: desirable when looking for biological degradation, undesirable when faced with loss of strength, colour etc
- Polymer degradation usually occurs due to hydrolysis of covalent bonds connecting the polymer chain
- Polymer degradation can happen because of heat, light, chemicals and galvanic action
- **Ozone cracking is the cracking effect of ozone on rubber products such as tyres, seals, fuel lines etc.** Usually prevented by adding antiozonants to the rubber before vulcanization
- Chlorine can cause degradation of plastic as well, especially plumbing
- **Resin Identification Code is the system of labelling plastic bottles on the basis of their constituent polymers.** This Code helps in the sorting and recycling of plastic bottles
- Degradation of plastics can take hundreds to thousands of years

Biodegradable plastics

- Biodegradable plastics are plastics than can break down upon exposure to sunlight (especially UV), water, bacteria etc
- Biopol is a biodegradable polymer synthesized by genetically engineered bacteria
- Ecoflex is a fully biodegradable synthetic polymer for food packaging

Bioplastics

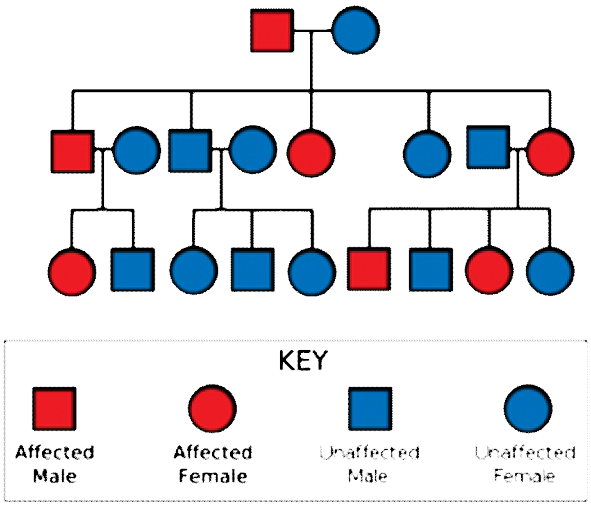
- They are organic plastics derived from renewable biomass sources such as vegetable oil, corn, starch etc

Oxy-biodegradable plastics

- Plastics to which a small amount of metals salts have been added
- As long as the plastic has access to oxygen the metal salts speed up process of degradation
- Degradation process is shortened from hundreds of years to months

BIOLOGY: GENETIC DISORDERS

About genetic disorders



Huntington's disease is inherited in the autosomal dominant fashion

- Genetic disorders are disorders that are passed on from generation to generation
- They are caused by abnormalities in genes or chromosomes

- Some genetic disorders may also be influenced by non-genetic environmental factors. Eg: cancer
- Most genetic disorders are relatively rare and only affect one person in thousands or millions
- To recollect, males have XY chromosome pairs while females have XX pairs

Single Gene Disorders

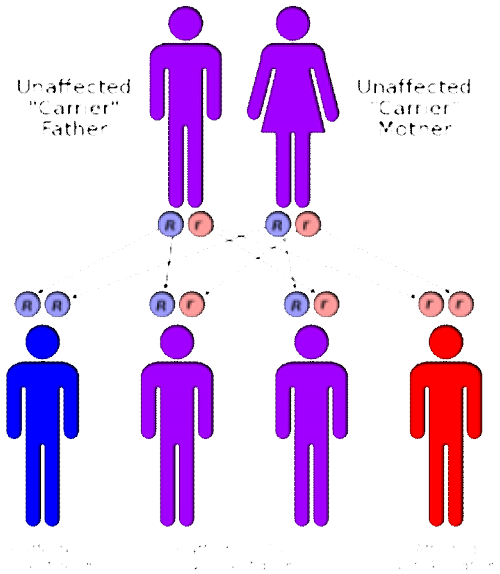
- Single gene disorders result from the mutation of a single gene
- They can be passed onto subsequent generations in multiple ways
- Single gene disorders include sickle cell disease, cystic fibrosis Huntington disease

Multiple gene disorders

- Multiple gene disorders result from mutation on multiple genes in combination with environmental factors
- They do not have a clear pattern of inheritance, which makes it difficult to assess risk of inheriting a particular disease
- Examples include heart disease, diabetes, hypertension, obesity, autism

TYPES OF SINGLE GENE GENETIC DISORDERS

1. **Autosomal dominant**



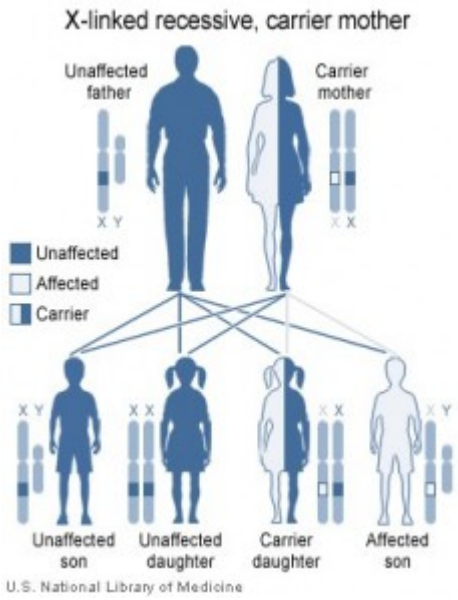
Sickle cell disease is inherited in the autosomal recessive pattern

1. **Only one mutated copy of the gene is necessary for inheritance of the mutation**
2. Each affected person usually has one affected parent
3. **There is a 50% chance that the child will inherit the mutated gene**
4. Autosomal dominant disorders usually have low penetrance i.e. although only one mutated copy is needed, only a small portion of those who inherit that mutation will develop the disorder
5. **Eg: Huntington's disease, Marfan syndrome**

2. **Autosomal recessive**
    1. **Two copies of the gene must be mutated for a person to be affected**
    2. An affected person usually has unaffected parents who each have one mutated gene
    3. **There is a 25% chance that the child will inherit the mutated gene**
    4. **Eg: Cystic fibrosis, sickle cell disease, Tay-Sachs disease, dry earwax, Niemann-Pick disease**
3. **X-linked dominant**

1. X-linked dominant disorders are caused by mutations on the X chromosome
2. Males and females are both affected by such disorders. However, males are affected more severely
3. **For a man with a X-linked dominant disorder, his sons will all be unaffected**(since they receive their father's Y chromosome) **while his daughters will all be affected** (since they receive his X chromosome)
4. **A woman with a X-linked dominant disorder has a 50% chance of passing it on to progeny**
5. **Eg: Hypophosphatemic rickets, Rett syndrome, Aicardi syndrome**

4. **X-linked recessive**



X-linked recessive with a carrier mother

1. Caused by mutations on the X-chromosome
2. Males are affected more frequently than females
3. **The sons of a man affected by a X-linked recessive disorder will not be affected, while his daughters will carry one copy of the mutated gene**
4. **The sons of a woman affected by a X-linked recessive disorder will have have a 50% chance of being affected by**

the disorder, while the daughters of the woman have a 50% chance of becoming carriers of the disorder

5. **Eg: colour blindness, muscular dystrophy, hemophilia A**

5. **Y-linked disorders**
    1. Caused by mutations on the Y chromosome
    2. **Y chromosomes are present only in males**
    3. **The sons of a man with Y-linked disorders will inherit his Y chromosome and will always be affected while the daughters will inherit his X chromosome and will never be affected**
    4. **Eg: male infertility**
6. **Mitochondrial disorders**
    1. These disorders are caused by mutations in the mitochondrial DNA
    2. **Only mothers can pass on mitochondrial disorders to children,** since only egg cells (from the mother) contribute mitochondria to the developing embryo
    3. **Eg: Leber's Heriditary Optic Neuropathy**

PHYSICS: WAVES

Overview

- A wave is a disturbance that travels across space and time
- Propagation of waves usually involves transference of energy without transferring mass. This is achieved by oscillations or vibrations around fixed locations
- Mechanical waves require a medium for transmission (e.g. sound)
- Electromagnetic waves do not require a medium and can travel in vacuum (e.g. light)
- Longitudinal waves are those with vibrations parallel to the direction of wave propagation. E.g. sound waves
- Transverse waves are those with vibrations perpendicular to the direction of travel. E.g. electromagnetic waves including light
- **Waves on a string are an example of transverse waves**

Properties of waves

1. **Reflection**: It is the change in direction of a wave at the interface between two media. Examples include reflection of light, sound etc
2. **Refraction**: It is the change in direction of a wave due to a change in its speed. Examples: refraction of light when it passes through a lens
3. **Diffraction**: Bending of waves as they interact with obstacles in their path. Example: rainbow pattern when light falls on a CD or DVD
4. **Interference**: Superposition of two waves that come into contact
5. **Dispersion**: the splitting up of waves by frequency
6. **Polarization**: the oscillation of a wave in only one direction. Exhibited only by transverse waves (like light), not exhibited by longitudinal waves (like sound)

Wave properties in everyday life

- The floor of a lake or the ocean appears closer than it actually is. This is because of refraction of light
- The red ring around the Sun is due to diffraction of light
- **We can hear but not see across corners, this is because of diffraction of sound**(e.g. we can hear but not see a person in the next room)
- **The rainbow and the blue colour of sky are both due to dispersion of light**
- Sunglasses use polarization filters to block glare

SOUND WAVES

About Sound

- Sound is a mechanical wave that is transmitted as longitudinal waves through gases, plasma and liquids. However, in solids it can travel as both longitudinal and transverse waves

- **Sound cannot travel in vacuum, it needs a medium for propagation**
- The speed of sound in air is 330 m/s

Perception of sound

- The frequency range 20 Hz to 20 MHz is known as the audible range, where human beings can detect sound waves
- The upper frequency limit decreases with age i.e. as we get older, our ability to detect higher pitches (shrills) decreases
- Other species uses different ranges for hearing. E.g. dogs can perceive frequencies higher than 20 KHz
- Increased levels of sound intensity can cause hearing damage. Hearing can be damaged by sustained exposure to 85 dB or by short term exposure to 120 dB sound. A rocket launch usually involves about 165 dB

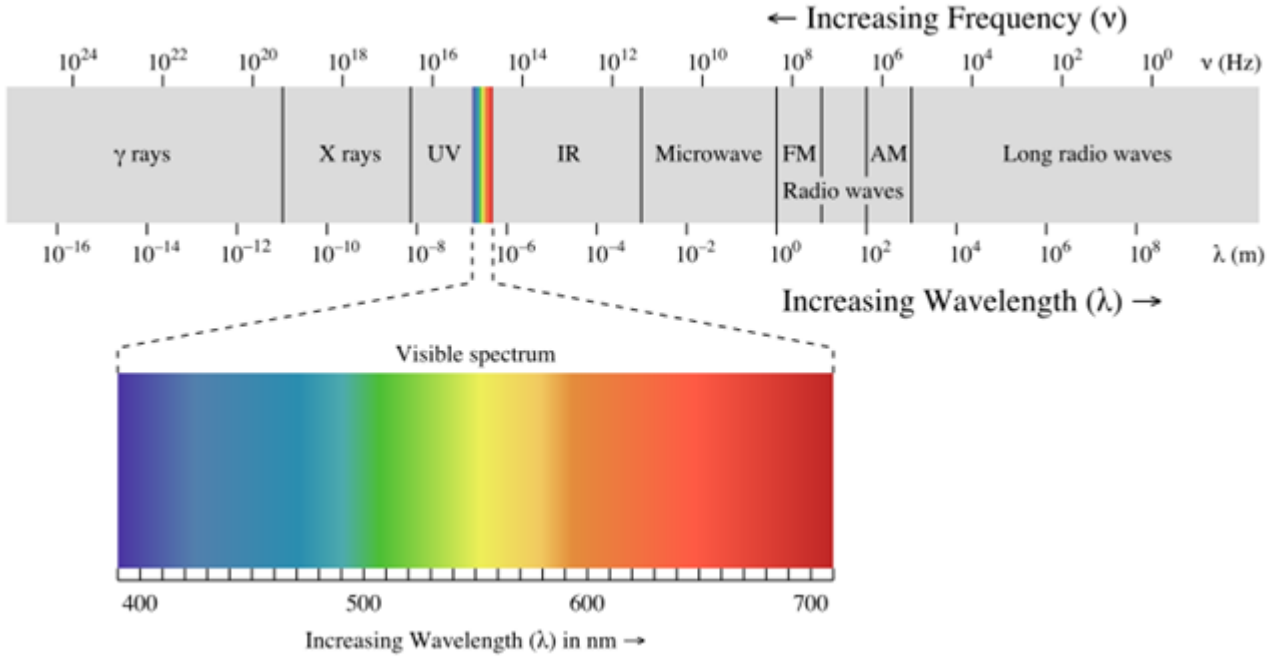
Sonar systems

- Sound Navigation and Ranging is a technology that uses sound propagation for navigation and communication
- Primarily used under water because light attenuates very quickly in water whereas sound travels farther
- First developed by R.W. Boyle and A.B. Wood in 1917 in Britain
- Applications include military, fisheries, wave measurement, ocean-floor mapping etc
- Sonar is used by marine mammals (like dolphins and whales) for communication as well
- **Bats communicate by means of SONAR at frequencies over 100 MHz (beyond the human range)**

ELECTROMAGNETIC WAVES

Electromagnetic Spectrum

"क्या पढ़ना है क्या छोड़ना है, सफलता के लिए अभ्यर्थी / प्रतिभागी को यह जानना आना चाहिए"



Electromagnetic radiation and applications

Radiation	Applications
Radio waves	RADAR, TV, cell phones, microwaves
Microwaves	Wi-Fi
Infrared (IR)	Night vision, thermography, imaging
Visible light	Sight
Ultraviolet (UV)	Sun burn, water disinfection
X-rays	Astronomy, medicine
Gamma rays	PET scans, cancer therapy, astronomy, food sterilization

Radar systems:

- Radio Detection and Ranging is a technology that uses radio waves to identify moving and fixed objects
- Developed by Robert Watson-Watt in 1935 in Britain
- Radar works by measuring the waves that are reflected back from an object. Radar can detect objects at ranges where sound or visible light would be too weak
- Applications include aircraft detection, air traffic control, highway speed detection, weather detection etc

More about electromagnetic waves

- Radio waves are reflected by the ionosphere and hence can be received anywhere on the earth.
- TV transmission penetrates the ionosphere and hence is not received like radio waves. Thus TV transmission is limited to line-of-sight
- At night, the radio reception improves because the ionosphere is not exposed to sunlight and hence is more settled
- Bats communicate by means of SONAR at frequencies over 100 MHz (beyond the human range). Other animals like dolphins and whales use SONAR as well

CHEMISTRY: RADIOACTIVITY

About radioactivity

- It is the process by which an unstable atomic nucleus spontaneously decays (loses energy) by emitting ionizing particles and radiation
- This decay results in the atom of one type (parent nuclide) transforming into an atom of a different type (daughter nuclide)
- Eg: Carbon-14 emits radiation and transforms into nitrogen-14
- **The SI unit of radioactivity is Becquerel (Bq).** Another commonly used unit is the Curie (Ci)

- **Radioactivity of a material is quantified by its half life.** This is the time taken for a given amount of a radioactive material to decay to half its initial value
- **Radiation can be measured using scintillation counters and Geiger counters**

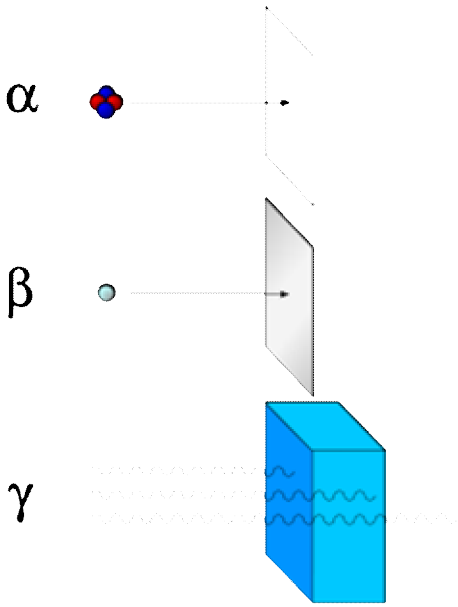
History of radioactivity research

- **Radioactivity was first discovered by French scientist Henri Becquerel in 1896**
- Research in radioactivity of uranium led Marie Curie to isolate a new element Polonium and to separate Radium from Barium
- The dangers of radioactivity was discovered by Nikola Tesla in 1896, when he intentionally subjected his fingers to X-rays
- **Henri Joseph Muller was awarded the Nobel Prize in Physiology or Medicine in 1946 for his discovery (in 1927) of the harmful genetic effects of radiation**

Transmutation of elements

- **Isotopes:** they are atoms of an element with the same atomic number but different mass number (eg uranium-238 and uranium-235)
- **Isobars:** elements with same mass number but different atomic number. Usually occurs when a radioactive nucleus loses a beta particle (eg. Thorium-234 and palladium-234)
- **Isotones:** radioactive nuclei that contain the same number of neutrons (eg. Radium-226 and Actium-227)
- **Isomers:** are different excitation states of nuclei. The higher-energy (unstable) element undergoes isomeric transition to form the less energetic variant without change in atomic or mass number

Types of radioactive decay



Alpha rays can be stopped by a sheet of paper, beta rays by aluminium shielding, while gamma rays can only be reduced by a thick layer of lead

- Radioactive radiation can be split into three types of beams
- **Alpha rays:** they are helium particles that carry a positive charge. They have low energy and can be stopped by a sheet of paper
- **Beta rays:** they are streams of electrons and carry negative charge. They have higher energy than alpha rays
- **Gamma rays:** they are high energy rays (like X-rays) that carry no electrical charge

Radioactivity and the Big Bang theory

- According to the Big Bang theory stable isotopes of the lightest elements (H, He, Li, Be, B) were formed immediately after the Big Bang
- Radioactive (unstable) isotopes of these light elements have long since decayed, and isotopes of elements heavier than boron were not produce at all in the Big Bang
- **Thus, the radioactive materials currently in the universe were formed later and are relatively young compared to the age of the universe**

- These radioactive nuclei were formed in nucleosynthesis in stars and during interactions between stable isotopes and energetic particles
- **For instance, carbon-14 is constantly produced in the earth's upper atmosphere due to interactions between cosmic rays and nitrogen**

Applications of radioactivity

- **Radioisotopic labeling**: used to track the passage of a chemical through the human body. Some common radio isotopes used for labeling are
  - Tritium: used to label proteins, nucleic acids
  - Sodium-22 and Sodium-36: ion transporters
  - Sulphur-35: proteins and nucleic acids
  - **Phosporous-32 and Phosphorous-33: nucleotides (like DNA)**
  - Iodine-125: thyroxine
  - Carbon-14 is not used for radioactive labeling due to its long half life (5730 years)
- **Random number generators:** based on the premise that radioactive decay is truly random
- **Radiometric dating:** used to date materials based on a comparison between observed abundance of radioactive isotopes and its decay products, using known decay rates. The most common methods of radiometric dating are
  - Carbon dating: when organic matter grows, it traps carbon-14. The age of the organic matter can be estimated by measuring the amount carbon-14 remaining in the body. Used for dating material up to 60,000 years old
  - Potassium-argon dating: used in geochronology and archeology, especially for dating volcanic material. Used for samples older than a few thousand years
  - Uranium-lead: one of the oldest and most refined radiometric dating techniques. Used in geochronology to estimate material from 1 million to 4.5 billion years old.**A variant, the lead-lead dating scheme was used by American scientist Clair Cameron**

Patterson to estimate the age of the earth (4.55 billion years) in 1953

Radioactive therapy

- Used for palliative and therapeutic treatment
- Common applications include treatment of thyroid eye disease, heterotopic ossification, trigeminal neuralgia
- In low doses, it is used for cancer treatment. However, in large doses, it can cause cancer
- Total body irradiation is used to prepare the body to receive a bone marrow transplant

Radiation poisoning

- It is a form of damage to organ tissue due to excessive exposure to ionizing radiation
- Caused by exposure to large doses of radiation in short periods of time, or by exposure to small doses over long periods
- Increases the probability of contracting other diseases like cancers, tumours and genetic damage
- Common symptoms are nausea and vomiting
- Common occurrances of radiation poisoning include nuclear warfare, nuclear reactor accidents, spaceflight (exposure to cosmic rays), ingestion and inhalation of radioactive compounds (such as strontium in cow's milk)
    - In Nov 2006, Russian dissident died due to suspected deliberate ingestion of Polonium-210

BIOLOGY: BIOMOLECULES

1. **Lipids**
    - They are a broad group of molecules that include fats, fatty acids, sterol, waxes, glycerides and phospholipids
    - Fats are a subgroup of lipids called triglycerides

- Cholesterol is an example of the type of lipids called sterol
- **The main functions of lipids include energy storage, cell signaling and cell structure**

2. **Carbohydrates**
   - They are organic compounds that contain only carbon, hydrogen and oxygen
   - They belong to 3 types: monosaccharides, disaccharides and polysaccharides
   - **Monosaccharides**
     - Monosaccharides are the simplest form of carbohydrates, and cannot be broken down any further.
     - Eg: glucose and fructose
     - Monosaccharides dissolve in water, taste sweet and are called "sugars"
     - **Used as energy source and in biosynthesis**
   - **Disaccharides**
     - Disaccharides are compounds made by two monosaccharides bound together.
     - Eg: sucrose and lactose
     - Like monosaccharides, disaccharides dissolve in water, taste sweet and are called "sugars"
     - Used for carbohydrate transport
   - **Polysaccharides**
     - Polysaccharides are compounds made by complex chains of monosaccharides.
     - Eg: cellulose, glycogen
     - **Used for energy storage (glycogen) and for cell walls (cellulose)**
     - **Cellulose is the most abundant organic molecule on Earth**

3. **Amino acids**
   - They are molecules that contain an amine group and a carboxyl group
   - Eg: glycine, monosodium glutamate
   - **They are the building blocks of proteins**
   - Applications include metabolism, drug therapy, flavour enhancement, manufacture of biodegradble plastics

4. **Proteins**
    - They are compounds made from amino acids
    - **The first protein to be sequenced was insulin, by Frederick Sanger who won the Nobel Prize in Chemistry for this in 1958**
    - **The first protein structures to be solved were hemoglobin and myoglobin by Max Perutz and Sir John Cowdrey Kendrew in 1958.** They won the Nobel Prize in Chemistry for this achievement in 1962
    - Proteins are used as enzymes, in muscle formation, as cell cytoskeleton, cell signaling and immune responses
    - The process of digestion breaks down protein into free amino acids that are then used in metabolism
5. **Nucleic acids**
    - They are macromolecules formed by chains of nucleotides
    - Common examples include DNA and RNA
    - **DNA (Deoxyribonucleic acid)**
        - Contains two strands of nucleotides arranged in a double helix structure
        - In cells, DNA is organized into long structures called chromosomes
        - Used primarliy for long term storage of genetic information
        - **DNA was first isolated by Swiss physician Friedrich Miescher in 1869**
        - **The double helix structure was suggested by James Watson and Francis Crick in 1953.** They, alongwith Maurice Wilkins won the Nobel Prize in Physiology or Medicine for this discovery in 1962
    - **RNA (ribonucleic acid)**
        - Contains one strand of nucleic acids
        - Less stable than DNA
        - Used primarily for protein synthesis
        - Messenger RNA carries information from DNA to the ribosome. Translation RNA translates the information in the mRNA

- **RNA synthesis was discovered by Severo Ochoa of Spain, for which he won the Nobel Prize in Physiology or Medicine in 1959**

Matching cell functions to biomolecules

Function	Biomolecule
Cell structure	Lipid
Impact protection	Lipids and proteins
Enzymes	Proteins
Energy storage	Carbohydrates, proteins, lipids
Cell movement and support	Proteins (actin and myosin)
Protein synthesis	Nucleic acids (RNA)
Hormones	Proteins
Immediate cellular energy	Carbohydrates (glucose)
Electrical and thermal insulation	Lipids
Storage of amino acids	Proteins
Genetic information	Nucleic acids (DNA)

PHYSICS: HEAT

Overview

- Heat is the process of energy transfer from one system to another
- **Units of heat: Joules (J), Calories, British Thermal Unit (BTU)**
- Temperature is a measure of internal energy (enthalpy)
- **Heat transfer can happen spontaneously only from a warmer to a colder body.**Reverse heat transfer can only happen with the aid of an external source such as a heat pump.

Mechanisms of heat transfer

- **Conduction is the most significant heat transfer mechanism in solids.** It occurs as hot high energy molecules interact with neighbouring and transfer heat to them. Eg: heat transfer from one end of a metal rod to another
- **Convection is most significant in liquids and gases.** This happens when hot molecules move and transfer energy to other molecules. Eg: boiling of water. When water is heated on a stove, hot water from the bottom rises and displaces colder liquid which falls.
- **Radiation is the only form of heat transfer possible in the absence of a medium.**Heat is transferred in the form of electromagnetic radiation. Eg: heat from the sun reaching the earth.

Heat transfer in everyday life

- Copper is used in construction of boilers and cooking utensils because it is a good conductor of heat
- Air is a poor conductor
- Wool and cotton are good insulators i.e. poor conductors. Their insulation arises mainly due to air spaces between molecules
- Double-walled glass doors with air between them are better insulators than windows with a single thick glass layers
- **Eskimos live in snow huts because snow is a poor conductor of heat**, and hence protects them from the extreme cold outside.
- Land and sea breeze, ocean currents are arise due to convection
- The boiling point of water at sea level and atmospheric pressure is 100C. When extra heat is added, it **changes the phase** of water from liquid to gas (water vapour).

Thermometers

- Thermometers can be divided into two groups:
    - **Primary thermometers:** measure temperature directly based on the property of matter. They are relatively complex and not used commonly. Eg: thermometers based on velocity of sound in gas, thermal noise of an electrical resistor etc.

    - **Secondary thermometers:** measure temperature relative to a pre-calibrated quantity. They are easy to use and used commonly. **Alcohol thermometer, mercury thermometer, medical thermometer are all secondary thermometers**
- **In cold winter places, alcohol thermometers are used instead of mercury thermometers because the freezing point of alcohol is lower**
- For extra-low temperature measurements (-200 C), Pentane is used
- Water is not suitable for use in thermometers because it freezes at 0 C and has irregular expansion
- **Mercury is used for common medical thermometers because**
    - It does not cling to glass and hence reading is easy
    - It is opaque and easily seen
    - Its expansion is uniform and hence calibration is easier
    - It is a better conductor of heat than alcohol and hence responds more rapidly to changes of temperature
    - It has low specific heat capacity and hence is more sensitive

Common appliances based on heat

- **Solar cooker:** is a box made of insulating material such as wood, cardboard etc. The box has a glass cover to retain heat inside by greenhouse effect. The inside of the box is painted black to increase heat absorption.
- **Pressure cooker:** Pressure cooker increases the boiling point of water by increasing pressure. When the boiling point of water increases, food cooks faster. Pressure cookers are especially essential in hill stations because at higher altitudes the boiling point of water decreases due to lower atmospheric pressure
- **Refrigerator and Air-conditioner:** are heat pumps that transfer heat from inside to the external environment. They use a **refrigerant** which is a compound that undergoes reversible phase change from gas to liquid. Common refrigerants include ammonia, sulphur dioxide, carbon dioxide and methane. The use of chlorofluorocarbons has been phased out due to concerns regarding depletion of the ozone layer.

CHEMISTRY: ELECTROLYTES

Electrolytes in the human body

- **Electrolytes are required in the body to maintain balance between intracellular and extracellular liquids.** In particular, it is important to maintain the osmotic gradient between inside and outside.
- Electrolyte balance is maintained by oral and intravenous intake
- Kidneys flush out excess electrolytes
- Dehydration and overhydration are caused by electrolyte imbalance
- Hormones that maintain electrolyte balance are antidiuretic hormone, aldosterone and parathyroid hormone
- **The most common electrolyte in the body is salt (sodium chloride)**

Functions of electrolytes in the body

- Maintain blood pH
- Muscle and neuron activation
- Hydration of the body

Other common applications of electrolytes

- Sports drinks
- Batteries
- Fuel cells
- Electroplating
- Capacitors

Sports Drinks

- Sports drinks replenish the body's water and electrolyte levels after dehydration caused by exercise, vomiting, diarrhea etc.
- They are made of electrolytes containing sodium and potassium salts
- Examples of sports drinks: Glucon-D, Gatorade etc
- Simplest electrolyte drink that can be made at home is water + sugar + salt

Batteries

Battery	Electrode	Electrolyte	Other notes
Alkaline	Zinc, Manganese oxide	Potassium Hydroxide	
Daniell cell	Copper, Zinc	Copper sulphate, zinc sulphate	
Leclanche cell	**Zinc, carbon**	**Ammonium chloride**	**Precursor of modern dry cell**
Voltaic pile	Copper, zinc	Brine	First electric battery, invented in 1880
Zinc carbon	**Zinc, carbon, manganese dioxide**	**Zinc chloride, ammonium chloride**	**Most common battery**
Zinc chloride	Same as above	Zinc chloride	Improvement on zinc carbon battery
Lead-acid	Lead, lead dioxide	Sulphuric acid	Oldest rechargeable battery Used in vehicles as they provide high surge currents
Lithium-ion	Graphite, Lithium Cobalt oxide	Non-aqueous lithium salts	Rechargable Slow self-discharge, high energy to weight ratio
Nickel Cadmium	Nickel oxide hydroxide, cadmium		Rechargable Last longer, more stable than lithium ion
Fuel cell	Hydrogen (fuel), oxygen (oxidant)	Polymer membrane Aqueous alkaline solution	Consumes reactant from an external source High energy efficiency and high reliability No moving parts Used in space shuttles, submarines

Common electrolytes and their uses

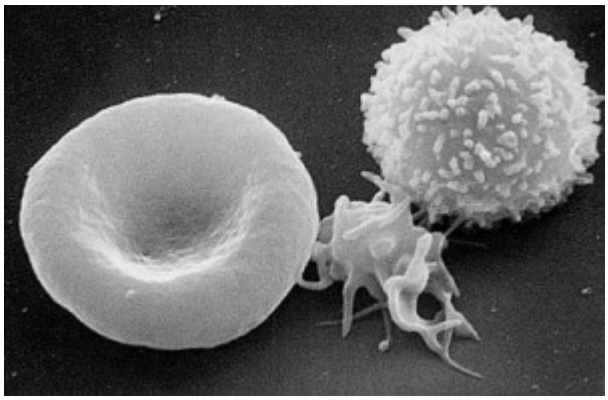
Electrolyte	Uses	Other notes
Sodium chloride	Primary component of extracellular fluid Food preservative	
Sodium hydroxide (caustic soda)	Manufacture of paper, soaps, detergents, drain cleaners Purification of drinking water	
Silver nitrate	Photographic films Water disinfection (esp. on space shuttles)	
Hydrochloric acid	Manufacture of PVC, household cleaners Food additives (like gelatin)	Found naturally in gastric acid

	Leather processing	
Sulphuric acid	Lead-acid batteries Ore processing Fertilizer manufacture	Soluble in water at all concentrations One of the largest products of chemical industry
Nitric acid	Determining metal traces in solutions Wood finishing	Colourless when pure, yellows with age Highly corrosive
Acetic acid	Manufacture of soft drink bottles Photographic films Synthetic fibres and fabrics	Dilute acetic acid is called vinegar
Ammonium hydroxide (aqueous ammonia)	Cleaning agent	
Calcium hydroxide (slaked lime or pickling lime)	Sewage treatment Whitewash, plaster, mortar Hair relaxers	Natural mineral form is called portlandite (rare mineral occurring in volcanic rocks)

BIOLOGY: BLOOD

Overview

- **Blood is a specialized body fluid that delivers necessary substances to various cells (like nutrients and oxygen) and transports waste products away from those cells**
- Blood accounts for 7% of human body weight
- The average human adult has a blood volume of approx. 5 litres
- Arteries carry inhaled oxygen-rich blood from the heart to the tissues, while veins carry carbon dioxide rich blood (de-oxygenated) from the tissues to the lungs to be exhaled



SEM image of a RBC, a platelet and a WBC (L to R)

Composition of blood

- Blood is made of plasma, Red Blood Cells, White Blood Cells (including leukocytes and platelets)
- Plasma constitutes about 54.3% of blood, RBCs 45% and WBCs about 7%
- RBCs contain hemoglobin and distribute oxygen to tissues
- Leukocytes attack and remove pathogens and provide immunity
- Platelets are responsible for clotting of blood
- Plasma is the blood's liquid medium. It circulates dissolved nutrients and removes waste products. By itself, it is yellow in colour

Functions of blood

- Supply oxygen to tissues
- Supply nutrients such as glucose, amino acids and fatty acids
- Remove waste such as carbon dioxide, urea and lactic acid
- Provide immunity against pathogens
- Coagulation
- Transport hormones
- Regulate pH
- Regulate core body temperature

Colour of blood

- Colour is primarily determined by hemoglobin
- Arterial blood is bright red, due to the presence of oxygen
- Venous blood is dark red, due to deoxygenation
- **Blood in carbon monoxide and cyanide poisoning is bright red**
- Blood of most molluscs (marine animals like squids, oysters, snails, octopuses etc) is blue due to the presence of copper containing protein hemocyanin

Blood Groups

Blood Group	Can donate to	Can receive from
A	A and AB	A and O
B	B and AB	B and O
AB	AB only	All groups
O	All groups	O only

Medical disorders related to blood

Disorder	Cause	Other notes
Bleeding		An adult can lose 20% of blood volume before the first symptom (restlessness) sets in
Dehydration	Loss of volume due to loss of water	
Atherosclerosis	Reduced blood flow through arteries	
Thrombosis	Coagulation of blood vessels	
Hypoxia (lack of oxygen)	Narrowing of blood vessels Problem with pumping action of heart	Can lead to ischemia (tissue with insufficient blood) or to infarction i.e. necrosis (tissue death)
Anemia (insufficient RBC)	Bleeding, nutritional deficiencies	
Sickle-cell disease	**Mutation of hemoglobin leading to abnormal sickle shape of RBC**	**Sickle shaped RBCs do not have the flexibility to travel through many blood vessels Extremely painful disease with no known cure Found commonly in malaria-infested areas because sickle cells offer resistance to malaria**
Leukemia	Abnormal proliferation of WBCs in the bone marrow	
Hemophilia	**Dysfunction of clotting mechanism**	**Lack of coagulation means simple wounds become life-threatening Causes hemarthosis (bleeding into joints), which is painful and crippling Linked to X chromosome Occurs usually in males only**
Thrombophilia	Abnormal propensity to coagulate	
Blood-borne infections	Infection by a disease-carrying vector	Examples: HIV, Hepatitis, Malaria
Carbon monoxide poisoning	Carbon monoxide binds to hemoglobin preventing oxygen transport	Body tissues die due to lack of oxygen

PHYSICS

PRESSURE

1. **Units**
   - atmosphere, technical atmosphere
   - mm, cm, inches of mercury

- mm, cm, inch, foot of water
- kip, ton-force, pound-force
- pound per square inch
- bar, decibar, millibar
- barye, dyne
- sthene per square metre, pieze

2. **Pressure in everyday life**
   - **Transpirational pull in plants** (negative pressure caused by surface tension), used to suction water from the water to leaves
   - Casimir effect: physical force betwen two uncharged metal plates in vaccuum. Used in nanotechnology
   - **Atmospheric pressure decreases with elevation.** Due to this boiling point of water decreases with elevation
   - Blood pressure is the pressure exerted by circulating blood on the walls of blood vessels. For a healthy adult human the pressure should be 115 mm Hg (systolic) and 75 mm Hg (diastolic)
   - **A microphone works on the principle of sound pressure.** A thin membrane converts sound pressure into an electrical signal
   - **Caisson Disease (aka The Bends or Decompression Sickness) occurs due to sudden change in atmospheric pressure.** It happens when a person moves from a high pressure environment to a low pressure. Examples include divers returning from depth, workers in caissons during bridge construction, sudden drop in aircraft pressure etc. Can lead to paralysis and death.
   - **Vaccuum** is a volume of space where pressure is less than atmospheric pressure. Examples include vaccuum cleaners, deep space, incandescent light bulb

GRAVITATION

1. **History of gravitational theory**

- 4th century BCE: Aristotle proposed heavy bodies are attracted towards the center of the universe due to an inner *gravitas*
- **628 CE: Brahmagupta recognized a force of attraction**. He followed the Heliocentric solar system and propsed gravitational attraction between the Sun and the Earth
- 1660s: Robert Hooke explains celestial gravity
- 1687: Isaac Newton proposes law of universal gravitation
- 1915: Albert Einstein proposes theory of general relativity

2. **Gravitation in everyday life**
   - Objects falling freely towards the earth's surface have an acceleration due to gravity $g = 9.8 \frac{m}{s^2}$ This is also known as **g-force**
   - **Escape velocity** is the speed needed to break free from a gravitational field. On the surface of the Earth it is 11.2 km/s
   - **Weightlessness** occurs in orbit when all gravitational forces acting on an object are uniformly distributed. Weightlessness does not occur due to an absence of gravity.

CHEMISTRY

CERTAIN COMMON SUBSTANCES

1. **Hydrogen**
   - Has same atomic number and atomic weight: 1
   - **Most abundant element in the universe**
   - Is the lightest element
   - isotopes are Protium, Deutrium, Tritium
   - Heavy water: water which has Deutirum instead of Hydrogen. Obtained by electrolysis of water. **Used as moderator in nuclear reactors**
   - Used to prepare vanaspati by hydrogenation of vegetable oil
2. **Oxygen**
   1. Most abundant element on earth's crust (50% of all elements)
   2. Used for artificial respiration, and along with Nitrogen as an anesthetic
3. **Water**

- About 70% of earth's surface and 65% of body weight
- Hardness of water due to dissolved salts of Calcium and Magnesium
- Temporary hardness due to bicarbonates of Ca and Mg. Can be removed by boiling
- Permanent hardness due to chlorides and sulphates of Ca and Mg. Can not be removed by boiling
- **Rain water is the purest form of water**
- River water is hard water
- Spring water purer than river water
- Sea water is hard water. Contains Sodium Chloride in addition to salts of Ca and Mg
- Mineral water: spring water with minerals and having medicinal value

4. **Nitrogen**
   - Most abundant in atmosphere (78%)
   - Occurs in animals and plants in the form of protein
   - Used to manufacture fertilizers and explosives
   - Liquid nitrogen used in refrigeration
5. **Phosphorus**
   - Found in bones, brain and urine
   - Glows in dark
   - Red phosphorus used to make matches
   - White phosphorus used in smoke screens
6. **Carbon**
   - Second most abundant element in human body after Oxygen
   - Occurs in free state as diamond, coal and graphite
   - **Diamond: purest form of carbon, hardest naturally occurring substance**
   - **Graphite: only non-metal to act as a good conductor of electricity**. Used to make lead pencils and lubricants
   - Coal: formed by bacterial decomposition of plant material. Peat coal has lowest carbon content (60%), anthracite has highest (90%)
   - Carbon gas: not a gas. Obtained by heating powdered coal and tar in absence of air. Good conductor of electricity

- Coke: obtained by heating coal in absence of air. Used as household fuel and in steel industry
- **Wood charcoal:** obtained by burning wood. **Used to make gas masks**, acts as bleaching agent
- Bone charcoal: obtained by destructive distillation of bones. Used as a decolouring agent in sugar industry
- **Lamp Black**: obtained by burning vegetable oil. **Used to make printer's ink and boot polish**

7. **Sodium**
   - Does not occur in free state
   - **Highly reactive, always kept under kerosene**
   - Used to make sodium vapour lamps
   - Removes traces of water in alchohol manufacturing
8. **Silver**
   - **Best conductor of electricity**
   - Used to make jewellery, mirrors and hair dyes
9. **Gold**
   0. **Highly inert, does not react with water, air, alkalies or acids.** Dissolves in *aqua regia*. Used to make electron microscope
10. **Aluminium**
    0. Third most abundant on earth's crust (8%)
    1. Used to make cooking utensils, transmission wires, paint
    2. Alloys Duralumin and Magnalumin used in aircraft building

HALOGENS

Halogen	Occurrence	Uses
Fluorine	Gas Found in soil, sea water Found in tooth enamel	• Refrigerant • Toothpaste • Fungicide • **Polythene (Teflon)**
Chlorine	Gas Found in common salt	• Chlorination of water • Bleaching • DDT manufacture • Anesthetic • **Tear gas**
Bromine	Liquid	• Silver Bromide for photographic plates

		• **Added to petrol to avoid lead accumulation**
Iodine	Solid Found in sea water, sea weeds Found in thyroid gland	• Tincture iodine, iodex • Added to salt to avoid goitre

COMPOUNDS OF SODIUM AND THEIR USES

Compound	Uses
Sodium peroxide	• Bleaching agent
Sodium hydroxide (caustic soda)	• Soap • Paper • Petroleum refining
Sodium carbonate	• Glass • Washing soda • Softening water • Petroleum refining
Sodium bicarbonate (baking soda)	• Baking powder • Fire extinguishers
Sodium chloride (common salt)	• Food
Sodium nitrate (Chile saltpetre)	• Food preservative • Fertilizer • Explosives • Dyes
Sodium sulphate (Glauber's salt)	• Glass • Soap
Sodium thiosulphate (hypo)	• Photography • Textiles

COMPOUNDS OF POTASSIUM AND THEIR USES

Compound	Uses
Potassium hydroxide (caustic potash)	• Soap
Potassium bromide	• Photography
Potassium nitrite (nitre)	• Gun powder
Potassium chlorate	• Explosives

	• Germicide
Potassium carbonate (potash)	• Glass

ALLOYS OF COPPER AND THEIR USES

Alloy	Components	Uses
Bell metal	Copper, Tin	• Making bells • Utensils
Brass	Copper, Zinc	• Utensils • Cartridges
Bronze	Copper, Tin, Zinc	• Utensils • Coins • Statues
German silver	Copper, Zinc, Nickel	• Utensils • Coils
Gun metal	Copper, Tin, Zinc	• Guns • Gears • Casting

BIOLOGY

HISTORY OF CELL STUDIES

1. 1665: Robert Hooke discovers cells in cork
2. 1839: Theodor Schwan and Matthias Jakob Schleiden found cell theory
3. 1931: Ernst Ruska builds first Transmission Electron Microscope at the University of Berlin
4. **1953: Watson and Crick discover double helix structure of DNA.** They, along with Maurice Wilkins, won the Nobel Prize in Physiology or Medicine in 1962

GENETIC MATERIAL IN A CELL

1. DNA used mainly for storing genetic information
2. RNA used mainly for information transport. Sometimes used for genetic storage in certain viruses

3. Human cell encodes genetic information in DNA
4. **Human genetic material found in nuclear genome and mitochondrial genome**
5. Nuclear genome divided into 23 pairs of DNA molecules called chromosomes
6. Mitochondrial genome codes for 13 proteins used in mitochondrial energy production

COMPONENTS OF A CELL

1. **Cell Membrane**
   - Separates interior of a cell from outside environment
   - Semi-permeable
   - Made of proteins and lipids
   - **Protein receptors are found on the cell membrane**
2. **Cytoplasm**
   - Part of a cell enclosed withing cell membrane
   - Contains three major elements: cytosol, inclusions, organelles
3. **Cytosol**
   - Translucent fluid made of water, salts and organic molecules
   - Makes up 70% of cell volume
   - **Contains protein filaments (that make up the cytoskeleton) and vault complexes**
4. **Inclusions**
   - Small insoluble particles suspended in cytosol
   - Include energy storage materials such as starch and glycogen
5. **Organelles**
   - Compartments withing the cell that have specific functions. Eg: mitochondria, golgi apparatus, lysosomes etc
6. **Mitochondria and Chloroplasts**
   - Both generate energy in the cell
   - Mitochondria uses Oxygen to generate ATP
   - Chloroplasts generate carbohydrates and Oxygen from carbon dioxide and water
   - **Mitochondria found in plants and animals. Chloroplasts found only in plants**
7. **Ribosomes**

- Large complex of RNA and protein molecules

8. **Nucleus**
   - Contains chromosomes
   - **Site of DNA replication and RNA synthesis**
9. **Golgi Apparatus**
   - Found in eukaryotes only
   - Process and package proteins and lipids synthesised by a cell
10. **Lysosomes and Peroxisomes**
    - Lysosomes have digestive enzymes
    - Digest excess or worn-out organelles, food particles, virus/bacteria
    - Peroxisomes have enzymes that rid the cell of toxic peroxides
11. **Vacuoles**
    - Store food and waste

FUNCTIONS OF A CELL

1. **Cell metabolism**
   1. Cell metabolism required for cell growth
   2. Metabolism is the process by which cells process nutrient molecules
   3. **Catabolism: cell produces energy** by breaking down complex molecules
   4. **Anabolism: cell uses energy** to construct complex molecules and perform other functions
2. **Cell division**
   - Required for building tissue and procreation
   - Prokaryotic cells divide by binary fission
   - Eukaryotic cells divide by *mitosis* or *meiosis*
   - Mitosis produces two identical daughter cells, meiosis produces two daughter cells each with half the number of chromosomes
   - DNA replication is required every time a cell divides
3. **Protein synthesis**
   - New proteins formed from amino acids
   - Consists of two steps: transcription and translation

ASK AND TELL...

1. Prokaryotes are
    1. animals without developed nervous systems
    2. organisms lacking nucleus
    3. primitive plants without vascular systems
    4. plants that do not produce flowers and fruits
2. Honey that has high concentration of sugar does not decay because
    1. it contains natural anti oxidants that prevents bacterial attack
    2. bacteria can't survive in active state in a solution of high osmotic strength as water is drawn out
    3. bacteria can't survive in active state as it is deprived of oxygen
    4. none of these
3. The number of chromosomes in a bacterium is
    1. 1
    2. 2
    3. 4
    4. varies with species
4. Granum is a component of
    1. chloroplasts
    2. golgi apparatus
    3. ribosomes
    4. starch grains
5. In a plant cell, DNA is found in
    1. chloroplasts
    2. mitochondria
    3. nucleus
    4. all these

Distribution of elements on the surface of the earth

Element	Distribution	Element	Distribution
Oxygen	49.85%	Silicon	26.03%

Aluminium	7.28%	Calcium	3.18%
Sodium	2.33%	Potassium	2.23%
Magnesium	2.11%	Hydrogen	0.97%
Titanium	0.41%	Chlorine	0.20%
Carbon	0.19%	Others	1.00%

Metals and their ores

Substance	Ore	Substance	Ore
Calcium	Limestone, marble, chalk	Mercury	Cinnabar
Copper	Copper pyrites, Cuprite	Potassium	Carnelite, Saltpetre
Cement	Limestone and clay	Sodium	Rock salt, Cryolite
Glass	Silica and lime stone	**Thorium**	**Monozite**
Iodine	**Sea weeds**	Titanium	Rutile, limenite
Iron	Hematite, Magnatite, Iron pyrites	**Uranium**	**Pitchblende**
Gold	Aurite	Silver	Argentite

Metals and their alloys

Alloy	Component
Brass	Copper, Zinc
Bronze	Copper, Tin, Zinc
Gun metal	Copper, Tin, Zinc
Duralmin	Aluminium, Copper, Magnesium, Manganese
Solder	Aluminium, Lead, Tin
Pewter	Lead, Tin

Speed is the rate of change of distance

$$speed = \frac{distance}{time}$$

Velocity is the rate of change of displacement. It signifies both the speed and the direction of movement of an object.

Acceleration is the rate of change of velocity.

$$acceleration = \frac{velocity}{time}$$

Acceleration due to gravity is the acceleration experienced by an object as it falls freely towards the ground. It is constant throughout the surface of the earth.

$$g = 9.8 \frac{m}{s^2}$$

Momentum is a measure of the quantity of motion possessed by a body.

$$momentum = mass * velocity$$

Equations of motion

Let an object be moving for time *t* at an acceleration *a* resulting in a displacement *s*. If the initial velocity of the object is *u* and the final velocity *v*, the following equations hold true

$$v = u + at$$

$$s = ut + \frac{at^2}{2}$$

$$v^2 - u^2 = 2as$$

Newton's laws of motion

First law: A body continues in its state of rest or uniform motion unless compelled to change by an unbalanced force

Second law: A body of mass *m* under an acceleration *a* experiences a force *F* given by $F = ma$

Third law: Whenever a body *A* exerts a force *F* on another body *B*, the second body *B* exerts force *-F* on *A*.

QUESTIONS

1. The universal law of motion was propounded by
    1. Kepler
    2. Galileo
    3. Newton
    4. Copernicus
2. The gravitational force with which the Sun attracts the Earth is
    1. less than the force with which the Earth attracts the Sun
    2. the same as the force with which the Earth attracts the Sun
    3. more than the force with which the Earth attracts the Sun
    4. constant throughout the year
3. The mass of a body is different from its weight.
    1. Mass is variable whereas the weight is constant
    2. Mass varies very little at different places whereas weight varies significantly
    3. Mass is constant but weight increases from the pole to the equator
    4. mass is a measure of quantity of matter whereas weight is a force
4. The weight of a body is
    1. same everywhere on the surface of the earth
    2. maximum at the poles
    3. maximum at the equator
    4. more on hills than in plains
5. If a body is taken from the Earth to the Moon,
    1. its mass will be different but weight will still be the same
    2. both mass and weight will be different
    3. mass will be the same but weight will be different
    4. mass and weight will both remain unchanged

"क्या पढ़ना है क्या छोड़ना है, सफलता के लिए अभ्यर्थी / प्रतिभागी को यह जानना आना चाहिए"