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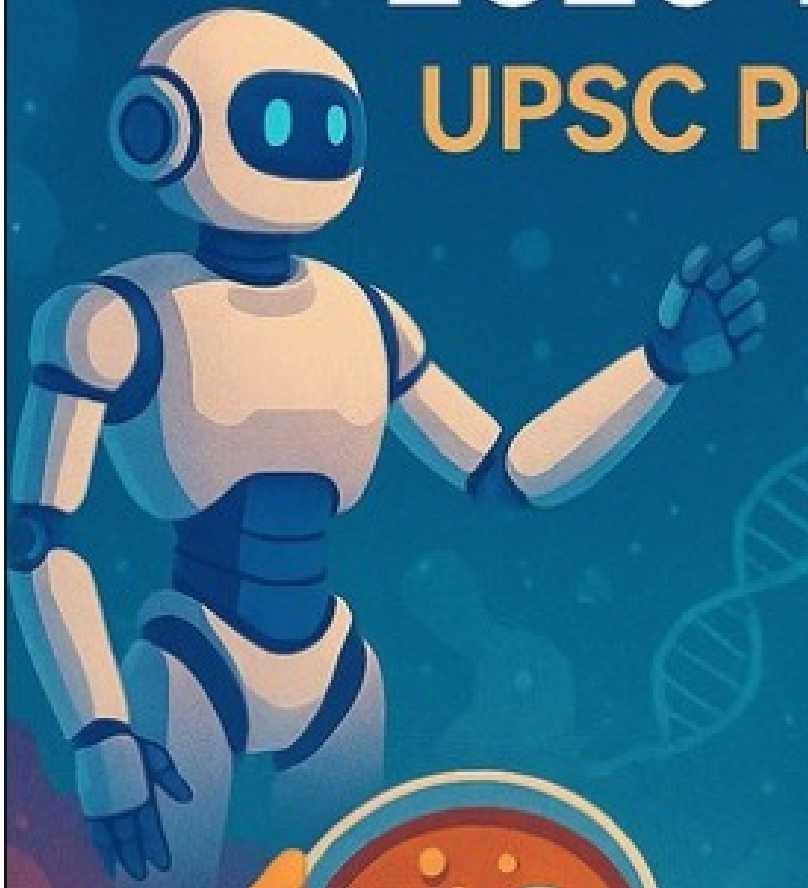
PYQs with explanation

2020-2025

UPSC Prelims



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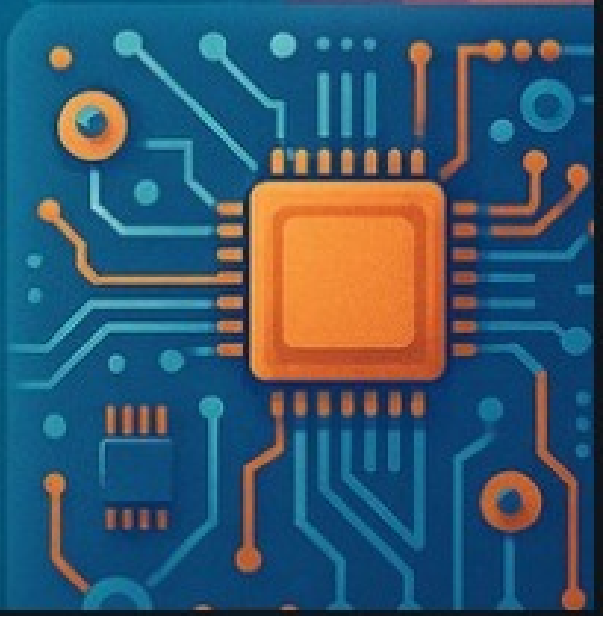

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6 Year Solved UPSC Prelims Science & Technology PYQs With Explanation 2020- 2025

Contents

Solved UPSC Prelims S&T PYQs With Explanation 2025

1. Consider the following types of vehicles:
I. Full battery electric vehicles
II. Hydrogen fuel cell vehicles
III. Fuel cell-electric hybrid vehicles
How many of the above are considered as alternative powertrain vehicles?
(a) Only one
(b) Only two
(c) All the three
(d) None

1.Ans-c
Explanation
Approaches to decarbonise the transport sector and reduce the use of fossil fuels:

i. ***Alternative powertrains***—These are powertrains that are not based exclusively on the internal combustion engine. The main options include **hybrids and plug-in hybrids, full battery electrics, and hydrogen fuel cell vehicles , Fuel cell electric vehicles (FCEVs)**
ii. ***Low carbon fuels***—These are liquid or gaseous fuels that can be used in combustion engines, existing or modified. The main options include e-fuels (i.e., synthetic fuels produced using electrical energy) and biofuels.

Hence all the three are correct

2. With reference to Unmanned Aerial Vehicles (UAVs), consider the following statements:
I. All types of UAVs can do vertical landing.
II. All types of UAVs can do automated hovering.
III. All types of UAVs can use battery only as a source of power supply.
How many of the statements given above are correct?
(a) Only one
(b) Only two
(c) All the three
(d) None

2.Ans-d
Explanation
Early UAVs development is generally divided into two separate types, Fixed Wing UAV (FWUAV), and rotorcraft UAV (RUAV).
FWUAVs typically have longer endurance and thus can reach further than RUAV in a single flight, but require runways for take-offs and landings.
RUAVs on the other hand, are more manoeuvrable and able to take-off and land vertically without any runway but has much lesser endurance due to their low efficiency in power consumption and low speed.
Hybrid Vertical-Take-Off-Landing (VTOL) aircraft will have the advantages of both FWUAV and RUAV

Drones, are generally classified as **single rotor (helicopter), multi-rotor (multicopter), fixed wing, and fixed-wing hybrid VTOL according to their physical structures.**

Single-rotor drones are small-sized helicopters, and fueled or electric types are available. Working with a single blade and fuel offers advantages such as increasing stability and flying longer distances, but it also brings safety risks.
Multicopters are the smallest, lightest, and most widely used drones on the market. Multicopters are divided into models with four engines (quadcopter), six engines (hexacopter), and eight engines (octocopter) according to the number of motors.
Fixed-wing drones: Unlike rotary wings, they use wings like a regular airplane instead of vertical lift rotors to provide lift . In other words, they only need to use energy to move forward. They are much more efficient as they do not use additional power to stay in the air, so they can cover longer distances and scan much larger areas. Gasoline-powered ones can remain in the air for 16 hours or more.
The main disadvantage of a fixed-wing aircraft is that they cannot fly in one spot. Depending on their size, they need a runway or launcher to get them into the air. **Fixed-wing also makes launching and landing them much more difficult, as a runway, parachute, or net may be needed for a safe landing again after the flight.**
Fixed-wing hybrid *Vertical-Take-Off-Landing(*VTOL)drone: Fixed-wing hybrid VTOL drones are a new hybrid category that can also take off and land vertically, combining the advantages of fixed-wing UAVs and the ability to hover.
Fixed-wing hybrid VTOL unmanned aerial vehicles have the advantages of flying vertically and hovering, offering greater versatility than fixed-wing drones and the durability needed to travel long distances with heavy payloads. On the other hand, they could be better in both forward flying and hovering features and the need for specialised personnel in the flight and control of these types of drones is an important consideration.

Their power sources classify drones as battery-powered, gasoline-powered, hydrogen fuel cell, and solar drones.
Hence none of the statements are correct

3. In the context of electric vehicle batteries, consider the following elements:
I. Cobalt
II. Graphite
III. Lithium
IV. Nickel
How many of the above usually make up battery cathodes?
(a) Only one
(b) Only two
(c) Only three
(d) All the four

3.Ans-c
Explanation
Every electric vehicle (EV) is a lithium-ion battery that depends on several key minerals that help power it. The minerals used are

Mineral	Cell part
Aluminium	Cathode, Casing, Current collectors
Nickel	Cathode
Copper	Current collectors
Steel	Casing
Manganese	Cathode
Cobalt	Cathode
Lithium	Cathode
Iron	Cathode
Graphite	**Anode**

Hence, only 1,2,4 are correct

4. Consider the following:
I. Cigarette butts
II. Eyeglass lenses
III. Car tyres
How many of them contain plastic?
(a) Only one
(b) Only two
(c) All the three
(d) None

4.Ans-c
Explanation
Cigarette butts are actually the most abundant form of plastic waste in the world.
Common Eyeglass Lens Materials- Standard glass ,Standard plastic ,Polycarbonate, Trivex.
Car tyres are made from around 24 per cent synthetic rubber - a variation of plastic made using petroleum by-products - that breaks down as the vehicles travel.
Microplastic residue from car tyres account for 28% of microplastics entering the environment globally.
All the three are correct .

5. Consider the following substances:
I. Ethanol

II. Nitroglycerine
III. Urea
Coal gasification technology can be used in the production of how many of them?
(a) Only one
(b) Only two
(c) All the three
(d) None

5.Ans-b
Explanation
Coal is one of the most abundant natural resources in the country. Coal gasification technology enables conversion of coal into syngas (synthetic gas)
Syngas can be used to produce Gaseous Fuels such as Hydrogen, Substitute Natural Gas (SNG or Methane), Di-Methyl Ether (DME), Liquid Fuels such as Methanol, Ethanol, Synthetic diesel and Chemical and Petrochemicals like Methanol derivatives, Olefins, Propylene, Mono-Ethylene Glycol (MEG). Acetic Acid , Formaldehyde , nitrogenous fertilizers including Ammonia , Urea, Ammonium nitrate , DAP
Hence 1 and 3 are correct

Nitroglycerine is an explosive liquid which was first made by Ascanio Sobrero in 1846 by treating glycerol with a mixture of nitric and sulphuric acid. It is not produced by Coal Gasification .
Hence2 is in correct

6.What is the common characteristic of the chemical substances generally known as CL-20, HMX and LLM-105, which are sometimes talked about in media?

(a) These are alternatives to hydro-fluorocarbon refrigerants

(b) These are explosives in military weapons

(c) These are high-energy fuels for cruise missiles

(d) These are fuels for rocket propulsion

6.Ans-b
Explanation
CL-20, or Octa-Nitro-Cubane, is a Nitramine class of explosive 15 times as powerful as HMX, His/Her Majesty Explosive or High Melting Explosive or Octogen.
CL-20, so named after the China Lake facility of the Naval Air Weapons Station in California, US, was first synthesized by Dr. Arnold Nielson in 1987. HMX dates from 1941
LLM-105 was first produced at Lawrence Livermore National Laboratory in 1995. It can withstand high temperatures without blowing up, making it a candidate for warheads used in hypersonic missiles, which fly and manoeuvre at more than five times the speed of sound.

7. Consider the following statements:
I. It is expected that Majorana l chip will enable quantum computing.

II. Majorana l chip has been introduced by Amazon Web Services (AWS).
III. Deep learning is a subset of machine learning.
Which of the statements given above are correct?
(a) I and II only

(b) II and III only

(c) I and III only

(d) I, II and III

7.Ans-c

Explanation

Microsoft has recently unveiled a groundbreaking advancement in quantum computing with the introduction of its new quantum chip, Majorana 1.
Hence Statement 1 is correct
Amazons first-ever quantum computing chip is Ocelot.
Hence Statement 2 is incorrect
Deep learning is a subset of machine learning that uses multilayered neural networks, called deep neural networks, to simulate the complex decision-making power of the human brain. Some form of deep learning powers most of the artificial intelligence (AI) applications in our lives today
Hence Statement 3 is correct

8.With reference to monoclonal antibodies, often mentioned in news, consider the following statements:
I. They are man-made proteins.
II. They stimulate immunological function due to their ability to bind to specific antigens.
III. They are used in treating viral infections like that of Nipah virus.
Which of the statements given above are correct?
(a) I and II only
(b) II and III only
(c) I and III only
(d) I, II and III

8.Ans-d

Explanation

'Mono' means 'one' and 'clone' means 'identical copy'. Monoclonal antibodies are identical copies of one type of antibody.
The production of monoclonal antibodies is an in vitro process by the use of tissue-culture techniques.
Hence statement 1 is correct
Antibodies are ***proteins*** produced by a type of white blood cell called a lymphocyte. Pathogens have proteins on their surface called antigens. When a pathogen infects the body, the lymphocytes recognise these antigens as foreign and attack them by producing antibodies.
Antibodies bind to specific antigens on pathogens. This means that only one type of antibody will bind to a matching antigen.
Hence statement 2 is correct

Monoclonal antibodies, as a highly effective immunotherapeutic treatment against viral infections, are now widely used for pre- or postexposure protection against infectious diseases caused by highly virulent and lethal viruses, such as Ebola virus (EBOV)and severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), and Nipah virus (NiV)

NiV41 and NiV42 - Two neutralising antibodies (NiV41 and NiV42) targeting the NiV receptor binding protein (RBP) were identified. antibodies derived from NiV41 display cross-reactivity against both NiV and Hendra virus (HeV), whereas the antibody based on NiV42 is only specific to NiV.
Hence statement 3 is correct

9.Consider the following statements:
I. No virus can survive in ocean waters.
II. No virus can infect bacteria.
III. No virus can change the cellular transcriptional activity in host cells.
How many of the statements given above are correct?
(a) Only one
(b) Only two
(c) All the three
(d) None

9.Ans-d
Explanation
Viruses inhabit the world's oceans in great numbers. One spoonful of seawater can hold up to a billion virus particles
Hence statement 1 is incorrect
A bacteriophage is a type of virus that infects bacteria. The word "bacteriophage" literally means "bacteria eater," because bacteriophages destroy their host cells.
Hence statement 2 is incorrect
The ability to shut off host gene expression is a shared feature of many viral infections, and it is thought to promote viral replication by freeing host cell machinery and blocking immune responses.
Hence statement 3 is incorrect

10.Consider the following statements:
Statement I: Activated carbon is a good and an attractive tool to remove pollutants from effluent streams and to remediate contaminants from various industries.
Statement II:Activated carbon exhibits a large surface area and a strong potential for adsorbing heavy metals.
Statement III: Activated carbon can be easily synthesized from environmental wastes with high carbon content.
Which one of the following is correct in respect of the above statements?
(a) Both statement II and Statement III are correct and both of them explain Statement I
(b) Both Statement II and Statement III are correct but only one of them explains Statement I
(c) Only one of the Statements II and III is correct and that explains Statement I
(d) Neither Statement II nor Statement III is correct.

10.Ans-c

Explanation

Activated carbons are produced from carbon of vegetable origin (peat, lignite, coal or nutshells). The activation process creates an extensive pore structure that allows considerable adsorption onto an active surface area above 400 m2/g.

Activated carbon products can be put to a range of uses, including the purification, concentration and separation of gases from liquids, purifying drinking water, waste water and sewage treatment as well as controlling emissions. They also have further applications in the food, chemical and pharmaceutical industries.

Hence statement 2 is correct

The production method of activated carbon consists of the following main process steps:

Devolatilization and Carbonization of raw material

The Carbonization process comprises heating of the raw material to a temperature around 600 °C. This process also removes volatiles from the raw material

Activation of the carbonized material

The carbonized material is activated at temperatures around 950 °C with a gasification agent (usually steam) which removes a proportion of the carbon atoms by gasification

The steam activation process steps are performed in reactors such as rotary kilns, multiple hearth kilns, shaft kilns, and other high temperature kilns.

So It cannot be easily synthesised , it involves substantial costs .

Hence statement 3 is incorrect

So Only Statements II is correct and that explains Statement I

11. GPS-Aided Geo Augmented Navigation (GAGAN) uses a system of ground stations to provide necessary augmentation. Which of the following statements is/are correct in respect of GAGAN?

I. It is designed to provide additional accuracy and integrity.
II. It will allow more uniform and high quality air traffic management.
III. It will provide benefits only in aviation but not in other modes of transportation.

Select the correct answer using the code given below.

(a) I, II and III
(b) II and III only
(c) I only
(d) I and II only

11. Ans-d

Explanation

GAGAN is the acronym for GPS Aided GEO Augmented Navigation. The GAGAN uses a system of ground stations to provide necessary augmentations to the GPS standard positioning service(SPS) navigation signal. A network of precisely surveyed ground reference stations (INdianReference Stations INRES) is strategically positioned across the country to collect GPS satellite data. Using this information, the master control centre (INdian Master Control Centre INMCC) generates messages to correct any signal errors. These correction messages are then uplinked through (INdian Land

Uplink Station INLUS) and broadcast through communication satellites (Geostationary) to receivers onboard aircraft using the same frequency as GPS.

The GAGAN is designed to provide the additional accuracy, availability, and integrity necessary to enable users to rely on GPS for all phases of flight, from en route through approach for all qualified airports within the GAGAN service volume.
Hence statement 1 is correct

GAGAN will also provide the capability for increased accuracy in position reporting, allowing for more uniform and high-quality Air Traffic Management (ATM).
Hence statement 2 is correct

In addition, GAGAN will provide benefits beyond aviation to all modes of transportation, including maritime, highways, and railroads
Hence statement 3 is incorrect

12. Consider the following statements:
Statement I: Some rare earth elements are used in the manufacture of flat television, screens and computer monitors,
Statement II:Some rare earth elements have phosphorescent properties.
Which one of the following is correct in respect of the above statements?
(a) Both Statement I and Statement II are correct and Statement II explains Statement I
(b) Both Statement I and Statement II are correct but Statement II doesnot explain Statement I
(c) Statement I is correct but Statement II is not correct
(d) Statement I is not correct but Statement II is correct

12. Ans-a
Explanation
Rare earth elements are used in several high technology industrial products.
In the ceramic and glass industry rare earth element containing compounds are used for high temperature materials, for coatings, polishing, coloring, decoloring and as glass additives. The main other uses of rare earth elements are in permanent magnets, **phosphors in color television tubes,** x-ray tubes, fluorescent lamps, electronic and computer devices and lighter flints.
Hence statement 1 is correct
Rare Earth Metals (REM) like europium and terbium are known for their phosphorescent properties
Hence statement 2 is correct and explains statement 1

13. Consider the following statements:
I. Indian Railways have prepared a National Rail Plan (NRP) to create a future ready railway system by 2028.
II. 'Kavach' an Automatic Train Protection system developed in collaboration with Germany.
III. 'Kavach' system consists of RFID tags fitted on track in station section.
Which of the statements given above are not correct?
(a) I and II only
(b) II and III only
(c) I and III only
(d) 1, II and III

13. Ans- a

Explanation

Indian Railways have prepared a National Rail Plan (NRP) for India – 2030. The Plan is to create a 'future ready' Railway system by 2030.

Statement 1 is incorrect

Kavach is an indigenously developed Automatic Train Protection (ATP) system.

Statement 2 is incorrect

India's capability to deploy the Kavach automatic train collision avoidance system is set to receive a boost with the approval of global companies, Germany's Siemens and Japan's Kyosan, to install it on the national transporter

Kavach aids the Loco Pilot in running of train within specified speed limits by automatic application of brakes in case Loco Pilot fails to do so and also helps the trains to run safely during inclement weather

Kavach was adopted as National ATP system in July 2020.

Implementation of Kavach System involves following Key Activities:

a. **Installation of Station Kavach at each and every station, block section.**
b. **Installation of RFID Tags throughout the track length.**
c. Installation of telecom Towers throughout the section.
d. Laying of Optical Fibre Cable along the track.
e. Provision of Loco Kavach on each and every Locomotive running on Indian Railways.

Statement 3 is correct

14. Consider the following Space missions :

I. Axiom-4
II. SpaDeX
III. Gaganyaan

How many of the space missions given above encourage and support micro-gravity research?

(a) Only one
(b) Only two
(c) All the three
(d) None

14. Ans-c

Explanation

The Axiom-4 mission

The Axiom-4 mission a collaborative effort of Axiom Space, NASA, European Space Agency (ESA) and Indian Space Research Organisation (ISRO)

During the 14-day mission docked to the orbiting laboratory, the astronauts will conduct global outreach activities, **microgravity** research and technology demonstrations.

PSLV-C60 SpaDeX mission

SpaDeX mission is a cost-effective technology demonstrator mission for the demonstration of in-space docking using two small spacecraft launched by PSLV.

PS4-Orbital Experiment Module, designated as POEM, refers to the usage of the spent fourth stage of the Polar Synchronous Launch Vehicle (PSLV). It provides an opportunity for the scientific community

to carry out certain in-orbit **microgravity** experiments for an extended duration of up to three months
PSLV-C60 SpaDeX mission is the fourth POEM Mission (in short POEM-4) in the series.

Gaganyaan
Indian Human Space Program, Gaganyaan aims to encourage and support Indian scientific community in **microgravity r**esearch activities through flight opportunities in ISRO's missions as well as joint international efforts.

15. With reference to India's defence, consider the following pairs:

Aircraft type	***: Description***
I. Dornier-228	: Maritime patrol aircraft
II. IL-76	: Supersonic combat aircraft
III. C-17 Globe-master III	: Military transport aircraft

How many of the pairs given above are correctly matched?
(a) Only one
(b) Only two
(c) All the three
(d) None

15. Ans-b
Explanation
Dornier-228
The Dornier 228 is a high-wing, twin-engine turboprop aircraft manufactured by Hindustan Aeronautics Limited (HAL) and RUAG Aerospace. The DO-228 is capable of carrying payloads up to around 5,200 lbs and has a maximum flight altitude of around 28,000 ft. It has been utilized for remote sensing and atmospheric research.
The Do-228 can be deployed in passenger and cargo transportation, as an air taxi, for corporate purposes, for aircrew training, **maritime surveillance**, search and rescue, border patrolling and medical evacuation missions.
Hence 1st pair is correctly matched

IL-76
The Ilyushin Il-76 is a robust cargo aircraft celebrated for its significant payload capacity and ability to transport bulk, heavy, and outsized loads. Its solid construction and advanced engineering make it ideal for a wide range of **logistical and transport operations.**
The Ilyushin Il-76, developed by the Ilyushin Design Bureau, first flew in 1971. It was originally designed to meet the airlift needs of the Soviet Union, capable of transporting heavy machinery, military equipment, and large cargo.
Hence 2nd pair is incorrectly matched

C-17 Globe-master III
A high-wing, four-engine, T-tailed **military transport aircraft,** the multi-service C-17 can carry large equipment, supplies and troops directly to small airfields in harsh terrain anywhere in the world. The massive, sturdy, long-haul aircraft tackles distance, destination and heavy, oversized payloads in unpredictable conditions. It has delivered cargo in every worldwide operation since the 1990s.

Boeing has partnered with the U.S. Air Force on C-17 sustainment since the delivery of the first aircraft in 1993.
Hence 3rd pair is correctly matched

16. Artificial way of causing rainfall to reduce air pollution makes use of
(a) silver iodide and potassium iodide
(b) silver nitrate and potassium iodide
(c) silver iodide and potassium nitrate
(d) silver nitrate and potassium chloride

16. Ans-a
Explanation
Cloud seeding is a weather modification technique that improves a cloud's ability to produce rain, in order to tackle pollution.
The most common chemicals used for cloud seeding include **silver iodide, potassium iodide and dry ice (solid carbon dioxide)**

Solved UPSC Prelims S&T PYQs With Explanation 2024

There were 7 Questions from Science & Technology in 2024, of which

- **1 Question from Energy (RTG)**
- **1 Question from Space (Stars)**
- **1 Question from Biology (Blood Vessels)**
- **1 Question from Physics (Radars)**
- **1 Question from Defence (Fifth-generation Aircraft)**
- **1 Question from Chemistry (Hydrogel)**
- **1 Question from Computing (Metaverse)**

The level of the questions was Moderate to Tough.

Most of the questions were aimed at testing the analytical abilities of the candidates.

1. With reference to radioisotope thermoelectric generators (RTGs), consider the following statements:
1. RTGs are miniature fission reactors.
2. RTGs are used for powering the onboard systems of spacecraft.
3. RTGs can use Plutonium-238, which is a by-product of weapons development.
Which of the statements given above are correct?
(a) 1 and 2 only
(b) 2 and 3 only
(c) 1 and 3 only
(d) 1, 2 and 3

1. Ans: b
Explanation:
Radioisotope Thermoelectric Generators (RTGs) are lightweight, **compact spacecraft power systems.** RTGs provide electrical power using heat from the natural radioactive decay of plutonium-238, in the form of plutonium oxide.
Sometimesreferred to as "nuclear batteries," **RTGs are not fission reactors,** nor is plutonium the type that is used for nuclear weapons.
Hence, statement 1 is incorrect & statement 2 is correct.

The fuel in an RPS — short for radioisotope power systems — is **plutonium oxide,** a radioactive material that produces alpha particles. Alpha particles are a particular type of ionizing radiation that can be shielded by material as thin as a piece of paper.
Plutonium-238 is not the type of plutonium used for nuclear weapons and would not work well as fuel in a nuclear reactor.

In 1959, a prototype RTG generated a sustained 2.5 watts of power over 90 days rapid advances in nuclear chemistry — in the U.S., an outgrowth of the World War II-era Manhattan Project that produced the first nuclear weapons — yielded an array of new radioactive materials. One of these, Pu-238, is nearly ideal for fueling RTGs.
Hence, statement 3 is correct.

2. Consider the following statements:
Statement I: Giant stars live much longer than dwarf stars.
Statement II: Compared to dwarf stars, giant stars have a greater rate of nuclear reactions.
Which one of the following is correct in respect of the above statements?
(a) Both Statement-I and Statement-II are correct and Statement-II explains Statement-I
(b) Both Statement-I and Statement-II are correct, but Statement-II does not explain Statement-I
(c) Statement I is correct, but Statement II is incorrect
(d) Statement I is incorrect, but Statement II is correct

2. Ans: d
Explanation:
There are two kinds of very large stars. Giant stars have masses from eight times to as much as 100 times that of the mass of our sun. These massive stars have hotter and denser cores than dwarf stars (stars that are smaller than five times the mass of our sun). Therefore, **giant stars have a greater rate of the nuclear reactions that light up stars.** Massive stars also use up the hydrogen fuel in their core faster, despite starting out with much more of it, meaning they **live much shorter lives than dwarf stars.**
Dwarf stars will shine for trillions of years while some Giant stars will live for only a few million years.

Hence, statement 1 is incorrect & statement 2 is correct.

3. Which one of the following is synthesised in the human body that dilates blood vessels and increases blood flow?

(a) Nitric oxide

(b) Nitrous oxide

(c) Nitrogen dioxide

(d) Nitrogen pentoxide

3. Ans: a
Explanation:
Vasodilation refers to a widening of the blood vessels within the body. This occurs when the smooth muscles in the arteries and major veins relax.

Vasodilation occurs naturally in response to low oxygen levels or increases in body temperature. Its purpose is to increase blood flow and oxygen delivery to parts of the body that need it most.

The release of certain chemicals within the body can cause vasodilation. Examples include nitric oxide and carbon dioxide, as well as hormones such as histamine, acetylcholine, and prostaglandins.

A doctor may sometimes induce vasodilation as a treatment for high blood pressure , also known as hypertension, and its related conditions

Hence, option a is correct.

4. Consider the following activities:
1. Identification of narcotics on passengers at airports or in aircraft
2. Monitoring of precipitation
3. Tracking the migration of animals
In how many of the above activities can the radars be used?
(a) Only one
(b) Only two
(c) All three
(d) None

4. Ans: b
Explanation:
RADAR is an electromagnetic system for the detection and location of target objects such as aircraft, ships, spacecraft, vehicles, people, and the natural environment which can reflect a signal back. It uses electromagnetic radio waves to determine the angle, range, or velocity of objects.

A weather radar can determine the **precipitation type** (rain, snow, hail, etc.) and spot its location. With the help of a weather radar map, it is also possible to predict where the rain will be moving next and how intense it will be.

Radar has several benefits over other techniques to **study migration** such as visual observations, trapping, and banding, as it works well at altitude and over large distances, is unaffected by the absence of light, and is relatively independent of weather conditions.

Hence 2 and 3 are correct with respect to RADARS

Radars are not used for detection of Narcotics rather other techniques like

Trace narcotic detectors offer a vital tool for identifying microscopic chemical signatures from drugs and residues. Tiny samples are analyzed to reveal narcotic evidence even when no drugs are visible.

Trace detectors collect minute samples via methods like air puffs or swabs wiped over surfaces and materials. Advanced instrumentation analyzes each sample for the presence of chemical markers associated with narcotics. Trace residues of drugs, manufacturing chemicals, or cutting agents can be identified even at levels invisible to the naked eye.
Ion Mobility Spectrometry (IMS) and Mass Spectrometry provide rapid yet highly precise identification of narcotic signatures. IMS analyzes the mobility rate of ionized molecules in an electric field, while mass specrometry separates compounds by their mass-to-charge ratio.
Both methods can detect drug traces down to pictograms or nanograms. This enables the discovery of clandestine threats that evade standard security screening.

Full-body X-ray scanners:- X-ray scanners can be an effective tool for detecting narcotics and other hazardous items. Leveraging state-of-the-art neural network algorithms and knowledge of human body physiology, the software visualizes suspicious areas with an indication of the probability of drug and narcotic presence. In a matter of seconds, it analyzes images and outlines potential areas where narcotics and drugs may be concealed.

Hence, option b is correct.

5. Consider the following aircraft:
1. Rafael
2. MiG-29
3. Tejas MK-1

How many of the above are considered fifth-generation fighter aircraft?
(a) Only one
(b) Only two
(c) All three
(d) None

5. Ans: d
Explanation:
Fifth-generation fighter aircraft are the most technologically advanced jets ever built. They were designed to operate with the help of digital programs and fly by wire to counter the threats they faced on the battlefield. Sophisticated avionics, stealth technology, and super manoeuvrability are just a few advantages over older jets that give them domination in the sky.

few countries have decided to pursue the development of fifth-generation fighter jets:

- Lockheed F-22 Raptor and F-35 Lighting II - USA
- Sukhoi T-50 PAK-FA – Russia
- Chengdu J-20 and Shenyang J-31 Gyrfalcon – China

Hence, option d is correct.

6. In which of the following are hydrogels used?
1. Controlled drug delivery in patients
2. Mobile air-conditioning systems
3. Preparation of industrial lubricants

Select the correct answer using the code given below:
(a) 1 only
(b) 1 and 2 only
(c) 2 and 3 only
(d) 1, 2 and 3

6. Ans: a
Explanation:
Hydrogel products constitute three-dimensional networks that contain a group of polymeric materials, the hydrophilic structure of which renders them **capable of holding large amounts of**

water. These biomaterials can integrate large quantums of biological fluids and swell. When swelled, they are soft & rubbery and resemble the living tissue, exhibiting excellent biocompatibility.

Hydrogels are smart enough to respond to fluctuations in environmental stimuli (ionic strength, pH, temp, presence of enzyme, electric field, etc.)

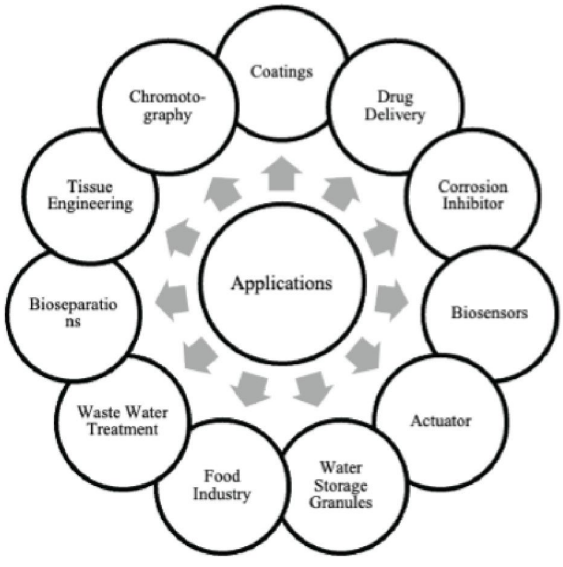
Applications of Hydrogel

Important advantages of hydrogels

- They show high absorption capacity,,
- They maintain the pH value neutral after swelling into water,
- They have the least soluble content and the least residual monome,
- They achieve the desired rate of absorption related to the needs of the application,
- They have high durability and stability during storage,
- They have high biodegradability,
- They are colorless, odorless, and non-toxic,
- They have high photostability.

Application of hydrogels

- Drug delivery systems
- Dyes and heavy metal ions removal in waste water
- contact lenses,
- **Scaffolds in tissue engineering**
- **Biosensors**
- **Injectable hydrogel for spinal cord regeneration**
- **Supercapacitor hydrogels**
- Impact protectors (cushioning)



Mobile Air Conditioning (MAC) system

- Mobile Air Conditioning (MAC) system, is commonly known as car AC or vehicle AC system.
- The air conditioning system in a car works by manipulating refrigerant between a liquid and a gaseous state. As the refrigerant changes states, it absorbs heat and humidity from the vehicle and allows the system to give off cool, dry air.
- The refrigerant used in automotive air conditioning systems has changed from R-12 (Freon) to R-134a and now to R-1234yf, which produces fewer greenhouse gases.
- Almost 100% of new passenger cars sold in the EU use HFO-1234yf as refrigerant.
- Hydrogels have no relevance in Car air conditioning systems

Active cooling vs Passive Cooling

Active cooling typically involves refrigerant-based systems. Active cooling solutions go beyond natural heat dissipation by using external energy and more complex components to actively remove heat,these systems rely on powered mechanisms like compressors and refrigerant cycles to transfer heat out of the system

A typical passive cooling system includes components like heat exchangers, radiators, pumps, and fans. Heat generated by an application's powertrain components is transferred to a coolant fluid (water-glycol, for instance) and circulated through the system. The coolant moves through radiators or heat exchangers, where the heat is dissipated into the air, often with the help of electric fans to improve airflow.

MIT engineers have now found that polyethylene glycol (PEG) — a hydrogel commonly used in cosmetic creams, industrial coatings, and pharmaceutical capsules — can absorb moisture from the atmosphere even as temperatures climb. It could be used for **passive cooling** or water harvesting in warm climates.

Hydrogels cannot be used for active cooling

Industrial lubricants
There are several types of industrial lubricants, including mineral oils, synthetic oils, greases, solid lubricants, and specialty lubricants. Each type has its own unique properties and applications

They are employed to reduce friction, **prevent wear,** dissipate heat, and protect against corrosion in moving parts.

Grease

Grease is a semisolid lubricant that consists of a base oil thickened with a soap-like material called a thickener. It offers excellent adhesion, sealing properties, and **resistance to water washout**. Grease is commonly used in applications with slow or intermittent movement, high loads, and extreme temperatures.

Liquid Lubricants

Liquid lubricants, commonly referred to as oils, are fluid lubricants that offer excellent lubrication properties. They are used in applications where continuous lubrication is required, such as circulating systems or machinery with complex parts.

Liquid lubricants are available in various formulations, including mineral oils, synthetic oils, and vegetable-based oils.

Mineral oils are derived from crude oil (Fractional distillation))and are cost-effective, while synthetic oils are chemically engineered to offer superior performance, such as high-temperature stability and extended oil change intervals.

Vegetable-based oils are environmentally friendly options that are biodegradable and less toxic.

The Effects of Water on a Lubricant

Not only does water have a direct harmful effect on machine components, but it also plays a direct role in the ageing rate of lubricating oils.

Hydrogel has no relevance in Lubricant production

Hence, option a is correct.

7. Which one of the following words/phrases is, most appropriately used to denote "an interoperable network of 3D virtual worlds that can be accessed simultaneously by millions of users, who can exert property rights over virtual items"?

(a) Big data analytics
(b) Cryptography
(c) Metaverse
(d) Virtual matrix

7. Ans: c

Explanation:

The **metaverse** implies a shared environment that spans a multitude of 3D virtual worlds. Participants in the metaverse will be able to move freely through these virtual worlds, taking their identities, entitlements and goods with them. At least that's one vision of how a universe of 3D virtual worlds will work.

Hence, option c is correct.

Solved UPSC Prelims S&T PYQs With Explanation 2023

There were 10 Questions from Science & Technology in 2023, of which

- **1 Question from Genetics (Aerial Metagenomics)**
- **2 Questions from Biotechnology (Microsatellite DNA, Biofilters)**
- **1 Question from Physics (Accelerometer)**
- **1 Questions from Energy (Uranium)**
- **1 Questions from Defence (Missiles)**
- **1 Question from Diseases (Wolbachia)**
- **1 Question from Chemistry (Carbon Fibres)**
- **2 Questions from Space (Stars, Navigation)**

The level of the questions was moderate.

1. 'Wolbachia method' is sometimes talked about with reference to which one of the following?
(a) Controlling the viral diseases spread by mosquitoes
(b) Converting crop residues into packing material
(c) Producing biodegradable plastics
(d) Producing biochar from thermo-chemical conversion of biomass

1. Ans: a
Explanation:
How mosquitoes spread diseases?

- Mosquitoes do not naturally carry viruses – they can only get them from infected people.
- Since only female mosquitoes bite humans, only female mosquitoes can transmit viruses.
- Mosquitoes pick up viruses by biting infected people. When they bite again, they can transmit the virus to the next person. This is how mosquito-borne diseases spread.
- The Aedes aegypti mosquito is the main transmitter of dengue, Zika, chikungunya and yellow fever viruses.
- Aedes aegypti mosquitoes originated in Africa, but they have spread through tropical and subtropical regions around the world.

About Wolbachia

- Wolbachia is one of the world's most common types of bacteria, present in 50% of all insect species, including bees, beetles, butterflies, moths, and fruit flies. . Wolbachia bacteria cannot make people or animals (for example, fish, birds, pets) sick.

- Wolbachia lives inside insect cells and is passed from one generation to the next through an insect's eggs. Aedes aegypti mosquitoes don't normally carry Wolbachia, however many other mosquitoes do.
- Wolbachia blocks viruses like dengue, chikungunya and Zika from growing in the bodies of Aedes aegypti mosquitoes. This means that Wolbachia mosquitoes have a reduced ability to transmit viruses to people.
- When Wolbachia is established in a mosquito population it results in a decreasing incidence of dengue, Zika, chikungunya.
- World Mosquito Program, breeds Wolbachia mosquitoes. Then, in partnership with local communities, release them into areas affected by mosquito-borne diseases.
- Which means less risk of disease in communities where Wolbachia is established in the local mosquito population.
- Wolbachia method can protect communities from mosquito-borne diseases without posing risk to natural ecosystems. This method is natural and self-sustaining.
- People are constantly exposed to Wolbachia through the foods they eat and the insects that bite them, but it causes no known health risks. It also does not affect the food chains of other species because Wolbachia does not reduce mosquito populations.
- **Other methods of controlling mosquitoes are** Insecticide spraying, the Sterile Insect Technique, the Incompatible Insect technique, and Genetic Modification. But these techniques are not self-sustaining.

Hence, option a is correct.

2. 'Aerial metagenomics' best refers to which one of the following situations?
(a) Collecting DNA samples from air in a habitat at one go
(b) Understanding the genetic makeup of avian species of a habitat
(c) Using air-borne devices to collect blood samples from moving animals
(d) Sending drones to inaccessible areas to collect plant and animal samples from land surfaces and water bodies

2. Ans: a
Explanation:
Metagenomics:
Meta derives from the Greekword, which encompasses a wide array of meanings, such as "with", "after", "alongside", "on top of" and "beyond".
Metagenomics, , is the study of the total genetic material directly obtained from the ***microorganisms living in a particular environment***, like microbes living in the animal gut or in any particular ecological environment. Metagenomics projects are used to study the genomics of community of organisms.

Applications of Metagenomics

- It helps to study the diversity of microbial communities and how the diversity of these microbes changes with changes in the environment.
- Metagenomics may also help in identifying novel genes or enzymes with the significant industrial applications. For example, the study of microbial communities living in extreme environments, like high temperature sulphur springs can help to identify the novel enzymes that are resistant and functional at such high temperatures. Thus, metagenomics has

applications in understanding the genomes of gut microbes, throat microbes, microbes present on a toilet seat, and many more.

- It provides an insight about the genome of diverse forms of microbes and their correlations. For example, study of genomes of diverse forms of viruses may provide an understanding about virus-host interaction, epidemiology and also evolution of viruses.

Environmental DNA (eDNA) and Aerial Metagenomics

DNA can be easily released by an organism , all living beings constantly shed bits of DNA, left behind from skin, scales, hair, urine, feces, pollen and more into environment, such a DNA is called Environmental DNA (eDNA). This DNA can be found in air, water, or soil.

All species shed DNA during life or in death, providing an opportunity to monitor biodiversity via environmental DNA (eDNA).

This environmental DNA, or eDNA, has "changed everything" about how scientists study biodiversity and conservation.

Aerial Metagenomics is about extracting eDNA from the atmosphere. It involves plucking the DNA concerned from thin air.

Hence, option a is correct.

3. 'Microsatellite DNA' is used in the case of which one of the following?

(a) Studying the evolutionary relationships among various species of fauna
(b) Stimulating 'stem cells' to transform into diverse functional tissues
(c) Promoting clonal propagation of horticultural plants
(d) Assessing the efficacy of drugs by conducting series of drug trials in a population

3. Ans: a
Explanation:
Microsatellites, also known as Short Tandem Repeats, are short segments of DNA, typically one to six base pairs long, that repeat multiple times at specific genomic locations. These non-coding sequences vary among individuals, making them useful as polymorphic markers for studying inheritance, creating DNA fingerprints, and analyzing genetic diversity. Their unique patterns can be inherited and are valuable for evolutionary studies, pedigree analysis, and understanding population structure.

Hence, option a is correct.

4. Consider the following actions:
1. Detection of car crash/collision which results in the deployment of airbags almost instantaneously.
2. Detection of accidental free fall of a laptop towards the ground which results in the immediate turning off of the hard drive
3. Detection of the tilt of smartphone which results in the rotation of display between portrait and landscape mode

In how many of the above actions is the function of the accelerometer required?
(a) Only one
(b) Only two
(c) All three
(d) None

4. Ans: c
Explanation:
An accelerometer is a device that measures acceleration forces, such as gravity and motion, by converting them into electrical signals.

An accelerometer works by utilizing an electromechanical sensor that is designed to measure either static or dynamic acceleration.

Static acceleration is the constant force acting on a body, like gravity or friction. These forces are predictable and uniform to a large extent. For example, the acceleration due to gravity is constant at 9.8 m/s – and the gravitation force is almost the same at every point on Earth.

Dynamic acceleration forces are non-uniform, and the best example is vibration or shock. A car crash is an excellent example of dynamic acceleration

When an accelerometer detects a sudden change in a car's speed, signaling an imminent collision, it triggers an electrical circuit that makes the airbags inflate.

Hence, statement 1 is correct.

In a laptop, the accelerometer senses freefall and parks the hard drive—usually—before the device hits the ground.

Hence, statement 2 is correct.

Accelerometer in cellphone, MP3 player, or handheld games console, sense when you tilt it from side to side. That's how a cellphone automatically figures out when to switch the screen layout from portrait to landscape.

Hence, statement 3 is correct.

Accelerometer in Rockets measure changes in rocket speed ,apogee (when a craft is at its maximum distance from Earth or another mass, so its acceleration due to gravity is at a minimum) and orientation (because tilting something changes the way gravity acts on it and the force it feels).

Accelerometers are also widely used in inertial navigation and guidance systems in such things as airplane and ship autopilots.

Applications of Accelerometer

Accelerometers are versatile sensors used in various sectors to measure acceleration and orientation. Key applications include:

- Consumer Electronics: Integrated into smartphones and wearables for screen orientation, step tracking, and gaming.

- Automotive: Essential for vehicle dynamics, airbag deployment, and anti-theft systems.
- Aerospace and Aviation: Used in navigation systems and aircraft performance monitoring.
- Industrial: Employed for vibration analysis, enabling predictive maintenance.
- Healthcare: Assist in patient monitoring and rehabilitation by tracking body movement.
- Building Monitoring: Detect vibrations in structures to assess stability and seismic activity.

5. Consider the following statements:
1. Ballistic missiles are jet-propelled at subsonic speeds throughout their flights, while cruise missiles are rocket-powered only in the initial phase of flight.
2. Agni-V is a medium-range supersonic cruise missile, while BrahMos is a solid-fuelled intercontinental ballistic missile.
Which of the statements given above is/are correct?
(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

5. Ans: d
Explanation:
Ballistic missiles
Ballistic missiles are powered initially by **a rocket or series of rockets in stages,** but then follow an unpowered trajectory that arches upwards before descending to reach its intended target. Ballistic missiles can carry either **nuclear or conventional warhead.**
There are **four general classifications of ballistic missiles** based on their range, or the maximum distance the missile can travel:

- **Short-range:** less than 1,000 kilometers (approximately 620 miles), also known as “tactical” ballistic missiles.
- **Medium-range:** between 1,000 and 3,000 kilometers (approximately 620-1,860 miles), also known as “theater” ballistic missiles.
- **Intermediate-range:** between 3,000 and 5,500 kilometers (approximately 1,860-3,410 miles)
- **Long-range:** more than 5,500 kilometers (approximately 3,410 miles), also known as intercontinental or strategic ballistic missiles.
- **Intercontinental ballistic missiles (ICBMs)** can fly much further than the minimum range; for example, Russia could hit Chicago with an ICBM launched from the Krasnoyarsk ICBM base, which is located 9,156 kilometers (5,689miles) away.

Cruise missiles

Cruise missiles are unmanned vehicles that are **propelled by jet engines**, much like an airplane. They can be launched from ground, air, or sea platforms.

Cruise missiles **remain within the atmosphere** for the duration of their flight and can fly as low as a few meters off the ground.

Flying low to the surface of the earth expends more fuel but makes a cruise missile very difficult to detect.

Cruise missiles are self-guided and use multiple methods to accurately deliver their payload, including **terrain mapping, global positioning systems (GPS) and inertial guidance**, which uses **motion sensors and gyroscopes** to keep the missile on a pre-programmed flight path.

As advanced cruise missiles approach their target, remote operators can use a camera in the nose of the missile to see what the missile sees. This gives them the option to manually guide the missile to its target or to abort the strike.

Brahmos Cruise missile

- Brahmos is a **two-stage missile** with a **solid propellant booster engine as its first stage** which brings it to **supersonic speed** and then gets separated. **The liquid ramjet or the second stage** then takes the missile closer to 3 Mach speed in cruise phase. **Stealth technology** and guidance system with advanced embedded software provides the missile with special features.
- The missile has **flight range of upto 290 km** with **supersonic speed** , it operates on ***Fire and Forget principle***
- The range of the missile was **originally capped at 290km** as per obligations of the **Missile Technology Control Regime.** Following India's entry into the club in June 2016, the range has been **extended to 450km** and work is on to extend it to 600km and beyond

Agni-V Ballistic missile

- Agni-V uses a **three-stage solid fuelled engine** and is capable of striking targets at ranges upto 5,000 Kms and can reach most parts of China.
- The Agni-V, which currently has range of up to 5,000 kilometre as officially claimed technically qualifies only as an intermediate range ballistic missile (IRBM), and not an Intercontinental ballistic missiles (ICBM) because ICBMs are missiles with ranges over 5,500 km. But the official claim of 5,000 km probably understates the range of the missile, with many reports claiming it is a true ICBM with an 8,000 km range.
- On March 11,2024 , the Indian Defense Research and Development Organization (DRDO) undertook the maiden test of its indigenously developed **Agni-V MIRV (Multiple Independently Targetable Re-Entry Vehicle) missile.** The flight test, named Mission Divyastra .
- With MIRV technology a **single intercontinental ballistic missile (ICBM)** can carry and deliver **multiple warheads at different locations several hundred kilometers apart.**
- MIRV capability is a complex technology and India is among a small group of countries – the United States, United Kingdom, Russia, France, and China – that have developed it.

Hence, both statements 1 & 2 are incorrect.

6. Consider the following statements:
Statement- I: India despite having uranium deposits, depends on coal for most of its electricity production.
Statement- II: Uranium, enriched to the extent of at least 60%, is required for the production of electricity.
Which one of the following is correct in respect of the above statements?

(a) Both Statement-I and Statement-II are correct and Statement-II is the correct explanation for Statement-I
(b) Both Statement-I and Statement-II are correct and Statement-II is not the correct explanation for Statement-I
(c) Statement-I is correct but Statement-II is incorrect
(d) Statement- I is incorrect but Statement- II is correct

6. Ans: c

Explanation:

India's three-stage nuclear power programme is a long-term plan that involves the use of three different types of reactors to produce energy.

The first stage involves uranium-fueled heavy water reactors (HWRs) that produce plutonium.

The second stage, comprising of Fast Breeder Reactors (FBRs) are fuelled by mixed oxide of Uranium238 and Plutonium239, recovered by reprocessing of the first stage spent fuel

The third and final stage involves using the recovered materials to create 232Th/233U fuel for advanced heavy water reactors (HWRs)

This programme is necessary because India has abundant thorium reserves but little uranium, and the use of a thorium fuel cycle in the third stage is a key feature of the programme.

Indian Prime Minister Narendra Modi in March 2024 witnessed the start of fuel loading at the 500 MWe Prototype Fast Breeder Reactor at Kalpakkam in Tamil Nadu in **Fast breeder reactors form the second stage of India's three-stage nuclear programme. India is presently in second stage of India's three-stage nuclear programme**

Since thorium is used in the third stage, presently, India depends substantially on Coal for Power generation

Hence, statement I is correct.

Uranium is a naturally occurring radioactive element

There are three natural isotopes of uranium — uranium-234 (U-234), uranium-235 (U-235) and uranium-238 (U-238). U-238 is the most common one, accounting for around 99 per cent of natural uranium found on earth. Most nuclear reactors use fuels containing U-235, however, natural uranium typically contains only 0.72 per cent of U-235 and, most reactors need a higher concentration of this isotope in their fuel. Therefore, the U-235 concentration is being artificially increased through a process called enrichment.

Uranium enrichment is the process, through which the isotopic proportion of U-235 is increased from 0.72 per cent to up to 94 per cent.

Uranium is considered low-enriched if its isotopic proportion of U-235 remains below 20 per cent. Most commercial reactors use low-enriched uranium (LEU) below five per cent as fuel, which is also often referred to as “reactor-grade uranium”. LEU does not deteriorate and can be safely stored for many years.

If uranium is enriched beyond 20 per cent, it is considered highly enriched. Uranium with such high isotopic proportions of U-235 is mostly used in **naval propulsion reactors (for example in submarines), nuclear weapons** and some research reactors.

Hence, statement II is incorrect.

7. Consider the following:
1. Carbon fibres are used in the manufacture of components used in automobiles and aircrafts.
2. Carbon fibres once used cannot be recycled.
Which of the statements given above is fare correct?
(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

7. Ans: a
Explanation:
The Carbon fibres are composed of carbonised polymers, which are lengthy chains of molecules joined by strong bonds between carbon atoms. A precursor material is heated to around 3,000°C in an environment of inert gases to create the fibres. The most commonly used precursor is polyacrylonitrile (PAN), which is produced by the petrochemicals industry. Alternatively, pitch made from coal tar is occasionally utilised. The fibres are spun into yarns, molded into tapes, or threaded into bobbins once they have carbonised. They can also be woven into fabric sheets, depending on the intended use.
Because it is incredibly strong and lightweight, carbon fibre is appealing. Being the strongest fibre, they have 10 times the strength of steel and eight times the strength of aluminum. The carbon fibre is also five times lighter than steel and half the weight, or less, of aluminum. Nor does it corrode. Therefore, they are used in aircrafts and automobiles.

Hence, statement 1 is correct.

On their own, carbon fibres are brittle and can break easily. But their strength comes in tension (they resist being pulled apart). So, the fibres need to be aligned in such a way to impart their strength by distributing loads throughout a structure.

Carbon fibres can be made from manufacturing offcuts or recycled material and can themselves be recycled.

Hence, statement 2 is incorrect.

8. With reference to the role of biofilters in Recirculating Aquaculture System, consider the following statements:
1. Biofilters provide waste treatment by removing uneaten fish feed.
2. Biofilters convert ammonia present in fish waste to nitrate.
3. Biofilters increase phosphorus as a nutrient for fish in water.
How many of the statements given above are correct?
(a) Only one

(b) Only two
(c) All three
(d) None.

8. Ans: b

Explanation:

About Recirculatory Aquaculture System (RAS)

- Instead of the traditional method of growing fish outdoors in open ponds and raceways, in RAS system fish are typically reared in indoor/outdoor tanks in a controlled environment.
- In RAS water is recycled and reused by passing it through mechanical and biological filters and after suspended matter is removed.
- The **steps in RAS include solids removal, ammonia removal, CO2 removal and oxygenation.**

Biolfilters: A biological filter consists of various material such as plastic beads (bioball), net fiber, molluscan shells, fiberglass, ceramic or rock that has large amounts of surface area for colonizing the nitrifying bacteria cells which grow on all surfaces of the biofilter media.

How does filtration works?

To remove these wastes, the mechanical filters and biofilter or biological filters are used.
Mechanical filtration: Mechanical filtration of the outlet water from the fish tanks is used for the removal of suspended organic and inorganic wastes. The removal of **solid waste including uneaten fish feed is the first stage in serial filtration design.** Smaller particles of organic sediments are consumed by microscopic organisms including bacteria. But not all the organic matter is removed in the mechanical filter; the finest particles will pass through the filter along with dissolved compounds such as phosphate and nitrogen which are then removed using biofilters.

Hence, statement 1 is correct.

Biolfilteration: The breakdown of organic matter and ammonia is a biological process carried out by bacteria in the bio-filter. **Heterotrophic bacteria** oxidize/breakdown the left organic matter by consuming oxygen and producing carbon dioxide and ammonia. **Nitrifying bacteria convert ammonia into nitrite and finally into nitrate.** The bacteria that convert ammonia to nitrite are known collectively by their genus name Nitrosomonas. Like ammonia, the nitrite produced by the Nitrosomonas bacteria is toxic to aquatic organisms and must be oxidized further to a less toxic form of nitrogen. This is accomplished by genus of bacteria called Nitrobacter.

Hence, statement 2 is correct.

Efficiency of bio-filtration depends primarily on Water temperature, oxygen and pH level. To reach an acceptable nitrification rate, water temperatures should be kept within 10 to 35 °C (optimum around 30 °C) and pH levels between 7 and 8. A lower pH level reduces the efficiency of the bio-filter. Under anaerobic conditions, hydrogen sulfide (H2S) can be produced, especially in saltwater systems. This gas is extremely toxic to fish, even in low concentrations, and fish will be killed if hydrogen sulfide is generated in the system.
Note: Phosphate is an inert substance, with no toxic effect, but nitrogen in the form of free ammonia (NH3) is toxic and needs to be transformed into non-toxic form in the bio-filter.

How Phosphates are removed from RAS?

In recirculating aquaculture systems, cultivated fish **cannot incorporate all the phosphate contained in the feed**. Excess phosphate ends up in the culture water and in the sludge produced, which can harm other aquatic life in the area by causing algae blooms. **One method of phosphorus removal is adsorption** (adsorbent RhizoSorb (base material of aluminum oxide) is used) which is a surface phenomenon that is often used to bind dissolved pollutants to a solid-phase medium and remove them from water. Thus biofliters reduce the amount of phosphorus in water.

Hence, statement 3 is incorrect.

9. Consider the following pairs:

Objects in space	**Description**
1. Cepheids	Giant clouds of dust and gas in space
2. Nebulae	Stars which brighten and dim periodically
3. Pulsars	Neutron stars that are formed when massive stars run out of fuel and collapse

How many of the above pairs are correctly matched?
(a) Only one
(b) Only two
(c) All three
(d) None

9. Ans: a
Explanation:
Cepheids, also called Cepheid Variables, are stars which brigthen and dim periodically. This behavior allows them to be used as cosmic yardsticks out to distances of a few tens of millions of light-years

A nebula is a giant cloud of dust and gas in space. Some nebulae (more than one nebula) come from the gas and dust thrown out by the explosion of a dying star, such as a supernova. Other nebulae are regions where new stars are beginning to form.

Hence, 1st and 2nd pairs are incorrectly matched.

Pulsars are rapidly rotating neutron stars that blast out pulses of radiation at regular intervals ranging from seconds to milliseconds.

A pulsar is the crushed core of a massive star that ran out of fuel, collapsed under its own weight and exploded as a supernova.

Hence, 3rd pair is correctly matched.

10. Which one of the following countries has its own Satellite navigation system?
(a) Australia
(b) Canada
(c) Israel
(d) Japan

10. Ans: d

Explanation:

Global navigation satellite system (GNSS) is a general term describing any satellite constellation that provides positioning, navigation, and timing (PNT) services on a global or regional basis.

Global Positioning System (GPS)

- The Global Positioning System (GPS) is a U.S.-owned utility that provides users with positioning, navigation, and timing (PNT) services.
- GPS is the most prevalent GNSS, other nations are fielding, or have fielded, their own systems to provide complementary, independent PNT capability.
- The GPS space segment consists of a constellation of satellites transmitting radio signals to users.
- The United States is committed to maintaining the availability of at least 24 operational GPS satellites, 95% of the time.
- GPS satellites fly in medium Earth orbit (MEO) at an altitude of approximately 20,200 km (12,550 miles). Each satellite circles the Earth twice a day.

Other Global Navigation Satellite Systems (GNSS)

BeiDou Navigation Satellite System (BDS)

BeiDou, or BDS, is a global GNSS owned and operated by the People's Republic of China. BDS was formally commissioned in 2020. The operational system consists of 35 satellites. BDS was previously called Compass.

Galileo

Galileo is a global GNSS owned and operated by the European Union. The EU declared the start of Galileo Initial Services in 2016 and plans to complete the system of 24+ satellites in 2021.

GLONASS

GLONASS (Globalnaya Navigazionnaya Sputnikovaya Sistema, or Global Navigation Satellite System) is a global GNSS owned and operated by the Russian Federation. The fully operational system consists of 24+ satellites.

Indian Regional Navigation Satellite System (IRNSS) / Navigation Indian Constellation (NavIC)

IRNSS is a regional GNSS owned and operated by the Government of India. IRNSS is an autonomous system designed to cover the Indian region and 1500 km around the Indian mainland. The system consists of 7 satellites. In 2016, India renamed IRNSS as the Navigation Indian Constellation (NavIC, meaning "sailor" or "navigator").

Quasi-Zenith Satellite System (QZSS)

QZSS is a regional GNSS owned by the Government of Japan and operated by QZS System Service Inc. (QSS). QZSS complements GPS to improve coverage in East Asia and Oceania. Japan declared the official start of QZSS services in 2018 with 4 operational satellites, and plans to expand the constellation to 7 satellites by 2023 for autonomous capability.

Hence, option d is correct.

Solved UPSC Prelims S&T PYQs With Explanation 2022

There were 14 Questions from Science & Technology in 2022, of which

- **2 Questions from Bio-Technology (Vaccines, DNA barcoding)**
- **5 Questions from Computing (open-source digital platforms, Web 3-0, SaaS, qubit, NFTs)**
- **2 Questions from Physics (Solar Flare, Communication Technology)**
- **1 Question from Chemistry (Nanoparticle)**
- **1 Question from Defence (Fractional Orbital Bombardment)**
- **3 Questions from Biology (Bacteria, Probiotics, Lymphocytes)**

The level of the questions was moderate to tough.

1. Consider the following:
1. Aarogya Setu
2. CoWIN
3. Digi Locker
4. DIKSHA

Which of the above are built on top of open-source digital platforms?
(a) 1 and 2 only
(b) 2, 3 and 4 only
(c) 1, 3 and 4 only
(d) 1, 2, 3 and 4

1. Ans: d
Explanation:
A Digital Platform is a business-driven framework that allows a community of partners, providers and consumers to share, extend or enhance digital processes and capabilities for the benefit of all stakeholders involved through a common digital technology system.
Closed source software - The creator or copyright holder sells the proprietary or closed source software to end users, who are not allowed to edit, enhance or redistribute the product except as specified by the copyright holder. Ex- software applications such as Microsoft Word or Adobe Illustrator.

Open source software (OSS) is source code developed and maintained through open collaboration. Anyone can use, examine, alter and redistribute OSS as they see fit, typically at no cost.

"Open source" also refers to a community-based approach to creating intellectual property, such as software, through open collaboration, inclusiveness, transparency and frequent public updates.

Examples of open source - GitHub, Mozilla Firefox, Linux, WordPress, Bitcoin, and Android.

About Digilocker

- **DigiLocker is a secure cloud based platform** for storage, sharing and verification of documents & certificates.
- DigiLocker system is **developed on an Open Source stack** and the components in its entirety or in parts may be made available to other countries for their own implementation of a similar product.
- Utilization of cloud based services by DigiLocker for secure and scalable system can be good best practise to be replicated globally.

About Aarogya Setu

- On 2nd April 2020, India launched Aarogya Setu mobile App for helping augment the efforts of limiting the spread of COVID19, with an objective of enabling Bluetooth based contact tracing, mapping of likely hotspots and dissemination of relevant information about COVID19. The key pillars of Aarogya Setu have been transparency, privacy and security and in line with India's policy on **Open Source Software,** the source code of Aarogya Setu has now been made open source.

About DIKSHA

- DIKSHA (Digital Infrastructure for Knowledge Sharing) is a national platform for school education, an initiative of National Council for Educational Research and Training (NCERT), under the aegis of the Ministry of Education (MoE), GoI.
- **DIKSHA is built on open source technology,** made in India and made for India, which incorporates internet scale technologies and enables several use-cases and solutions for teaching and learning. DIKSHA is built using MIT licensed open source technology called Sunbird, which is a digital infrastructure for learning and solutions and offers over a 100 micro services as building blocks for the development of platforms and solutions.

About COWIN

- CoWin stands for Covid Vaccine Intelligent Work. In January 2021, the platform was unveiled by the union government as it launched the vaccination drive in the country.
- The primary feature is to give users a chance to book a vaccine slot anywhere in the country
- **The code for CoWin was made open source.** The government won't attach any intellectual property rights to it.

Hence, option d is correct.

2. With reference to Web 3-0, consider the following statements:
1. Web 3-0 technology enables people to control their own data.
2. In Web 3-0 world, there can be blockchain-based social networks.
3. Web 3-0 is operated by users collectively rather than a corporation.

Which of the statements given above are correct?
(a) 1 and 2 only

(b) 2 and 3 only
(c) 1 and 3 only
(d) 1, 2 and 3

2. Ans: d
Explanation:
Web3 is the third generation of the internet currently being built, where websites and apps will be able to process information in a smart human-like way through technologies like artificial intelligence (AI), machine learning (ML), Big Data, decentralized ledger technology (DLT), and more.
Web3 was in fact originally called the Semantic Web by World Wide Web inventor Tim Berners-Lee, and was aimed at being a more autonomous, intelligent, and open internet.

In Web3, data will be interconnected in a **decentralised way**, where as in Web 2.0, data is mostly stored in centralised repositories and therefore subject to manipulation or worse. Furthermore, users and machines will be able to interact with data.

Web3 networks will operate through **decentralised protocols** — the founding blocks of **blockchain and cryptocurrency technology.**

Hence, statements 1, 2 and 3 are correct.

3. With reference to "Software as a Service (SaaS)", consider the following statements
1.. SaaS buyers can customise the user interface and can change data fields.
2. SaaS users can access their data through their mobile devices.
3. Outlook, Hotmail and Yahoo! Mail are forms of SaaS.
Which of the statements given above are correct?
(a) 1 and 2 only
(b) 2 and 3 only
(c) 1 and 3 only
(d) 1, 2 and 3

3. Ans: d
Explanation:
Software as a service (SaaS) is application software hosted ***on the cloud and used over an internet*** connection by way of a web browser, mobile app or thin client.
Software as a service (SaaS) allows users to connect to and use cloud-based apps over the Internet. Common examples are email, calendaring, and office tools (such as Microsoft Office 365).

SaaS provides a complete software solution that you purchase on a pay-as-you-go basis from a cloud service provider. You rent the use of an app for your organization, and your users connect to it over the Internet, usually with a web browser.

All of the underlying infrastructure, middleware, app software, and app data are located in the service provider's data center.

The service provider manages the hardware and software, and with the appropriate service agreement, will ensure the availability and the security of the app and your data as well.

SaaS allows your organization to get quickly up and running with an app at minimal upfront cost.

Common SaaS scenarios

Web-based email service such as Outlook, Hotmail, or Yahoo! Mail

With these services, you log into your account over the Internet, often from a web browser. The email software is located on the service provider's network, and your messages are stored there as well.

You can access your email and stored messages from a web browser on any computer or Internet-connected device.

Hence, statement 3 is correct.

Advantages of SaaS

- **Gain access to sophisticated applications.** To provide SaaS apps to users, you don't need to purchase, install, update, or maintain any hardware, middleware, or software. SaaS makes even sophisticated enterprise applications, such as ERP and CRM, affordable for organisations that lack the resources to buy, deploy, and manage the required infrastructure and software themselves.
- **Pay only for what you use.** You also save money because the SaaS service automatically scales up and down according to the level of usage.
- **Use free client software.** Users can run most SaaS apps directly from their web browser without needing to download and install any software, although some apps require plugins. This means that you don't need to purchase and install special software for your users.
- **Access app data from anywhere**. With data stored in the cloud, users can access their information from any **Internet-connected computer or mobile device.** And when app data is stored in the cloud, no data is lost if a user's computer or device fails.

  Hence, statement 2 is correct.

- **Customization and integration.** SaaS services enable deep customization so apps can be configured specifically to each customer's requirements, including the functionality and look-and-feel of the product. Such systems can also be integrated with other business apps, especially across applications from a common software provider.

  Hence, statement 1 is correct.

- **Data and analytics.** With a SaaS application, all processes, data and files are carried out through a centralized platform, making it easy to collect, store and analyze data further, even for distributed teams.

4. Which one of the following statements best reflects the idea behind the "Fractional Orbital Bombardment System" often talked about in media?
(a) A hypersonic missile is launched into space to counter the asteroid approaching the Earth and explode it in space.
(b) A spacecraft lands on another planet, after making several orbital motions.
(c) A missile is put into a stable orbit around the Earth and de-orbits over a target on the Earth.

(d) A spacecraft moves along a comet with the same speed and places a probe on its surface.

4. Ans: c

Explanation:

Fractional orbital bombardment systems (FOBS) is a term coined by the West during the Cold War for a Soviet innovation that would exploit limitations in the US Ballistic Missile Early Warming (BMEW) radar system at that time.

The concept of the FOBS was to insert a thermonuclear warhead into a steeply inclined low altitude polar orbit, such that it would approach the continental United States (CONUS) from any direction, but primarily from the southern hemisphere.

The idea behind FOBS is, a warhead is put into a stable orbit and it deorbits over the target. The warhead would employ retrorockets to break itself out of orbit and fall on the target from a direction not covered by BMEW.

The FOB system is distinguished from an ICBM delivery system in that an ICBM take a ballistic trajectory that reaches an altitude of approximately 800 miles (1,300 kilometers) and releases its warhead or warhead bus, which then descends on a ballistic trajectory to its target

A FOBS trajectory launches a warhead and its delivery vehicle into an orbit of around 100 miles (160 kilometers) but breaks from that orbit before it completes a full revolution of the Earth.

FOBS , ICBM &MOBS

The FOB system is distinguished from an ICBM delivery system in that an ICBM take a ballistic trajectory that reaches an altitude of approximately 800 miles (1,300 kilometers) and releases its warhead or warhead bus, which then descends on a ballistic trajectory to its

Another concept explored by the Soviet Union was the multiple orbit bombardment system (MOBS), also called the nuclear-armed bombardment system (NABS), where a vehicle carrying either a single or several warheads would make one or more complete orbits of the Earth before it delivered its payload. MOBS are differentiated from FOBS in as their weapons complete one or more orbits before descending on its target.

A fractional orbital bombardment system has several advantages over traditional ballistic missiles: its range covers the entire Earth; it can execute an attack from a much larger number of directions; and the time required for payload delivery can be many minutes shorter than for a comparable ICBM payload.

Fractional orbital bombardment systems are inaccurate delivery mechanisms. The large velocity of the payload during re-entry and subsequent delivery creates a significant degree of error in targeting.

Unlike error-prone bombardment systems, a hypersonic glide vehicle can maneuver and adjust its flight path precisely after re-entry into the atmosphere. It can sustain atmospheric flight for an extended period (a “glide”), or even exit and re-enter the atmosphere later (a “skip”). Non-ballistic atmospheric entry enables hypersonic glide vehicles to avoid interception by following unpredictable flight paths, and to fly below the ceilings of radar detection systems.

A fractional orbital hypersonic delivery system combines these advantages with orbital bombardment to create the best of both worlds. A fractional orbital hypersonic delivery system can

deliver payloads up to 10 minutes faster than ICBMs. The trajectories of fractional orbital hypersonic delivery systems are difficult to track, both because they stay closer to the Earth and therefore below the floor of missile-defense radars, and also because of the increased manoeuvrability of the hypersonic glide vehicle payload.

Hence, option c is correct.

5. Which one of the following is the context in which the term "qubit" is mentioned?
(a) Cloud Services
(b) Quantum Computing
(c) Visible Light Communication Technologies
(d) Wireless Communication Technologies

5. Ans: b
Explanation:
What is quantum?

The quantum in "quantum computing" refers to the quantum mechanics that the system uses to calculate outputs. In physics, a quantum is the smallest possible discrete unit of any physical property. It usually refers to properties of atomic or subatomic particles, such as electrons, neutrinos, and photons.

What is a qubit?

A qubit is the basic unit of information in quantum computing. Qubits play a similar role in quantum computing as bits play in classical computing, but they behave very differently. Classical bits are binary and can hold only a position of 0 or 1, but qubits can hold a superposition of all possible states.

What is quantum computing?

Quantum computers harness the unique behavior of quantum physics—such as superposition, entanglement, and quantum interference—and apply it to computing. This introduces new concepts to traditional programming methods.

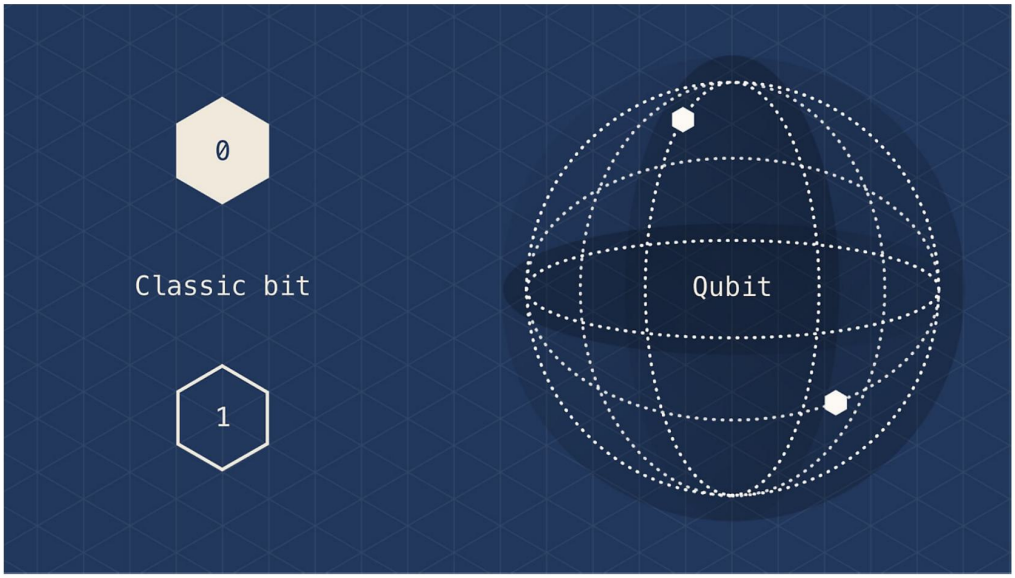
Qubit vs bit

Qubits are represented by a superposition of multiple possible states

A qubit uses the quantum mechanical phenomena of superposition to achieve a linear combination of two states. A classical binary bit can only represent a single binary value, such as 0 or 1, meaning that it can only be in one of two possible states. A qubit, however, can represent a 0, a 1, or any proportion of 0 and 1 in superposition of both states, with a certain probability of being a 0 and a certain probability of being a 1.

In superposition, quantum particles are a combination of all possible states. They fluctuate until they're observed and measured. One way to picture the difference between binary position and superposition is to imagine a coin. Classical bits are measured by "flipping the coin" and getting heads or tails. However, if you were able to look at a coin and see both heads and tails at the same time, as well as every state in between, the coin would be in superposition.

Superposition gives quantum computers superior computing power



Superposition allows quantum algorithms to process information in a fraction of the time it would take even the fastest classical systems to solve certain problems.

- The amount of information a qubit system can represent grows exponentially. Information that 500 qubits can easily represent would not be possible with even more than 2^500 classical bits.
- It would take a classical computer millions of years to find the prime factors of a 2,048-bit number. Qubits could perform the calculation in just minutes.

Hence, option b is correct.

6. Consider the following communication technologies:
1. Closed-circuit Television
2. Radio Frequency Identification
3. Wireless Local Area Network

Which of the above are considered Short-Range devices/technologies?
(a) 1 and 2 only
(b) 2 and 3 only
(c) 1 and 3 only
(d) 1, 2 and 3

6. Ans: d
Explanation:
Wireless devices that transmit **low power levels** and operate over **distances of up to a few hundred meters** are **Short Range Devices (SRD)**. They mostly use Radio frequencies to operate in a small area.

Short range communications as the systems providing wireless connectivity within a local sphere of interaction.
Short Range Devices (SRD) are radio devices that offer a low risk of interference with other radio services, usually because their transmitted power, and hence their range, is low. The definition 'Short Range Device' may be applied to many different types of wireless equipment, including various forms of:

- Access control (including door and gate openers)
- Alarms and movement detectors
- Closed-circuit television (CCTV)
- Cordless audio devices, including wireless microphones
- Industrial control
- Local Area Networks
- Medical implants
- Metering devices
- Remote control
- Radio frequency identification (RFID)
- Road Transport Telematics
- Telemetry.

They have a low **effective radiated power (ERP)** of typically 25-100 mW and thus do not interfere with other radio services. The frequencies used by these devices are called SRD frequencies. Other SRD wireless technologies include **Bluetooth, Wi-Fi, near-field communication (NFC), ultra-wideband (UWB).**

Hence, option d is correct.

7. Consider the following statements:
1. Biofilms can form on medical implants within human tissues.
2. Biofilms can form on food and food processing surfaces.
3. Biofilms can exhibit antibiotic resistance.
Which of the statements given above are correct?
(a) 1 and 2 only
(b) 2 and 3 only
(c) 1 and 3 only
(d) 1, 2 and 3

7. Ans: d
Explanation:
Bacteria often attach to surfaces and form **dense aggregations called biofilms or bacterial mats.** These films can range from a few micrometers in thickness to up to half a meter in depth, and may contain multiple species of bacteria, protists, and achaea.

Bacteria living in biofilms display a complex arrangement of cells and extracellular components, forming secondary structures such as microcolonies through which there are networks of channels to enable better diffusion of nutrients.

In natural environments, such as soil or the surfaces of plants, most bacteria are bound to surfaces in biofilms.

Biofilms are also important in medicine, as these structures are often present during chronic bacterial infections or in **infections of implanted medical devices**, and bacteria protected within biofilms are much harder to kill than individual isolated bacteria. Even more complex morphological changes are sometimes possible.

Hence, statement 1 is correct.

Biofilms is technically bacteria and exhibits all characteristics of bacteria including attaching to the food surfaces and antibiotic resistance.

Hence, statements 2 and 3 are correct.

8. Consider the following statements in respect of probiotics:
1. Probiotics are made of both bacteria and yeast.
2. The organisms in probiotics are found in foods we ingest but they do not naturally occur in our gut.
3. Probiotics help in the digestion of milk sugars.
Which of the statements given above is/are correct?
(a) 1 only
(b) 2 only
(c) 1 and 3
(d) 2 and 3

8. Ans: c
Explanation:
What are probiotics?

Probiotics are live microorganisms that are intended to have health benefits when consumed or applied to the body. They can be found in yogurt and other fermented foods, dietary supplements, and beauty products.

Although people often think of bacteria and other microorganisms as harmful "germs," many are actually helpful. **Some bacteria help digest food, destroy disease-causing cells, or produce vitamins.** Many of the microorganisms in probiotic products are the same as or similar to microorganisms that **naturally live in our bodies (It is also found it Gut).**

Hence, statement 2 is incorrect.

What types of bacteria are in probiotics?

Probiotics may contain a variety of microorganisms. The most common are bacteria that belong to groups called ***Lactobacillus*** **and** ***Bifidobacterium***. Other bacteria may also be used as probiotics, and so **may yeasts such as** ***Saccharomyces boulardii*****.** Different types of probiotics may have different effects.

Hence, statement 1 is correct.

Fermentation of milk by **lactobacillus bacteria in gut converts lactose sugar of milk into glucose** and galactose, which is **easily digestible by even the lactose-intolerant.** Therefore, probiotics helps in digestion of milk sugars.

Hence, statement 3 is correct.

9. In the context of vaccines manufactured to prevent COVID-19 pandemic, consider the following statements:
1. The Serum Institute of India produced COVID-19 vaccine named Covishield using mRNA platform.
2. Sputnik V vaccine is manufactured using vector based platform.
3. COVAXIN is an inactivated pathogen based vaccine.
Which of the statements given above are correct?
(a) 1 and 2 only
(b) 2 and 3 only
(c) 1 and 3 only
(d) 1, 2 and 3

9. Ans: b
Explanation:
About Vaccines

- A vaccine is a biological preparation that improves immunity to a specific disease. It typically contains an agent that resembles a disease-causing microorganism and is often made from weakened or killed forms of the microbe. The agent stimulates the body's immune system to recognize the agent as foreign, destroy it, and "remember" it so that the immune system can more easily recognize and destroy any of these microorganisms that it later encounters.
- vaccines are administered prior to infection. Their role is to prime the immune system to fight any future infections, so that they can be brought under control before the disease-causing microorganism have had a chance to multiply.
- Vaccines are of different types - killed Vaccines , attenuated Vaccines , toxoid Vaccines, subunit Vaccines, Conjugate Vaccines, experimental Vaccines , Valence Vaccines.

The different types of vaccines

There are three main approaches to designing a vaccine. Their differences lie in whether they use a **whole virus or bacterium**; **just the parts** of the germ that triggers the immune system; **or just the genetic material** that provides the instructions for making specific proteins and not the whole virus.

1. The whole-microbe approach

- **Inactivated vaccine**
- **Live-attenuated vaccine**
- **Viral vector vaccine**

1. Live-attenuated vaccines:

- Live-attenuated vaccines contain live pathogens from either a bacteria or a virus that have been attenuated or weakened.
- They are produced by selecting strains of a bacteria or virus that still produce a robust enough immune response but that does not cause disease.
- Attenuated viruses were one of the earliest methods of eliciting protective immune responses.

- Examples: **Measles, mumps, and rubella (MMR) vaccine, varicella (chickenpox) vaccine.**

2. Inactivated vaccines

- Inactivated vaccines take a live pathogen and inactivate or kill it. Then the vaccine is introduced to a human through a shot, the inactivated pathogen is strong enough to create an immune response, however, is incapable of causing disease.
- Examples: Polio vaccine, influenza vaccine, **Covaxin.**

Hence Statement 3 is correct.

3. Viral vector vaccines:

- Viral vector vaccines use a **harmless virus to deliver to the host cells the genetic code of the antigen** that one wants the immune system to fight against. Viral vectors are a gene delivery system, where information about the antigen is delivered, which triggers the body's immune response.
- Examples: Ebola vaccine, COVID-19 vaccine (AstraZeneca and Johnson & Johnson), **Covishield, Sputnik-V.**

2. The subunit approach

A subunit vaccine is one that only uses the very specific parts (the subunits) of a virus or bacterium that the immune system needs to recognize. It doesn't contain the whole microbe or use a safe virus as a vector. The subunits may be proteins or sugars (polysaccharides), conjugate. Most of the vaccines on the childhood schedule are subunit vaccines, protecting people from diseases such as **whooping cough, tetanus, diphtheria and meningococcal meningitis**.

3. The genetic approach (nucleic acid vaccine)

Unlike vaccine approaches that use either a weakened or dead whole microbe or parts of one, a nucleic acid vaccine just uses a section of genetic material that provides the instructions for specific proteins, not the whole microbe. DNA and RNA are the instructions our cells use to make proteins. In our cells, DNA is first turned into messenger RNA, which is then used as the blueprint to make specific proteins **example of mRNA vaccines are Comirnaty (Pfizer-BioNTech) and Spikevax (Moderna).**

Hence statement 1 is incorrect & statement 2 is correct.

10. If a major solar storm (solar-flare) reaches the Earth, which of the following are the possible effects on the Earth?
1. GPS and navigation systems could fail.
2. Tsunamis could occur at equatorial regions.
3. Power grids could be damaged.
4. Intense auroras could occur over much of the Earth.
5. Forest fires could take place over much of the planet.
6. Orbits of the satellites could be disturbed.
7. Shortwave radio communication of the aircraft flying over Polar Regions could be interrupted.

Select the correct answer using the code given below:
(a) 1, 2, 4 and 5 only

(b) 2, 3, 5, 6 and 7 only
(c) 1, 3, 4, 6 and 7 only
(d) 1, 2, 3,4, 5, 6 and 7

10. Ans: c
Explanation:
What is a solar flare?

A solar flare is an intense burst of radiation, or light, on the Sun. Flares are our solar system's most powerful explosive events – the most powerful flares have the energy equivalent of a billion hydrogen bombs, enough energy to power the whole world for 20,000 years.

How do solar flares affect Earth?

Solar flares only affect Earth when they occur on the side of the Sun facing Earth. Solar flares are rated into different classes based on their strength, or energy output, and the effect a flare will have on Earth depends on what class it is (B, C, M, and X classes, with X being the most intense).

The most dangerous emissions from flares are **energetic charged particles (primarily high-energy protons) and electromagnetic radiation (primarily x-rays).**

How does a solar storm affect us?

When directed toward Earth, a solar storm can create a major disturbance in Earth's magnetic field, called a geomagnetic storm, that can produce effects such as radio blackouts, power outages, and beautiful auroras.

- The x-rays from flares are stopped by our atmosphere well above the Earth's surface. They d**o disturb the Earth's ionosphere, however, which in turn disturbs radio communications**.
- X rays along with energetic ultraviolet radiation, they **heat the Earth's outer atmosphere**, causing it to expand. T**his increases the drag on Earth-orbiting satellites**, reducing their lifetime in orbit. Also, both intense radio emission from flares and changes in the atmosphere can degrade satellite communications, for example the precision of Global Positioning System (GPS) measurements can be degraded. This might cause an internet outage, meaning an internet shutdown.

Hence, statement 1 is correct.

- One serious problem that can occur during a geomagnetic storm is damage to Earth-orbiting satellites, especially those in high, **geosynchronous orbit**s. **Communications satellites are generally in these high orbits.** Either the satellite becomes highly charged during the storm and a component is damaged by the high current that discharges into the satellite, or a component is damaged by high-energy particles that penetrate the satellite.
- Currently **astronauts are not in immediate danger because they stay relatively near the Earth in low earth orbit.** They do have to be concerned about cumulative radiation exposure during space walks.
- The energetic particles from a **flare or CME would be dangerous to an astronaut on a mission to the Moon or Mars,** however.
- Solar storms, which are much more terrifying near the sun than on Earth, don't directly cause tsunamis on Earth. Regular tectonic activity continues regardless of solar wind activity.

Hence, statement 2 is incorrect.

- Another major problem that has occurred during geomagnetic storms has been the **temporary loss of electrical power over a large region**. The best known case of this occurred in 1989 in Quebec. High currents in the magnetosphere induce high currents in power lines, **blowing out electric transformers and power stations.** This is most likely to **happen at high latitudes, where the induced currents are greatest**, and in regions having long power lines and where the ground is poorly conducting. The **damage to satellites and power grids can be very expensive and disruptive**.

Hence, statement 3 is correct.

- One spectacular side-effect of increased solar activity during the solar cycle is aurora. When the energetic particles from the sun slam into Earth's atmosphere, dazzling light illuminates the sky. The color of the aurora depends on what chemicals in Earth's atmosphere the particles hit. **Red hues are produced from collisions with nitrogen molecules and green is produced by oxygen molecules.**

Hence, statement 4 is correct.

- Solar flares produce high energy particles and radiation that are dangerous to living organisms. However, on the surface of the Earth, we are well protected from the effects of solar flares by the Earth's magnetic field and atmosphere .Forest fires are not caused by solar storms. The flares are not strong till they reach the Earth so as to cause forest fires.

Hence, statement 5 is incorrect.

- When the solar cycle is at peak activity, it can pose a risk to communications on Earth and satellites. It can disturb the orbits of such satellites. The solar storm can endanger astronauts and Earth-orbiting spacecraft.

Hence, statement 6 is correct.

- Shortwave radio communication of the aircraft flying over Polar Regions could also be interrupted by the solar storms as the electronic equipments may malfunction.

Hence, statement 7 is correct.

11. With reference to Non-Fungible Tokens (NFTs), consider the following statements.
1. They enable the digital representation of physical assets.
2. They are unique cryptographic tokens that exist on a blockchain.
3. They can be traded or exchanged at equivalency and therefore can be used as a medium of commercial transactions.

Which of the statements given above are correct?
(a) 1 and 2 only
(b) 2 and 3 only
(c) 1 and 3 only
(d) 1, 2 and 3

11. Ans: a

Explanation:
An NFT or non-fungible token is a unique digital asset stored on the blockchain that serves as proof of ownership or authenticity for a **digital or physical** item/right.

Unlike fungible assets, NFTs are one-of-a-kind and cannot be replaced. They **use blockchain technology** to provide decentralized, secure, and transparent records of ownership and transfers.

Hence Statement 1& 2 are correct.

There is a close link between NFTs and cryptocurrencies as many NFTs **are traded** in cryptocurrencies and the fortunes of NFTs have tracked the performance of crypto as well as broader economic trends.

Fundamentally, NFTs are digital certificates that hold the potential to deliver significant value for both organizations and end users. For companies, NFTs provide a new way to connect with customers and create loyal communities. For users, they provide a new avenue for inclusive ownership in digital goods.

NFTs are non-fungible, meaning each token has unique properties and isn't worth the same amount as similar tokens. Art and collectibles are often considered non-fungible since only one original exists.

Hence Statement 3 is incorrect.

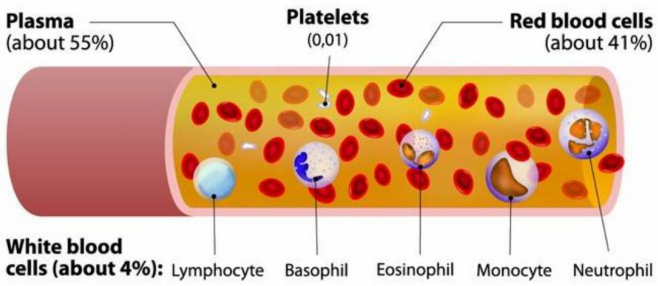
12. Which one of the following statements best describes the role of B cells and T cells in the human body?
(a) They protect the body from environmental allergens.
(b) They alleviate the body's pain and inflammation.
(c) They act as immunosuppressants in the body.
(d) They protect the body from the diseases caused by pathogens.

12. Ans: d
Explanation:

Blood Basics

Blood is a specialized body fluid. It has four main components: ***plasma, red blood cells, white blood cells, and platelets.***

Components of blood



The Components of Blood and Their Importance

1.Plasma

The liquid component of blood is called plasma, a mixture of water, sugar, fat, protein, and salts. The main job of the plasma is to transport blood cells throughout your body along with nutrients, waste products, antibodies, clotting proteins, chemical messengers such as hormones, and proteins that help maintain the body's fluid balance.

2.Red Blood Cells (also called erythrocytes or RBCs)

Known for their bright red color, red cells are the most abundant cell in the blood, accounting for about 40 to 45 percent of its volume.

Production of red blood cells is controlled by erythropoietin, a hormone produced primarily by the kidneys.

Red blood cells start as immature cells in the bone marrow and after approximately seven days of maturation are released into the bloodstream. The red blood cell survives on average only 120 days.

Red cells contain a special protein called hemoglobin, which helps carry oxygen from the lungs to the rest of the body and then returns carbon dioxide from the body to the lungs so it can be exhaled. Blood appears red because of the large number of red blood cells, which get their color from the hemoglobin.

3.White Blood Cells (also called leukocytes)

White blood cells protect the body from infection. They are much fewer in number than red blood cells, accounting for about 1 percent of blood.

There are different types of white blood cells

a. Lymphocyte : The other major type of white blood cell is a lymphocyte. Lymphocytes make antibodies to fight infection. They are found in the lymph nodes, thymus, spleen, tonsils, adenoids and bone marrow. They are also found in lymphatic tissue in other parts of the body, such as the appendix, the small intestine and other parts of the digestive system and respiratory system.

There are two main populations of these cells.

T lymphocytes help regulate the function of other immune cells and directly attack various infected cells and tumors.

B lymphocytes make antibodies, which are proteins that specifically target bacteria, viruses, and other foreign materials.

b. Granulocytes : Granulocytes fight infection and become active in response to tissue inflammation.

The 3 main types of granulocytes are: Neutrophils , Eosinophils and Basophils

Neutrophils : The most common type of white blood cell is the neutrophil, which is the "immediate response" cell and accounts for 55 to 70 percent of the total white blood cell count.

Each neutrophil lives less than a day, so bone marrow must constantly make new neutrophils to maintain protection against infection.

Eosinophils and Basophils, which attack and destroy certain parasites and are activated during an allergic reaction

c. Monocytes : Monocytes help fight infection by changing into cells called macrophages, which eat foreign invaders, such as bacteria and waste from dying cells.

4.Platelets (also called thrombocytes)

Unlike red and white blood cells, platelets are not actually cells but rather small fragments of cells. Platelets help the blood clotting process (or coagulation) by gathering at the site of an injury, sticking to the lining of the injured blood vessel, and forming a platform on which blood coagulation can occur.

A higher than normal number of platelets can cause unnecessary clotting, which can lead to strokes and heart attacks , Conversely, lower than normal counts can lead to extensive bleeding.

Where Do Blood Cells Come From?

Blood cells develop from **hematopoietic stem cells** and are formed in the bone marrow through the highly regulated process of hematopoiesis. Hematopoietic stem cells are capable of transforming into red blood cells, white blood cells, and platelets.

Stem cells are found in the bone marrow, blood and umbilical cord blood. Stem cells develop into blood cells in the bone marrow. When blood cells are mature and able to function, they leave the bone marrow and move into the blood.

Most stem cells are found in the bone marrow. Stem cells can also be found in smaller amounts in the bloodstream. These are called peripheral blood stem cells. Umbilical cord blood also has stem cells but there are fewer stem cells than those in the bone marrow and blood.

These stem cells can be found circulating in the blood and bone marrow in people of all ages, as well as in the umbilical cords of newborn babies. Stem cells from all three sources may be used to treat a variety of diseases, including leukemia, lymphoma, bone marrow failure, and various immune disorders.

Hence, option d is correct.

13. Consider the following statements:

DNA Bar-coding can be a tool to:
1. assess the age of a plant or animal.
2. distinguish among species that look alike.
3. identify undesirable animal or plant materials in processed foods.

Which of the statements given above is/are correct?

(a) 1 only
(b) 3 only

(c) 1 and 2
(d) 2 and 3

13. Ans: d

Explanation:

What Is DNA Barcoding

DNA barcoding is a method used to identify specimens through short, standardized segments of DNA. Each species has its own unique barcode, much like how every person has a distinct fingerprint. These DNA barcodes can be compared to a reference library, allowing for accurate identification of the species.

The DNA sequence helps identify different species, similar to how a supermarket scanner uses the black stripes of a UPC barcode to recognize purchases.

DNA barcoding helps identify unknown specimens by matching a specific section of their DNA, known as a barcode, with a reference database that contains DNA from known species.

Comparison to reference databases enables matching unknown samples to known species' barcodes, allowing fast taxonomic identification.

DNA barcoding is a powerful methodology that employs sequence analysis of standardized genetic regions to quickly and accurately characterize species diversity within intricate biological communities. This approach not only facilitates the identification of known species but also supports the discovery of new species, assists in phylogenetic analyses, and enhances our understanding of evolutionary processes.

The versatility of DNA barcoding has resulted in a wide range of applications across various fields.

In environmental science, it aids in assessing biodiversity, detecting invasive species, identifying agricultural pests and disease vectors, and monitoring ecosystem health.

In industry, DNA barcoding is employed to verify the authenticity of ingredients in food, pharmaceuticals, and other products, as well as for quality control purposes.

Forensic investigators also utilize barcoding to trace the origins of samples and combat wildlife trafficking.

Hence, statements 2 and 3 are correct.

The approximation of age of plants and animals is not done using DNA barcoding. Carbon dating is used to estimate the age of fossils.

Hence, statement 1 is incorrect.

14. Consider the following statements:
1. Other than those made by humans, nanoparticles do not exist in nature.
2. Nanoparticles of some metallic oxides are used in the manufacture of some cosmetics.
3. Nanoparticles of some commercial products which enter the environment are unsafe for humans.

Which of the statements given above is/are correct?
(a) 1 only

(b) 3 only
(c) 1 and 2
(d) 2 and 3

14. Ans: d

Explanation:

Nanoparticles are particles that exist on a nanometre scale (i.e., below 100 nm in at least one dimension). They can possess physical properties such as uniformity, conductance or special optical properties that make them desirable in materials science and biology. **Naturally occurring nanoparticles can be found in volcanic ash, ocean spray, fine sand and dust, and even biological matter (e.g. viruses).**

Nanoparticles, can have the same dimensions as biological molecules such as proteins. In living systems, they may immediately adsorb onto their surface some of the large molecules they encounter as they enter the tissues and fluids of the body.

Hence, statement 1 is incorrect.

Nanotechnology has revolutionised industry. It is used to improve wide-ranging products, from cosmetics, toys and toothpastes to textiles and missiles. They are important constituents of sunscreen lotions.

Some other uses of nanoparticles:

- **Harvesting CO2:** To help slow the climate-changing rise in atmospheric CO2 levels, researchers have developed nanoCO2 harvesters that can suck atmospheric carbon dioxide and deploy it for industrial purposes or convert it into useful products like methanol.
- **Cleansing Water:** Most toxic dyes used in textile and leather industries can be captured with nanoparticles. Appropriately designed magnetic nanomaterials can be used to separate pollutants such as arsenic, lead, chromium and mercury from water. In addition to removing dyes and metals, nanomaterials can also be used to clean up oil spills.
- Nanoparticles can **accelerate the anaerobic digestion of the sludge**, thus making it more efficient in terms of duration and enhanced production of the biogas.

Hence, statement 2 is correct.

While nanoparticles have potential to solve environmental problems, the small size that makes them useful for environmental cleanup also raises special concerns about health and persistence in the environment.

Key factors in the interaction with living structures include nanoparticle dose, the ability of nanoparticles to spread within the body, as well as their solubility. Some nanoparticles dissolve easily and their effects on living organisms are the same as the effects of the chemical they are made of. However, **other nanoparticles do not degrade or dissolve readily.** Instead, they **may accumulate** in biological systems and **persist for a long time**, which makes such nanoparticles of particular concern.

Nanoparticles accumulate in the environment and kill the beneficial bacteria. Nanoparticles are released into the environment through the products they are used in like **nanoparticles of zinc and titanium oxide damage DNA in cell lines**, nanotitanium dioxide particles interfere with the genetic functioning of zebrafish embryos. ***Hence, statement 3 is correct.***

Solved UPSC Prelims S&T PYQs With Explanation 2021

There were 12 Questions from Science & Technology in 2021, of which

- **3 Questions from Bio-Technology (Vaccines, Bollgard, ACE2)**
- **1 Questions from Genetics (Mitochondrial Diseases)**
- **3 Questions from Physics (Pressure Cooker, LED, Light year)**
- **3 Questions from Chemistry (Water, BPA, Triclosan)**
- **2 Questions from Biology (Viruses, Microbial Culture)**

The level of the questions was moderate to tough.

1. With reference to recent developments regarding 'Recombinant Vector Vaccines', consider the following statements:
1. Genetic engineering is applied in the development of these vaccines.
2. Bacteria and viruses are used as vectors.
Which of the statements given above is/are correct?
(a) 1 Only
(b) 2 Only
(c) Both 1 and 2
(d) Neither 1 nor 2

1. Ans: c
Explanation:
A recombinant vaccine is a vaccine produced through recombinant DNA technology. This involves inserting the DNA encoding an antigen (such as a bacterial surface protein) that stimulates an immune response into bacterial or mammalian cells, expressing the antigen in these cells and then purifying it from them.

Hence, statement 1 is correct.

Recombinant vaccines are usually produced by benefiting from bacteria, yeast, mammalian, and insect cells. This type of vaccine requires the insertion and transference of the DNA section responsible for encoding the antigen.

Most of the recombinant vaccines developed in the recent decays are classified as recombinant protein vaccines

In some live recombinant vaccines, an attenuated virus or bacterium is used as the carrier vector. These carriers make the immune system's response very similar to that of natural infectious microorganisms. The microorganism's DNA attaches to the vector and stimulates the human immune system.

Hence, statement 2 is correct.

2. In the context of hereditary diseases, consider the following statements:
1. Passing on mitochondrial diseases from parent to child can be prevented by mitochondrial replacement therapy either before or after in vitro fertilization of egg.
2. A child inherits mitochondrial diseases entirely from mother and not from father.
Which of the statements given above is/are correct?
(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

2. Ans: c
Explanation:
Children inherit mitochondrial DNA (mDNA) exclusively from their mothers. If a mother has a mDNA mutation, there is a possibility that she may pass this mutation on to her offspring. Mitochondrial replacement therapy (MRT) is an advanced technique used in in vitro fertilisation (IVF), which involves fertilising an egg with sperm in a controlled laboratory environment. This therapy enables women with mDNA mutations to conceive and give birth to children while reducing the risk of transmitting the mutation to their descendants.

MRT is performed using one of two methods: maternal spindle transfer or pronuclear transfer.

Maternal Spindle Transfer (MST)
Maternal Spindle Transfer (MST) is an innovative reproductive technique designed to prevent the transmission of mitochondrial DNA (mDNA) mutations from a mother to her child. The process begins with a careful selection of donor eggs. Each donor egg undergoes thorough screening to ensure that it is completely free from any mDNA mutations, guaranteeing a healthy source of mitochondria.
Once a suitable donor egg is identified, the next step involves the removal of the egg's nuclear DNA (nDNA), effectively vacating the donor egg of its genetic material while preserving its healthy mitochondria. This crucial step leaves the donor egg with robust mDNA, which is essential for cellular energy production.

Following this, the mother's nDNA, which carries her genetic traits, is precisely transplanted into the now-empty donor egg. This combination creates an egg that contains the biological mother's nDNA and the donor's healthy mDNA.

The final phase of MST involves fertilizing the transformed donor egg using in vitro fertilization (IVF) techniques. Once fertilization occurs, the resulting embryo is carefully implanted into the mother's uterus, allowing for the possibility of a healthy pregnancy while minimizing the risk of passing on mitochondrial diseases.

Pronuclear Transfer (PNT)
Pronuclear Transfer (PNT) is a sophisticated reproductive technique that is akin to Maternal Spindle Transfer (MST), but it utilises an egg fertilised in a laboratory setting by the mother and father's genetic material. The process unfolds in several detailed steps:
Creation of the Lab-Fertilized Egg: Initially, a lab-fertilized egg is formed by combining the biological mother's egg with sperm from the biological father. This step ensures that the resulting zygote contains the intended nuclear DNA (nDNA) from both parents.

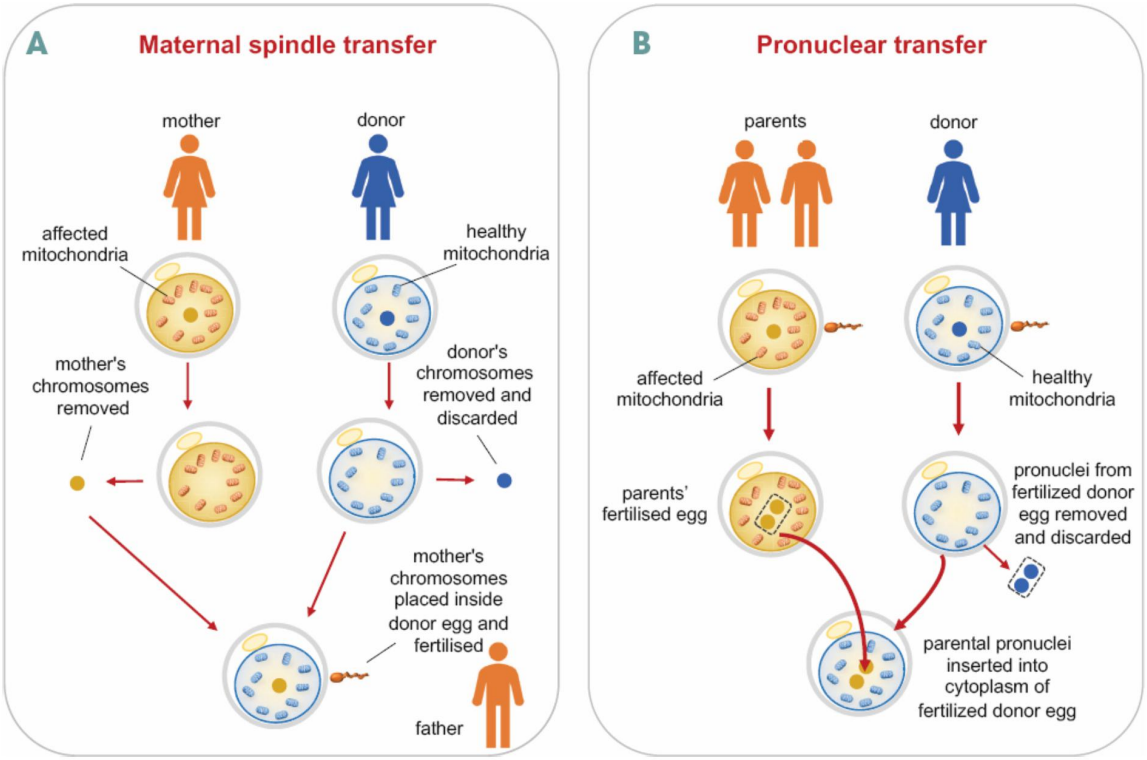
Selection of a Donor Egg: Next, a suitable donor egg is meticulously selected. This egg must be screened thoroughly to guarantee it is devoid of any mitochondrial DNA (mDNA) mutations, ensuring the highest chances of a healthy pregnancy.

Removal of Donor nDNA: The selected donor egg, which possesses healthy mDNA, undergoes a process where its nDNA is carefully extracted. This step is crucial, as it prepares the donor egg to receive the genetic material from the lab-fertilized egg without introducing any foreign nuclear DNA.

Transplantation of nDNA: Following the extraction, the nDNA from the lab-fertilized egg is transplanted into the donor egg. This action effectively reconstitutes the egg with the biological parents' genetic information while retaining the donor's healthy mDNA.

Implantation into the Mother's Uterus: Finally, the reconstructed egg is implanted into the biological mother's uterus through in vitro fertilisation (IVF). This step marks the culmination of the PNT process, with the hope of achieving a successful pregnancy.

Through these carefully orchestrated steps, Pronuclear Transfer aims to provide couples with the opportunity to conceive healthy children while minimising the risk of inherited mitochondrial diseases.



Mitochondrial Inheritance

Mitochondria are organelle present in the cytoplasm of the cells which are primarily responsible for energy production for all cellular activities.

Mitochondria contain their own distinct DNA, called mitochondrial DNA (mtDNA), which directs mitochondrial activities. Mitochondrial DNA has the same molecular structure and function as the DNA found in the nucleus, but it's organized somewhat differently

All cells contain several hundred of these oval-shaped structures that convert energy (derived from the breakdown of nutrients) to a form that can be used by cells.

Each mitochondrion contains several copies of a ring-shaped DNA molecule, or chromosome. While mitochondrial DNA (mtDNA) is distinct from chromosomal DNA, its molecular structure and functions are the same. The entire molecule has been sequenced and is known to contain around 40 genes that direct the conversion of energy within cells.

Like the DNA in a cell's nucleus, mtDNA is subject to mutations, and some of these mutations cause certain genetic disorders that result from impaired energy conversion.

Importantly, animals of both sexes inherit all their mtDNA, and thus all mitochondrial traits, from their mothers. Because mtDNA is inherited from only one parent, meiosis and recombination don't occur.

Hence, option c is correct.

3. Bollgard I and Bollgard II technologies are mentioned in the context of
(a) clonal propagation of crop plants
(b) developing genetically modified crop plants
(c) production of plant growth substances
(d) production of biofertilizers

3. Ans: b
Explanation:
Bollgard® cotton is the trademark given to a number of varieties of cotton bio-engineered to produce an insecticidal protein **Cry1Ac** from Bacillus thuringiensis (Bt). When produced by the modified cotton plants, this protein controls certain lepidopterous cotton insect pests.

This product has reduced cotton production costs and insecticide use by providing an effective alternative to chemical insecticides for the control of tobacco budworm, Heliothisvirescens; cotton bollworm, Helicoverpa zea; and pink bollworm, Pectinophora gossypiella

Bollgard, cotton, bio-engineered to resist lepidopterous insect pests, has had a dramatic effect on cotton production.

The product concept

Bacillus thuringiensis (Bt), a microorganism found in soil,was known to produce a potent, specific and safe protein insecticide Cry1Ac). This protein was well characterized, considered safe, and specific to the lepidopterous class of insects.

By introducing the genetic information encoding the insecticidal protein of Bt into plants, these plants would produce their own insecticide. This simple concept promised to reduce insecticide applications, improve insect control, and provide opportunities for aggressive integrated pest management systems while maintaining the inherent safety of this insecticidal protein.

Bollgard(®) cotton, expresses **Cry1Ac** insecticidal protein.

Bollgard® II cotton was developed by inserting the **cry2Ab** gene into DP50B Bollgard cotton containing the cry1Ac gene.

Tobacco budworm, cotton bollworm and pink bollworm are more susceptible to the Cry1Ac protein than to Cry2Ab, whereas fall armyworm, beet armyworm, cabbage looper and soybean looper are more susceptible to Cry2Ab than to Cry1Ac.

Bollgard I and II are approved in India.

In India Bt cotton is the only genetically modified (GM) crop that was approved for commercial cultivation in 2002.

Hence, option b is correct.

4. In a pressure cooker, the temperature at which the food is cooked depends mainly upon which of the following?
1. Area of the hole in the lid
2. Temperature of the flame
3. Weight of the lid

Select the correct answer using the code given below.
(a) 1 and 2 Only
(b) 2 and 3 Only
(c) 1 and 3 Only
(d) 1, 2 and 3

4. Ans: c

Explanation:

According to the principle of **Gay-lussac's Law**, P1/T1=P2/T2 i.e pressure and temperature are directly related. As pressure increases in the cooker, temperature also will naturally increase.

According to the **Ideal Gas Law PV=nRT**, as pressure increases, temperature must also increase to balance out the equation on both sides.

The pressure cooker works on the principle of increasing the internal pressure. Locking lids and the valve system release and regulate pressure in a pressure cooker.

As pressure increases inside the cooker, the high-pressure gas moves around the food and the food is cooked through convection.

Thus, the temperature at which the food is cooked depends mainly upon internal pressure which is regulated by the lid and valve but not the temperature of the flame.

Hence, option c is correct.

5. Consider the following:
1. Bacteria
2. Fungi
3. Virus

Which of the above can be cultured in an artificial /synthetic medium?
(a) 1 and 2 Only
(b) 2 and 3 Only
(c) 1 and 3 Only
(d) 1, 2 and 3

5. Ans: a

Explanation:

Microbes are diverse–protozoa, bacteria, fungi and microscopic animal and plant viruses, viroids and also prions that are proteinacious infectious agents.

Bacteria

Bacteria are the sole members of the Kingdom Monera. They are the most abundant micro-organisms. Bacteria occur almost everywhere. They also live in extreme habitats such as hot springs, deserts, snow and deep oceans where very few other life forms can survive. Many of them live in or on other organisms as parasites. **Bacterial culture was the first method developed to study the human microbiota,** using an artificial medium that allows the growth and isolation of bacteria. The first to have cultured a bacterium in a reproducible way was Louis Pasteur in 1860.

Viruses

Viruses are microscopic organisms that are dead outside a living cell. They reproduce only inside the cells of the host organism, which may be a bacterium, plant, or animal. **Viruses cannot be cultured synthetically.**

Fungi

The fungi constitute a unique kingdom of heterotrophic organisms. They show a great diversity in morphology and habitat. Some unicellular fungi, e.g., yeast are used to make bread and beer. Other fungi cause diseases in plants and animals; some are the source of antibiotics. Fungi are cosmopolitan and occur in air, water, soil and on animals and plants. They prefer to grow in warm and humid places. With the exception of yeasts which are unicellular, fungi are filamentous.

There are two general types of fungal culture media: natural and synthetic. Fungi can also be cultured synthetically. Media containing high carbohydrate source, nitrogen source are required for the growth of fungi at pH range of 5 to 6, and a temperature range from 15 to 37˚.

Hence, option a is correct.

6. Consider the following statements:
1. Adenoviruses have single-stranded DNA genomes whereas retroviruses have double stranded DNA genomes.

2. Common cold is sometimes caused by an adenovirus whereas AIDS is caused by a retrovirus.
Which of the statements given above is/are correct?
(a) 1 Only
(b) 2 Only
(c) Both 1 and 2
(d) Neither 1 nor 2

6. Ans: b
Explanation:
Adenovirus

Adenoviruses are non-enveloped, **double-stranded DNA viruses.** People with weakened immune systems are at high risk for developing severe illness caused by adenovirus infection.

Adenoviruses most commonly cause respiratory illness. The illnesses can range from the common cold to pneumonia, croup, and bronchitis. Depending on the type, adenoviruses can cause other illnesses such as gastroenteritis, conjunctivitis, cystitis, and, less commonly, neurological disease.

Retrovirus

Retroviruses are linear **single stranded RNA viruses** with a lipid containing glycoprotein viral envelope. After infecting a cell, a retrovirus uses an enzyme called reverse transcriptase to convert its RNA into DNA. The retrovirus then integrates its viral DNA into the DNA of the host cell, which allows the retrovirus to replicate. **HIV, the virus that causes AIDS, is a retrovirus.**

Hence, statement 1 is incorrect & statement 2 is correct.

7. Water can dissolve more substances than any other liquid because:
(a) it is dipolar in nature
(b) it is a good conductor of heat
(c) it has high value of specific heat
(d) it is an oxide of hydrogen

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

Unique features of Water:

1. It exists as a liquid over a wide range of temperature i.e from 0^0 to 100^0C.
2. It has the **highest specific heat,** due to which it warms up and cools down very slowly without causing shocks of temperature jerks to the aquatic life.

3. It has a **high latent heat of vaporisation**. Hence, it takes a huge amount of energy for getting vaporised. That's why it produces a cooling effect as it evaporates.
4. It is an excellent solvent for several nutrients. Thus, it can serve as a very good carrier of nutrients, including oxygen, which are essential to life. But, it can also easily dissolve various pollutants and become a carrier of pathogenic microorganisms.
5. Due to **high surface tension and cohesion** it can easily rise through great heights through the trunk even in the tallest of the trees like Sequoia.
6. It has an **anomalous expansion behaviour** i.e as it freezes, it expands instead of contracting and thus becomes lighter. It is because of this property that even in the extreme cold, the lakes freeze only on the surface. Being lighter the ice keeps floating whereas the bottom waters remain at a higher temperature and therefore, can sustain aquatic organisms even in extreme cold.

Hence, option a is correct.

8. With reference to street lighting, how do sodium lamps differ from LED lamps?
1. Sodium lamps produce light in 360 degrees but it is not so in the case of LED lamps.
2. As street-lights, sodium lamps have longer life span than LED lamps.
3. The spectrum of visible light from sodium lamps is almost monochromatic while LED lamps offer significant colour advantages in street lighting.
Select the correct answer using the code given below
(a) 3 only
(b) 2 only
(c) 1 and 3
(d) 1, 2 and 3

8. Ans: c
Explanation:
LEDs emit light in a specific direction, reducing the need for reflectors and diffusers that can trap light. The light **of sodium vapor lights is omnidirectional, 360 degrees** of light are produced using omnidirectional lighting. **LED lights produce 180 degrees of light**. Since light is frequently needed over a target region, this is usually advantageous (rather than all 360 degrees around the bulb).

Hence, statement 1 is correct.

Compared to all other lighting technologies, LEDs have a very long lifespan. New LEDs have a lifespan of at least 100,000 to 150,000 hours. So the lifespan of LED street lights is also very long. Sodium lamps fall well short of LEDs in lifespan, its life span is 18000 hours.

Hence, statement 2 is incorrect.

A **sodium-vapor lamp** is a gas-discharge lamp that uses sodium in an excited state to produce **monochromatic light at a characteristic wavelength near 589 nm**. Two varieties of such lamps exist: low-pressure and high-pressure.

LEDs can **emit light in a range of colours. A mix of red, green, and blue LEDs is sometimes used to make white light.**

Hence, statement 3 is correct.

9. The term 'ACE2' is talked about in the context of:
(a) genes introduced in the genetically modified plants
(b) development of India's own satellite navigation system
(c) radio collar for wildlife tracking
(d) spread of viral diseases

9. Ans: d
Explanation:
The **angiotensin-converting enzyme 2 (ACE2)** is a protein that has different roles such as catalytic, transporter of amino acids or viral receptor. It has an essential role in different systems, from cardiovascular regulation to viral infection.

The ACE attaches to cell membranes and works as the host functional receptor for the virus SARS-CoV-2 which causes Coronavirus Disease 2019 (COVID-19).

The SARS-CoV and the SARS-CoV-2 enter the human cell through the ACE2 receptor.

These two viruses have a surface anchored Spike (S) glycoprotein with surfaces receptor binding domains (RBD).

These two structures are critical for the entrance of the virus into the human cell. When the genetic material of the virus enters the cell, the membrane of the virus fusions with the host membrane cells.

SARS-CoV-2 has a significantly higher ACE2 binding affinity.

The 3-dimensional structure of the SARS-CoV-2 binding site has a more compact conformation, improved binding stability, and potentially enhances the ACE2 receptor binding affinity.

ACE2 expression

ACE2 is widely expressed in many different cells of the body.

It was observed to be highly expressed in endocrine tissues, gastrointestinal tract (e.g. ileum, liver and gallbladder), cardiovascular tissues, kidney and urinary bladder, testes and muscle tissues.

It was observed that central nervous system and lymphoid tissues express relatively low ACE2 levels.

They found that that the receptor it is not expressed in red blood cells.

In the lung, high mRNA ACE2 expression was detected in the parenchyma and in primary and tertiary bronchi. Relevant for the transmission and respiratory manifestations of SARS-CoV-2

Hence, option d is correct.

10. Bisphenol A (BPA), a cause of concern, is a structural/key component in the manufacture of which of the following kinds of plastics?
(a) Low-density polyethylene

(b) Polycarbonate
(c) Polyethylene terephthalate
(d) Polyvinyl chloride

10. Ans: b

Explanation:

PC (polycarbonate) has good transparency and average thermal stability, It also belongs to engineering plastics, such as organic glass, such as polymethyl methacrylate, polycarbonate, etc.

PC is a widely used material, such as phone cases, laptops, etc. It is particularly used in the manufacturing of baby bottles, space cups, etc. In recent years, milk bottles have been controversial due to their presence of bisphenol A. The residual bisphenol A in PC releases more and faster at higher temperatures. Therefore, PC water bottles should not be used to hold hot water.

Bisphenol A (BPA) is a banned in many countries in food contact materials, due to its potentially harmful health impact. The ban means that BPA will not be allowed in products that come into contact with food or drink, such as the coating on metal cans, reusable plastic drink bottles, water distribution coolers and other kitchenware.

BPA is a high production volume (HPV) chemical widely used in manufacturing polycarbonate plastics and epoxy resins used in nearly every industry. Humans appear to be exposed primarily through food packaging manufactured using BPA

Bureau of Indian Standards (BIS) banned the use of chemical Bisphenol A (BPA) in the manufacture of infant feeding bottles.

Hence, option b is correct.

11. Triclosan considered harmful when exposed to high levels for a long time, is most likely present in which of the following?

(a) Food preservatives
(b) Fruit-ripening substances
(c) Reused plastic containers
(d) Toiletries

11. Ans: d

Explanation:

Triclosan is an a**ntimicrobial active ingredient** used in several consumer products to in**crease their shelf life by stopping the growth of unwanted micro-organisms (**bacteria, fungi, protozoa, etc), which might degrade the product.

A wide range of consumer products contain triclosan. More than **80% of triclosan usage is in personal care products, cosmetics and household cleaning products**. These products contain between 0.1% and 0.3% triclosan. These items include:

- Fluoride toothpaste.
- Mouthwashes.

- Facial cleansers.
- Aftershave.
- Deodorants and body sprays.
- Lotions and creams.
- Cosmetics.
- Detergents and dishwashing liquids.
- Triclosan is part of other materials, including pesticides and textiles.
- Clothing, shoes, carpeting, furniture, toys and kitchenware all contain the ingredient.

In **2016, the U.S. Food and Drug Administration (FDA) banned the sale of consumer antiseptic wash products (soaps and body washes)** containing triclosan.

However, **India lacks any such regulation so far** on the use of trichlosan used products. The US FDA had banned triclosan from consumer anti bacterial soaps and body washes.

What are the side effects of triclosan?

Triclosan is an **endocrine-disrupting chemical.** That means it can harm endocrine system, leading to issues with proper hormone function. Exposure to the ingredient is of particular c**oncern to females**. That's because it **can cross the placenta and enter breast milk.**

When a product containing triclosan is used, the body can absorb small amounts of it and the skin or mouth can absorb the ingredient within one to four hours.

Hence, option d is correct.

12. Which one of the following is a reason why astronomical distances are measured in light years?
(a) Distances among stellar bodies do not change.
(b) Gravity of stellar bodies does not change.
(c) Light always travels in a straight line.
(d) Speed of light is always the same.

12. Ans: d
Explanation:
Light-year is the distance that light travels in one year. Light travels through interstellar space at 300,000 kilometers per second and 9.46 trillion kilometers per year in vacuum. The basic postulate of the **'theory of relativity'** is that the **speed of light is same in all inertial frames**. This can be broken down into two parts:

- The speed of light is independent of the motion of the observer.
- The speed of light does not vary with time or place.

The distances between the stellar bodies are very large. These bodies too are moving apart continuosly as the Universe is expanding. Therefore these above stated properties of light are the reasons that light is used to measure such large interstellar distances in light years.

Hence, option d is correct

Solved UPSC Prelims S&T PYQs With Explanation 2020

There were 13 Questions from Science & Technology in 2020, of which

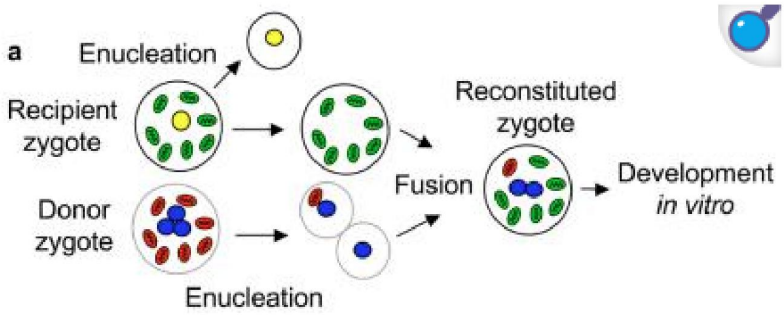
- **3 Questions from Computing (AI, PKI, Block Chain)**
- **2 Questions from Genetics (Pronuclear Transfer, Gene Editing)**
- **3 Questions from Physics (VLC, Drones, Solar Water Pumps)**
- **1 Questions from Energy (IAEA Safeguards)**
- **1 Question from Biology (Plant & Animal Cell)**
- **1 Question from Chemistry (CNTs)**
- **1 Question from Space (Evolved LISA)**
- **1 Question from Bio-Technology (Vaccines)**

The level of the questions was moderate to tough.

1. In the context of recent advances in human reproductive technology, "Pronuclear Transfer" is used for:
(a) Fertilisation of egg in vitro by the donor sperm
(b) Genetic modification of sperm-producing cells
(c) Development of stem cells into functional embryos
(d) Prevention of mitochondrial diseases in offspring

1. Ans: d
Explanation:
Mitochondrial DNA (mtDNA) mutations are a common cause of genetic disease with pathogenic mtDNA mutations. MtDNA is transmitted maternally only and it has been proposed that nuclear transfer techniques may be an approach to prevent the transmission of human mtDNA disease

Pronuclear transfer program is a reproductive method of transferring the nuclear DNA of a fertilized egg into a donor egg from which nuclea DNA has been removed. This technique is used to prevent maternally inherited mitochondrial DNA abnormalities.



Hence, option d is correct.

2. With the present state of development, Artificial Intelligence can effectively do which of the following?

1. Bring down electricity consumption in industrial units
2. Create meaningful short stories and songs
3. Disease diagnosis
4. Text-to-Speech Conversion
5. Wireless transmission of electrical energy

Select the correct answer using the code given below:

(a) 1, 2, 3 and 5 only
(b) 1, 3 and 4 only
(c) 2, 4 and 5 only
(d) 1, 2, 3, 4 and 5

2. Ans: b

Explanation:

Artificial intelligence is a field of science concerned with building computers and machines that can reason, learn, and act in such a way that would normally require human intelligence or that involves data whose scale exceeds what humans can analyze.

AI is a set of technologies that are based primarily on machine learning and deep learning, used for data analytics, predictions and forecasting, object categorization, natural language processing, recommendations, intelligent data retrieval, and more.

Applications and use cases for artificial intelligence

- **Speech recognition:** Automatically convert spoken speech into written text.
- **Image recognition**
- **Translation:** Translate written or spoken words from one language into another.
- **Predictive modeling:** Mine data to forecast specific outcomes with high degrees of granularity.
- **Data analytics:** Find patterns and relationships in data for business intelligence.
- **Cybersecurity:** Autonomously scan networks for cyber attacks and threats.
- **Reduce emission:** Reports predict that AI has the potential to help mitigate 5-10% of global GHG emissions by 2030
- **Reduce energy demand:** Computer chip maker Nvidia claims its new 'superchip' can deliver a 30 times performance improvement when running generative AI services, while using 25 times less energy.
- Artificial intelligence techniques ranging from machine learning to deep learning are prevalent in **healthcare for disease diagnosis, drug discovery, and patient risk identification.**

AI doesn't have the ability to truly innovate or think creatively--- it can only rearrange and analyze existing information.

Hence, statement 2 is incorrect.

Wireless power transmission (WPT)

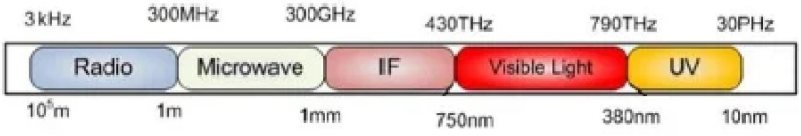
- **It** is the efficient transmission of electric power from one point to another through vacuum or an atmosphere without the use of wire or any other substance.
- This can be used for applications where either an instantaneous amount or a continuous delivery of energy is needed, but where conventional wires are unaffordable, inconvenient, expensive, hazardous, unwanted or impossible.
- The p**ower can be transmitted using inductive coupling for short range, resonant induction for mid range and electromagnetic wave power transfer for high range.**
- One of the major drawbacks in current power distribution system is the losses during the transmission of electrical energy. As the demands of power are increasingconveniently, power generation also increases and this leads to increase power loss during transmission.
- **So, AI is not used in wireless power transmission. Hence Statement 5 is incorrect.**

Hence, only statement 1,3 and 4 are correct.

3. With reference to Visible Light Communication (VLC) technology, which of the following statements are correct?
1. VLC uses electromagnetic spectrum wavelengths 375 to 780 nm
2. VLC is known as long-range optical wireless communication.
3. VLC can transmit large amounts of data faster than Bluetooth
4. VLC has no electromagnetic interference

Select the correct answer using the code given below:
(a) 1, 2 and 3 only
(b) 1, 2, and 4 only
(c) 1, 3 and 4 only
(d) 2, 3, and 4 only

3. Ans: c
Explanation:



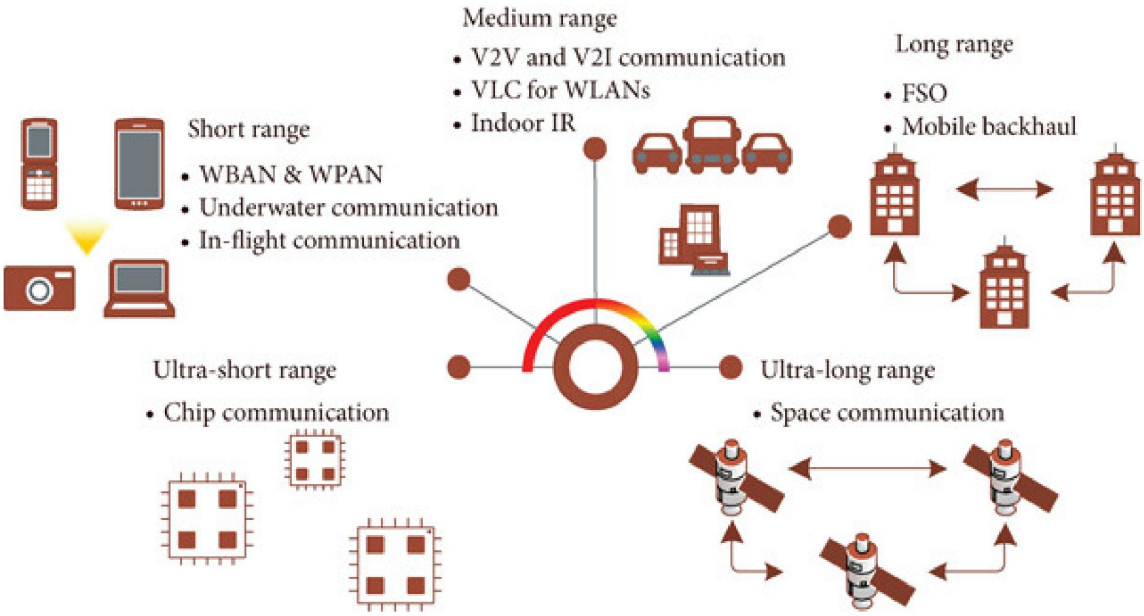
Optical wireless communication (OWC)

Conventional radio frequency (RF) technique which has a regulated and licensed electromagnetic spectrum band, spanning from **30 kHz to 300 GHz.** Due to an exponential increase in the wireless data traffic and advanced mobile devices, there are calamities that are emerging within the RF band.

This increase leads to spectral crisis such as congestion and maximum data rates that are low relative to OWC. Recent developments and standardization of various RF technologies are not able to overcome these looming crisis

OWC spectral band is between 300 GHz and 30 000 THz (wavelength between 1 mm and 10 nm) of the electromagnetic spectrum, covering the **infrared (IR), visible light, and ultraviolet (UV) light bands**

OWC technology has an edge over the RF technology due to various factors. These factors include but are not limited to high energy efficiency, widely spread bandwidth which is free from regulation, intrinsic security, and low economical costs.



The categories are briefly explained by giving examples of OWC applications.

- **Ultrashort range category** (typically about a range of 100 or less), OWC is used for optical communication between and within chips of integrated circuits (ICs).
- **Short-range category** (typically within a distance of about 1 m), OWC is used to create communication links between the ever-present electronic equipment for daily use. The said equipment form the wireless personal area networks (WPANs). Such networks wirelessly interconnect electronic devices that are used around an individual's personal work space. Moreover, the short range is used for the establishment of wireless body area networks (WBANs). WBAN is a network, which continually monitors the health of a patient by means of embedding one or more electronic devices within the body or surface mounting the device at a specific body part.

- **Medium-range category** (typically up to 10 km) is concerned with, but not limited to, indoor infrared and communication within the visible light spectrum band which is commonly known as visible light communication (VLC).
- **Long-range category Free-space optical communication (FSO**) communication which is also referred to as outdoor intrabuilding links, FSO communication, maximum data transfer rates up to 2.5 Gbps is possible, unlike the maximum data transfer rates of 622Mbps offered by RF

  communication systems. FSO involves the optical transmission of voice, video, and data using **air as the medium of transmission.**

- **Ultralong range** category (typically 4500 km to 10,000 km) is concerned with laser communication in space for intersatellite links.

In RF wireless communication systems, the scramble for spectrum is increasing by a very high magnitude yearly . To complement the conventional RF wireless communication systems is to explore other frequency bands in the electromagnetic spectrum, specifically the visible light band. This shift has led to the discovery of a potential and favorable wireless communication technique commonly referred to as VLC.

VLC constitutes optical links, which enable visible light sources to be employed for transmission of data using air as the transmission medium. VLC technology uses visible light part of the light spectrum. It uses wavelength range from 380 nm to 750 nm (i.e. frequency range from 430 THz to 790 THz) for communication.

For indoor application, the idea is that the existing illuminating devices are utilized to transmit data using the same energy which is being used for illumination. VLC is considered to be a medium-range communication technique. This is by virtue of propagation distance which is limited by the luminaries which in most cases are white light-emitting diodes (WLEDs).

Visible Light Communication (VLC) technology:

- The **Visible Light Communication (VLC) technology uses light instead of radio frequency signals to transmit the data**.
- The VLC technology uses the visible light spectrum (380 to 750 nanometers) to transmit data across a wireless network of communication.
- VLC-based networks can be used to provide fast, and highly stable internet connections in smaller coverage zones of offices and homes.
- The objective of VLC is t**o increase data rates in wireless communication and to have better performance of networks especially for indoor networks using light emitting diode (LED),** lamps.
- LiFi or light fidelity is a subtype of VLC technology that uses light waves in the visible/invisible/infrared spectrum to transmit data. Harald Haas first introduced it in his 2011.
- Bluetooth has a transfer rate of up to 2.1 Mbps, while Lifi has the data transmission rate up to 224 Gbps.

A comparison between VLC and RF technologies

- VLC offers a wireless communication service with an enormous bandwidth capable of transmitting at very high data rates. The VLC bandwidth is approximately **ten thousand folds that of the entire RF bandwidt**h.
- The luminaires used for VLC systems are energy efficient as they use less power despite their high light intensity, and they also come at a very low cost.
- The VLC systems are **much safer compared to RF systems** in the sense that there are minimal or no medical health complications caused by visible light. Emissions from RF equipment and devices may be harmful to humans and medical equipment if the radiation power exceeds a particular measure.
- In VLC systems, there is no requirement for sophisticated antennas to transmit data from the light source through the air.
- One more factor that makes VLC systems attractive over RF systems is that they have intrinsic security. The control of transmitted data in the physical layer is simple as communication is commonly in line of sight (LoS). This avoids invasion of the communication system by passive eavesdroppers.
- In contrast to RF, visible light is **not capable of penetrating solid surfaces such as walls.** The incapability of wall penetration enables the creation of small cells to transmit without interference between cell locations (i.e., intercell interference).
- RF communications are prone to problems, such as lack of spectrum resources, **electromagnetic interference** , VLC employs the unlicensed frequency spectrum resources at 400–800 THz , which can provide a high data transmission rate and a **strong resistance to electromagnetic interferences**
- Dueto its appealing advantages, including abundant and unregulated spectrum resources, no electromagnetic interference (EMI) radiation and high security, visible light communication (VLC) using light-emitting diodes (LEDs) or laser diodes (LDs) has been envisioned as one of the key enabling technologies for 6G and Internet of Things (IoT) systems.

Hence, statement 2 is incorrect and 1, 3 and 4 are correct.

4. With reference to "Blockchain Technology" consider the following statements:
1. It is a public ledger that everyone can inspect but which no single user controls.
2. The structure and design of the blockchain is such that all the data in it are about cryptocurrency only.
3. Applications that depend on the basic features of blockchain can be developed without anybody's permission.
Which of the statements given above is/are correct?
(a) 1 only
(b) 1 and 2 only
(c) 2 only
(d) 1 and 3 only

4. Ans: d
Explanation:
Blockchain is a shared, immutable ledger that facilitates the process of recording transactions and tracking assets in a business network.

An asset can be tangible (a house, car, cash, land) or intangible (intellectual property, patents, copyrights, branding). Virtually anything of value can be tracked and traded on a blockchain network, reducing risk and cutting costs for all involved.

Bitcoin is an unregulated, digital currency. Bitcoin uses blockchain technology as its transaction ledger.

Hence, statement 2 is incorrect.

Blockchain is ideal for delivering that information because it provides immediate, shared, and observable information that is stored on an immutable ledger that only permissioned network members can access. A blockchain network can track orders, payments, accounts, production and much more. And because members share a single view of the truth, you can see all details of a transaction end to end, giving you greater confidence, and new efficiencies and opportunities.

Key elements of a blockchain

Distributed ledger technology **All network participants have access to the distributed ledger** and its immutable record of transactions. With this shared ledger, transactions are recorded only once, eliminating the duplication of effort that's typical of traditional business networks.

Immutable records

No participant can change or tamper with a transaction after it's been recorded to the shared ledger. If a transaction record includes an error, a new transaction must be added to reverse the error, and both transactions are then visible.

Smart contracts

To speed transactions, a set of rules that are called a smart contract is stored on the blockchain and run automatically. A smart contract defines conditions for corporate bond transfers, include terms for travel insurance to be paid and much more.

Hence, statement 1 is correct.

How blockchain works

- As each transaction occurs, it is recorded as a "block" of data
- Those transactions show the movement of an asset that can be tangible (a product) or intangible (intellectual).
- The data block can record the information of your choice: who, what, when, where, how much. It can even record the condition, such as the temperature of a food shipment.
- Each block is connected to the ones before and after it
- These blocks form a chain of data as an asset moves from place to place or ownership changes hands.
- The blocks confirm the exact time and sequence of transactions, and the blocks link securely together to prevent any block from being altered or a block being inserted between two existing blocks.
- Transactions are blocked together in an irreversible chain: a blockchain
- Each additional block strengthens the verification of the previous block and hence the entire blockchain. Rendering the blockchain tamper-evident, delivering the key strength of

immutability. Removing the possibility of tampering by a malicious actor, and builds a ledger of transactions you and other network members can trust.

Benefits of blockchain

Greater trust

With blockchain, as a member of a members-only network, you can rest assured that you are receiving accurate and timely data. And that your confidential blockchain records are shared only with network members to whom you granted access.

Greater security

Consensus on data accuracy is required from all network members, and all validated transactions are immutable because they are recorded permanently. No one, not even a system administrator, can delete a transaction.

More efficiencies

With a distributed ledger that is shared among members of a network, time-wasting record reconciliations are eliminated. And to speed transactions, a set of rules that are called a smart contract can be stored on the blockchain and run automatically.

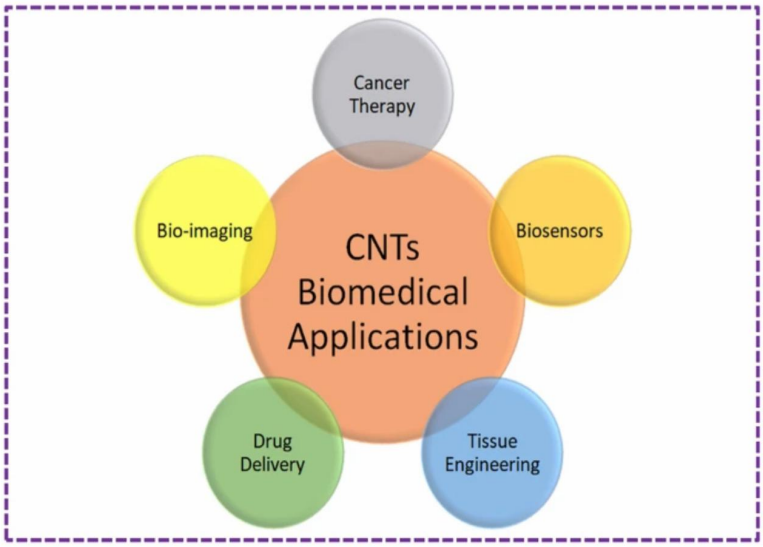
Many blockchains are entirely open source. This means that everyone can view its code. This gives auditors the ability to review. However, it also means there is no real authority on who controls the source code or how it is edited. Because of this, anyone can suggest changes or upgrades to the system.

Hence, statement 3 is correct.

5. When reference to carbon nanotubes, consider the following statements:
1. They can be used as carriers of drugs and antigens in the human body.
2. They can be made into artificial blood capillaries for an injured part of the human body.
3. They can be used in biochemical sensors.
4. Carbon nanotubes are biodegradable.

Which of the statements given above are correct?
(a) 1 and 2 only
(b) 2, 3 and 4 only
(c) 1, 3 and 4 only
(d) 1, 2, 3 and 4

5. Ans: c
Explanation:



Carbon nanotubes (CNTs) are carbon-based nanomaterials with a tubular structure composed of rolled up graphene sheets. These tubes can consist of single or multiple graphene layers. CNTs share the same π-bond character as graphene, allowing electrons to be delocalized throughout the structure.

Carbon Nanotubes Uses and Applications

- Automotive parts
- Electronics: circuitry, batteries, supercapacitors
- Photovoltaic technology - including solar panels, LEDs, sensors, transistors, field emitting devices, fuel cells, actuators (devices that power physical movement)
- Absorbents
- Catalysts
- Biomedicine: drug delivery, biosensing, bioimaging, nanorobotics, gene therapy and tissue regeneration (Biosensors are devices used to detect the presence or concentration of a biological analyte, such as a biomolecule, a biological structure or a microorganism.)
- Agriculture: bioremediation, water purification
- Carbon nanotubes can be added to a material or substance (nanocomposite) to enhance strength. This is useful, for example, in the manufacture of sportswear, or materials used in the deflection of projectiles including bullet-proof vests.

The greatest concern about the risk of CNTs is related to their unique physicochemical nature: specifically, these materials are extremely stable and difficult to degrade. Historically, it was widely accepted that CNTs could only be chemically degraded by strong oxidants or heat treatment in oxygen .In 2008, however, a pioneering study showed for the first time that **CNTs could be biodegraded** through enzymatic oxidation by horseradish peroxidase (HRP).

Capillary blood vessels are minute blood vessels, 5–10 µm in diameter, carrying blood from arterioles to venules.The capillaries are very thin and form a fine network called a capillary bed.

Limitations with carbon nanotubes

An important discovery has been made about the safety issues of using carbon nanotubes as biomaterials which come into contact with blood. When blood comes into contact with foreign surfaces the blood's platelets are activated which in turn leads to blood clots being formed. They found that the carbon nanotubes did actually stimulate blood platelet activation, subsequently leading to serious and devastating blood clotting.

This can be catastrophic in clinical settings.

Hence, option c is correct.

6. Consider the following activities:
1. Spraying pesticides on a crop field
2. Inspecting the craters of active volcanoes
3. Collecting breath samples from spouting whales for DNA analysis.

At the present level of technology, which of the above activities can be successfully carried out by using drones?
(a) 1 and 2 only
(b) 2 and 3 only
(c) 1 and 3 only
(d) 1, 2 and 3

6. Ans: d

Explanation:

Drones can be used to spray chemicals like fertilizers, pesticides, etc. based on the spatial variability of the crops and field. The amount of chemicals to be sprayed can be adjusted depending upon the crop conditions, or the degree of severity of the insect-pest attack. In this way, drones pave the pathway to precision agriculture.

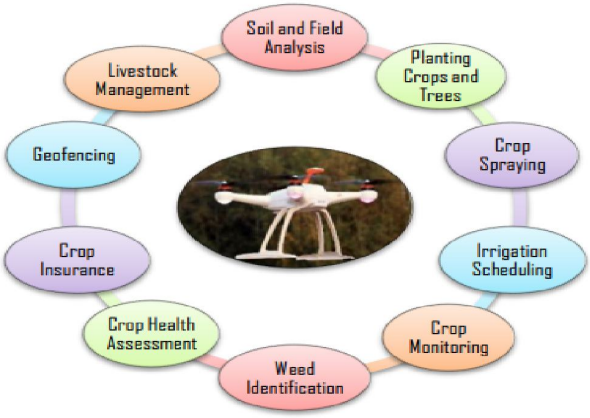


Figure 2. Applications of drones in agriculture

A drone, or unmanned aerial vehicle (UAV), is a remote-controlled device that allows a pilot to remain a safe distance from an active crater while the drone is maneuvered to the site of interest. Drones can be piloted manually or with an autonomous navigation system. Compact gas sensors can be mounted onto the drone that take measurements while the drone is in the air.

The concentrations of carbon dioxide (CO_2), sulfur dioxide (SO_2), and hydrogen sulfide (H_2S) can be measured by flying the drone right into the plume of gas as it emerges from the volcano.

The breath samples provided scientists with DNA and hormone and bacteria measurements. The breath samples provided scientists with DNA and hormone and bacteria measurements

Hence, statements 1, 2, 3 are correct.

7. The experiment will employ a trio of spacecraft flying in formation in the shape of an equilateral triangle that has **sides one million kilometers long, with lasers shining between the craft. The experiment in question refers to**
(a) Voyager-2
(b) New Horizons
(c) LISA Pathfinder
(d) Evolved LISA

7. Ans: d
Explanation:
The **evolved Laser Interfermoter Space Antenna (eLISA**) is a mission aiming at exploring the **Gravitational Universe from space for the first time.** It involves scientists from eight European countries – Denmark, France, Germany, Italy, The Netherlands, Spain, Switzerland, and the UK – as well as the support of several US-based ones.

The eLISA mission consists of a "Mother" and two "Daughter" spacecrafts. These will orbit the Sun in a triangular configuration. The three satellites will form a precision interferometer, with the two Daughter spacecrafts connected to the Mother one by 1 million km long laser beams. This interferometer will be capable of detecting gravitational waves at frequencies in the range of 0.1 mHz to 1 Hz. Such a frequency interval is not accessible on Earth due to arm length limitations and to noise caused by the terrestrial gravity gradient noise: in this sense, eLISA will complement the efforts of ground-based gravitational-wave detectors.

What are Gravitational Waves?
A gravitational wave is an invisible (yet incredibly fast) ripple in space.

More than 100 years ago,Albert Einstein came up with many ideas about gravity and space.

Einstein predicted that something special happens when two bodies—such as planets or stars—orbit each other. He believed that this kind of movement could cause ripples in space. These ripples would spread out like the ripples in a pond when a stone is tossed in. Scientists call these ripples of space gravitational waves.

Gravitational waves are invisible. However, they are incredibly fast. They travel at the speed of light (186,000 miles per second). Gravitational waves squeeze and stretch anything in their path as they pass by.

What causes gravitational waves?
The most powerful gravitational waves are created when objects move at very high speeds. Some examples of events that could cause a gravitational wave are:

- when a star explodes asymmetrically (called a supernova)
- when two big stars orbit each other
- when two black holes orbit each other and merge

But these types of objects that create gravitational waves are far away. And sometimes, these events only cause small, weak gravitational waves. The waves are then very weak by the time they reach Earth. This makes gravitational waves hard to detect.

How do we know that gravitational waves exist?

In 2015, scientists detected gravitational waves for the very first time. They used a very sensitive instrument called LIGO (Laser Interferometer Gravitational-Wave Observatory). These first gravitational waves happened when two black holes crashed into one another. The collision happened 1.3 billion years ago. But, the ripples didn't make it to Earth until 2015!

What do Gravitational Waves tell us?

Gravitational waves are a powerful new probe of the Universe that uses gravity instead of light to take measure of dynamical astrophysical phenomena. Studying gravitational waves gives enormous potential for discovering the parts of the universe that are invisible by other means, such as black holes, the Big Bang, and other, as yet unknown, objects.

LISA (Laser Interferometer Space Antenna) Pathfinder

ESA's (European Space Agency) LISA (Laser Interferometer Space Antenna) Pathfinder spacecraft demonstrated technologies required for LISA, a future space probe designed to detect ripples in space-time called gravitational waves.

Hence, option d is correct.

8. Consider the following statements:
1. Genetic changes can be introduced in the cells that produce eggs or sperms of a prospective parent.
2. A person's genome can be edited before birth at the early embryonic stage.
3. Human induced pluripotent stem cells can be injected into the embryo of a pig.

Which of the statements given above is/are correct?
(a) 1 only
(b) 2 and 3 only
(c) 2 only
(d) 1, 2 and 3

8. Ans: d

Explanation:

Gene editing is a type of gene therapy that removes, disrupts, alters, or corrects faulty elements of DNA within a gene of interest. Gene editing uses technology designed to make targeted changes inside the cell.

Somatic gene therapy and germ line gene therapy

Gene therapy can be divided into somatic gene therapy and germ line gene therapy, depending on the cells in which the genetic material is altered

Somatic cells are the cells which make up the vast majority of tissues in the body except for sex cells (eggs and sperm). In the case of somatic gene therapy the genetic material of human cells are altered. Such alterations **cannot be genetically transferred.**

Reproductive cells, known as germline cells or germ cells, are those **sex cells (eggs and sperm)** that pass on genes from parents to their children.

Our reproductive cells, known as germline cells or germ cells, are those sex cells (eggs and sperm) that pass on genes from parents to their children. Germline gene editing involves altering the specific genes of an egg, sperm cell, or **early embryo** (i.e., up to five days after fertilization) in a laboratory dish. Germline gene editing removes, disrupts, alters, or corrects faulty elements of DNA within a gene in sex cells.

In the case of germ line gene therapy the **genetic material of gametes are altered**. The alterations are transferred to the offspring and are therefore **genetically transferred.**

Hence, statements 1 & 2 are correct.

Embryo editing

Early embryos only have a few cells, so the number of targeted cells for editing would be much smaller. As the embryo develops, those few edited cells would divide, and divide again, and could theoretically result in the birth of a child with many cells having the desired edit.

An alternative to the embryo editing approach would be to edit the germ cells (egg or sperm) of one of the parents with the goal of then using in vitro fertilization (IVF) to create a fertilized embryo that has the desired genetic change

Clinical use of germline gene editing is prohibited in the United States, Europe, the United Kingdom, China, and many other countries around the world.

Embryonic stem cells (ESCs).

These are pluripotent stem cells derived from embryos. As ESCs are pluripotent they retain the ability to self-renew and to form any cell in the body. ESCs have the advantage of versatility due to their pluripotency, but the use of embryos in the development of therapeutic strategies raises some ethical concerns.

In addition, stem cell lines generated from embryos are not genetically matched to the patient which can increase the chance that the transplanted cell is rejected by the patient's immune system.

Human stem cells can integrate into developing pig embryos, a finding that could lead to new ways of growing human organs and studying early human development.

Human and pig pluripotent stem cells have emerged as promising tools in regenerative medicine. Compared to mice, pigs offer a more relevant animal model due to their genetic and physiological similarities to humans.

In addition, the integration of human PSCs into pig embryos and the use of pig PSCs for generating humanized pig organs through blastocyst complementation or blastoid formation have opened up new avenues for organ transplantation.

Hence, statement 3 is correct.

9. What is the importance of using Pneumococcal Conjugate Vaccines in India?

1. These vaccines are effective against pneumonia as well as meningitis and sepsis.
2. Dependence on antibiotics that are not effective against drug-resistant bacteria can be reduced.
3. These vaccines have no side effects and cause no allergic reactions.

Select the correct answer using the code given below:

(a) 1 only
(b) 1 and 2 only
(c) 3 only
(d) 1, 2 and 3

9. Ans: b

Explanation:

A vaccine is a biological preparation that improves immunity to a specific disease. It typically contains an agent that resembles a disease-causing microorganism and is often made from weakened or killed forms of the microbe. The agent stimulates the body's immune system to recognize the agent as foreign, destroy it, and "remember" it so that the immune system can more easily recognize and destroy any of these microorganisms that it later encounters.

vaccines are administered prior to infection. Their role is to prime the immune system to fight any future infections, so that they can be brought under control before the disease-causing microorganism have had a chance to multiply.

Vaccines are of different types - killed Vaccines , attenuated Vaccines , toxoid Vaccines, subunit Vaccines, Conjugate Vaccines, experimental Vaccines , Valence Vaccines

Conjugate Vaccines

Certain bacteria have polysaccharide outer coats that are poorly immunogenic. By linking these outer coats to proteins (such as toxins), the immune system can be led to recognize the polysaccharide as if it were a protein antigen.

Conjugate vaccines are better suitable where the polysaccharide outer coats of bacteria are poorly immunogenic.

Pneumococcal conjugate vaccine

Pneumococcal conjugate vaccine can prevent pneumococcal disease.
Pneumococcal disease refers to any illness caused by pneumococcal bacteria.

- These bacteria can cause many types of illnesses, including pneumonia, which is an infection of the lungs.

- Pneumococcal bacteria are one of the most common causes of pneumonia.
- Besides pneumonia, pneumococcal bacteria can also cause: Ear infections Sinus infections **Meningitis** (infection of the tissue covering the brain and spinal cord) **Bacteremia** (infection of the blood), **Sepsis** (a life-threatening reaction to an infection, Infection prevention is the only way to prevent sepsis)

An important way to reduce the risk of contracting infections is by receiving vaccinations that target certain illnesses.

Most pneumococcal infections are mild. However, some can result in long-term problems, such as brain damage or hearing loss. Meningitis, bacteremia, and pneumonia caused by pneumococcal disease can be fatal.

Sepsis is a life-threatening medical emergency caused by your body's overwhelming response to an infection. Without urgent treatment, it can lead to tissue damage, organ failure and death.

Bacterial infections are one of the most common causes of sepsis. Fungal, parasitic and viral infections are also potential sepsis causes.

Hence, statement 1 is correct.

Risks of Pneumococcal conjugate vaccine reaction - Redness, swelling, pain, or tenderness where the shot is given, and fever, loss of appetite, fussiness (irritability), feeling tired, headache, muscle aches, joint pain, and chills can happen after pneumococcal conjugate vaccination.

Hence, statement 3 is incorrect.

Vaccines for Antimicrobial Resistance (AMR)

Antimicrobial resistance (AMR) threatens the effective prevention and treatment of an ever-increasing range of infections caused by bacteria, parasites, viruses and fungi.

AMR occurs when bacteria, viruses, fungi or parasites change over time and no longer respond to medicines making infections harder to treat and increasing the risk of disease spread, severe illness and death. As a result, the medicines become ineffective and infections persist in the body, increasing the risk of spread to others.

vaccines are administered prior to infection. Their role is to prime the immune system to fight any future infections, so that they can be brought under control before the bacteria have had a chance to multiply.

Vaccination can help to combat overuse by preventing infections that would otherwise require antibiotic treatment and help curb the spread of resistant strains.

Vaccines are an essential tool as part of a holistic response to reduce AMR. They prevent both drug-sensitive and drug-resistant infections, reduce the use and overuse of antimicrobials, and slow the emergence and spread of drug-resistant pathogens.

Hence, statement 2 is correct.

10. In India, the term "Public Key Infrastructure" is used in the context of:
(a) Digital security infrastructure
(b) Food security infrastructure
(c) Health care and education infrastructure
(d) Telecommunication and transportation infrastructure

10. Ans: d
Explanation:
Public key infrastructure (PKI) is a co**mprehensive framework for assigning, identifying and verifying user identity through digital certificates** used for enabling **trustworthy and secure digital communications.**
Paired with public-key cryptography, digital certificates act as virtual passports—authenticating the identity and permissions of various users and entities when establishing secure end-to-end communication over public or private networks. Encompassing elements of software, hardware, policies and procedures, PKI formalizes the process to create, distribute, manage and revoke digital certificates.

Public key infrastructure (PKI) provides protocols to validate the authenticity of the digital certificates that underscore the trust in public key cryptography systems. A cornerstone of cybersecurity, **cryptography provides confidentiality, integrity, nonrepudiation and authenticity**. PKI adds validity to cryptographic systems by cryptographically binding digital certificates to unique users, institutions, entities and third parties.

The ability to establish the secure transfer of information between users, entities and devices enables ecommerce and banking platforms to collect financial information, allows Internet of Things (IoT) connected devices and establishes confidential lines of communication, for secure email web servers, cybersecurity specialists rely on data encryption to securely e**ncrypt (scramble) and decrypt (unscramble**) sensitive data.

The **two primary types of data encryption are known as public key cryptography and private key cryptography.**

What is public key cryptography?
Also known as asymmetric encryption or public key encryption, public key cryptography uses a pair of keys, a shared public key and a private key that is unique to each party. The public key is used for encryption while the private key is used for decryption.

What is private key cryptography?
Also known as symmetrical or secret key cryptography, private key cryptosystems use only one key for both encryption and decryption.

Cryptography is also used for common messaging applications like email and **WhatsApp to provide end-to-end encryption (E2EE**) and maintain the privacy of users' conversations. With E2EE, only the sender and intended recipient can decrypt and read their messages, making it nearly impossible for third parties—including users' own service providers—to access the content.

While symmetric cryptography is faster, asymmetric cryptography is often more practical and secure. In practice, both types of cryptosystems are often used together.

However, both types of systems can be vulnerable to so-called man-in-the-middle (MitM) attacks, in which a malicious eavesdropper might intercept secure data during transmission.

Hence, option d is correct.

11. Which of the following statements are correct regarding the general difference between plant and animal cells?
1. Plant cells have cellulose cell walls whilst animal cells do not.
2. Plant cells do not have plasma membranes, unlike animal cells which do.
3. Mature plant cell has one large vacuole whilst animal cell has many small vacuoles.
Select the correct answer using the code given below:
(a) 1 and 2 only
(b) 2 and 3 only
(c) 1 and 3 only
(d) 1, 2 and 3

11. Ans: c
Explanation:
Cells is the fundamental, structural and functional unit of life. All the plants and animals are made of cells. Some forms of life, however, are made of only a single cell, such as the many species of **bacteria** and **protozoa**. Cells, whether living on their own or as part of a multicellular organism, are usually too small to be seen without a light microscope.

All cells are surrounded by a structure called the **cell membrane** — which, much like the walls of a house, serves as a clear boundary between the cell's internal and external environments. The cell membrane is sometimes also referred to as the **plasma membrane**.

Plant cells have certain distinguishing features, including chloroplasts, cell walls, and intracellular vacuoles. Photosynthesis takes place in chloroplasts; cell walls allow plants to have strong, upright structures; and vacuoles help regulate how cells handle water and storage of other molecules.

PLASMA MEMBRANE OR CELL MEMBRANE :

- This is the outermost covering of the cell that separates the contents of the cell from its external environment. The plasma membrane allows or permits the entry and exit of some materials in and out of the cell. It also prevents movement of some other materials.
- **The cell membrane, therefore, is called a selectively permeable membrane. It is found in both plant and animals cells.**
- The plasma membrane is flexible and is made up of organic molecules called lipids and proteins. However, we can observe the structure of the plasma membrane only through an electron microscope.
- The flexibility of the cell membrane also enables the cell to engulf in food and other material from its external environment. **Such processes are known as endocytosis. Amoeba acquires its food through such processes.**

Hence, statement 2 is incorrect.

Cell Wall:

- Plant, fungi and bacteria, in addition to the plasma membrane in their cell, have another rigid outer covering called the cell wall. The cell wall lies outside the plasma membrane. **The plant cell wall is mainly composed of cellulose. Cellulose is a complex substance and provides structural strength to plants.**
- Cell walls permit the cells of plants, fungi and bacteria to withstand very dilute (hypotonic) external media without bursting. In such media the cells tend to take up water by osmosis. Because of their walls, such cells can withstand much greater changes in the surrounding medium than animal cells.

Hence, statement 1 is correct.

Vacuoles

- Vacoules are storage sacs for solid or liquid contents. **Vacuoles are small sized in animal cells while plant cells have very large vacuoles**. The central vacuole of some plant cells may occupy 50-90% of the cell volume. Most mature plant cells have a large central vacuole that helps to maintain the turgidity of the cell and stores important substances including wastes. Plant cells use vacuoles to adjust their size and turgor pressure. Vacuoles usually account for changes in cell size when the cytoplasmic volume stays constant.

Hence, statement 3 is correct.

12. In India, why are some nuclear reactors kept under " IAEA Safeguards" while others are not?
(a) Some use uranium and others use thorium
(b) Some use imported uranium and others use domestic supplies.
(c) Some are operated by foreign enterprises and others are operated by domestic enterprises
(d) Some are State-owned and others are privately-owned

12. Ans: b
Explanation:
Safeguards are a main plank in the global nuclear security regime because they allow the **IAEA to make sure that nuclear materials like uranium and plutonium in the civil power sector are never used in military programs.**

An Agreement between the Government of India and the IAEA for the ***Application of Safeguards to Civilian Nuclear Facilities*** **(nuclear safeguards agreement) was signed in 2009.**

Under this agreement India will decide on the reactors to be placed under IAEA safeguards only after assessing if these will be **fuelled by uranium procured from abroad.**

By placing the reactors under the IAEA safeguards, India gives the international nuclear energy watchdog access to them. This step was taken by the country in 2014 to demonstrate that its nuclear energy programme was for peaceful purposes.

This is a necessary step under the Indo-US nuclear deal.

There are at present 22 operational reactors in India, of which 14 are under the International Atomic Energy Agency (IAEA) safeguards.

Hence, option b is correct.

13. With reference to solar water pumps, consider the following statements:
1. Solar power can be used for running surface pumps and not for submersible pumps.
2. Solar power can be used for running centrifugal pumps and not the ones with piston.
Which of the statements given above is/are correct?
(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

13. Ans: d
Explanation:
A solar water pump is an application of photovoltaic technology which **converts solar energy into electricity** to run the pumping system thereby, replacing erratic grid supply and pollution-causing diesel-powered versions. The solar water pump is powered by solar modules that helps draw surface or ground water out for irrigation.

Solar power can be used for both DC and AC range of Solar Water Pumps in both Surface and Submersible categories.

Piston Pump and Centrifugal Pump both can be run on solar power that uses electricity generated from a photovoltaic array.

Surface pumps and submersible pumps are two types of pumps used to move fluids from one place to another. While both types of pumps serve the same basic purpose, there are several differences between the two.

- **Surface pumps are pumps that are installed on the surface, or above ground, and are used to draw water from a well or other water source. Th**ey are often used in residential and commercial applications, such as irrigation, water supply, and fire protection systems. Surface pumps come in a variety of types, i**ncluding centrifugal pumps, jet pumps, and positive displacement pumps. They** rely on atmospheric pressure to lift water.
- On the other hand**, submersible pumps are pumps that are designed to be completely submerged in water or other fluids.** They are typically used in applications such as groundwater supply, drainage, and sewage pumping. Submersible pumps are often more efficient than surface pumps because they do not have to work as hard to lift water from the source. They also have the advantage of being less noisy than surface pumps.
- **Centrifugal pumps operate on the principle of centrifugal force, which is generated by the rapid rotation of an impelle**r or an enclosed set of vanes within the pump. This rotation creates a low-pressure area at the centre of the impeller that makes liquid to be drawn into the pump. As the fluid moves outward due to centrifugal force, it gains velocity and is discharged from the pump outlet.

- **Reciprocating pumps functions by using a back-and-forth or reciprocating motion to transfer fluids.** Unlike **centrifugal pumps, which rely on rotation, reciprocating pumps utilise a piston**, diaphragm or a plunger to displace the fluid in a controlled manner. This reciprocating action creates a pressure differential that draws in the fluid on one stroke and then pushes it out on the return stroke.

Hence, both statements 1 & 2 are incorrect.

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