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{S&T – Applications – 2021/04} Nuclear Magnetic Resonance (NMR) & MRI

[D2E](#) | [Prelims + Mains](#) | [GS3](#) > S&T Applications

- According to researchers from the Centre for Science & Environment (CSE), major Indian brands are selling **honey adulterated with a modified sugar from China**.

Adulteration of Honey

- Initially, sugars from corn, sugarcane, rice, & beetroot used to be added to honey to increase sweetness.
- Such adulteration is detected by basic tests.
- The modified 'Chinese sugar', however, can only be detected by **Nuclear Magnetic Resonance (NMR)**.

- NMR tests have very recently been made **mandatory in India for honey that is meant for export**.

Impact of honey adulterated with Sugar Syrup

Economic Impact

- Sugar-syrup honey was often available at **half the price**.
- This is a big blow to **beekeepers (majority of them are in the North-East)**.

Health impact

- Pure honey has **antimicrobial & anti-inflammatory** properties.
- Consuming adulterated honey leads to unintended sugar ingestion which leads to **obesity**.

Measures required to prevent honey adulteration

- A mechanism for **traceability of source of honey** (blockchain technology can be used in this).
- Develop advanced **Nuclear Magnetic Resonance (NMR) testing** facilities in India (the existing facilities are not sophisticated enough & can be tricked easily) & make NMR tests mandatory for domestic market.
- Stringent enforcement of quality standards & hefty penalties for violations.

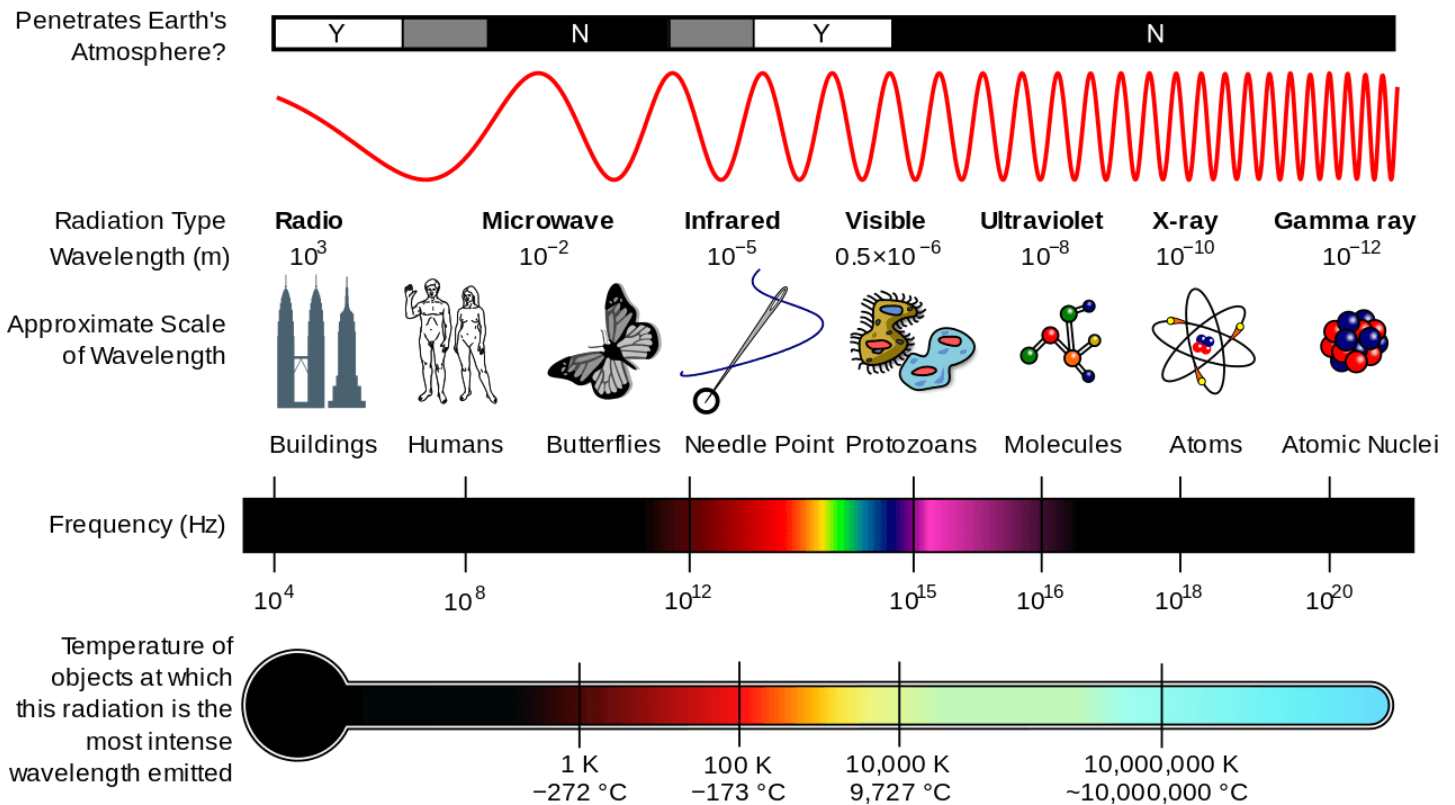
India's first honey testing lab

- India's first honey testing lab was set up by **National Dairy Development Board (NDDB)** at **Anand (known as Milk Capital of India; Amul dairy is here)**, Gujarat.
- The testing lab will unlock potential for apiarists to take advantage of exports to the US and Europe.
- Till recently, the exporters were required to **ship their samples to Germany for testing**.
- The development comes after National Bee Board's decade-long wait for a government testing facility.
- The new lab is the **only accredited laboratory** that can test honey samples as per FSSAI's regulations.

Nuclear Magnetic Resonance (NMR)

- Nuclear Magnetic Resonance is an analytical chemistry technique used in **quality control** & research.
- **Nuclear Magnetic Resonance (NMR)** can **determine the content at the molecular level**.
- **NMR spectroscopy** is the study of molecules
 - ✓ by recording the **interaction of radiofrequency (Rf) electromagnetic radiations**
 - ✓ with the **nuclei of molecules**
 - ✓ placed in a **strong magnetic field**.
- Hence NMR can be used to determine the **purity of a sample** as well as its **molecular structure**.

- The NMR test is **not required for honey that is being marketed locally** but is **needed for export**.



Microwaves are at the higher frequency end of the radio wave band (Electromagnetic Spectrum – [Wikipedia](#))

Magnetic resonance imaging (MRI)

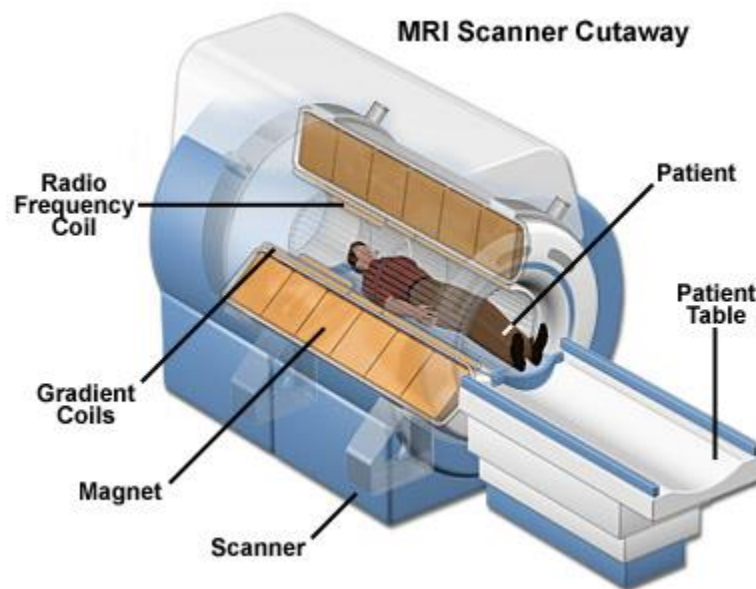
- MRI is a medical imaging application of nuclear magnetic resonance (NMR).**
- MRI is used in radiology to form pictures of the anatomy and the physiological processes of the body.
 - ⇒ **Radiology**: medical discipline that uses medical imaging to diagnose & treat diseases.
 - ⇒ **Imaging techniques in radiology**: **X-ray (ionizing radiation)**, **ultrasound (no ionizing radiation – it uses sound waves and sonar technology)**, **computed tomography (CT – 5 to 10 times more ionizing radiation than X-ray)**, **magnetic resonance imaging (MRI – no ionizing radiation)**, etc.
- MRI scanners use **strong magnetic fields** and **radio waves** to generate images of the organs in the body.
- MRI does **not involve X-rays or the use of ionizing radiation**, which distinguishes it from **CT**.
- Hence MRI is seen as a better choice than a CT scan.
- Compared with CT scans, MRI scans typically take longer and are louder.
- In addition, people with metal medical implants may be unable to undergo an MRI examination safely.
- This is because of the **strong magnetic fields** employed by the MRI Scanner.

Magnetic Field in an MRI Scanner

- MRI scanners have **giant electromagnets** with field strengths of between **0.5 tesla and 1.5 tesla** (1,500 times more powerful than a fridge magnet and **30,000X the geomagnetic field**).
- For reference, a fridge magnet is about 0.001 tesla, and the **Earth's magnetic field is 0.00005 tesla**.

Working of an MRI Scanner

- The human body is mostly water (hydrogen and oxygen), and when in the massive, stable magnetic field of the scanner, the **hydrogen protons** get aligned in the same direction.
- A radiofrequency source is then switched on and off, repeatedly knocking the protons out of line and back into alignment.
- Receivers pick up radio signals that the protons send out, and by combining these signals, the machine creates a detailed image of the body's inside.
- Because of the machine's giant magnetic field, hospitals and diagnostic centres issue detailed guidelines to ensure **no metal objects are brought close**.



Accidents while scanning

- [Accidents occur when metal objects are mistakenly brought close to the MRI Scanner.](#)
- When people stand in the way of a metal object and an MRI Scanner, they may be knocked out by the fast-moving metal object which is strongly attracted by the strong electromagnets of MRI Scanner.

{S&T – Bio – 2021/04} New nutrient rich crop & vegetable varieties

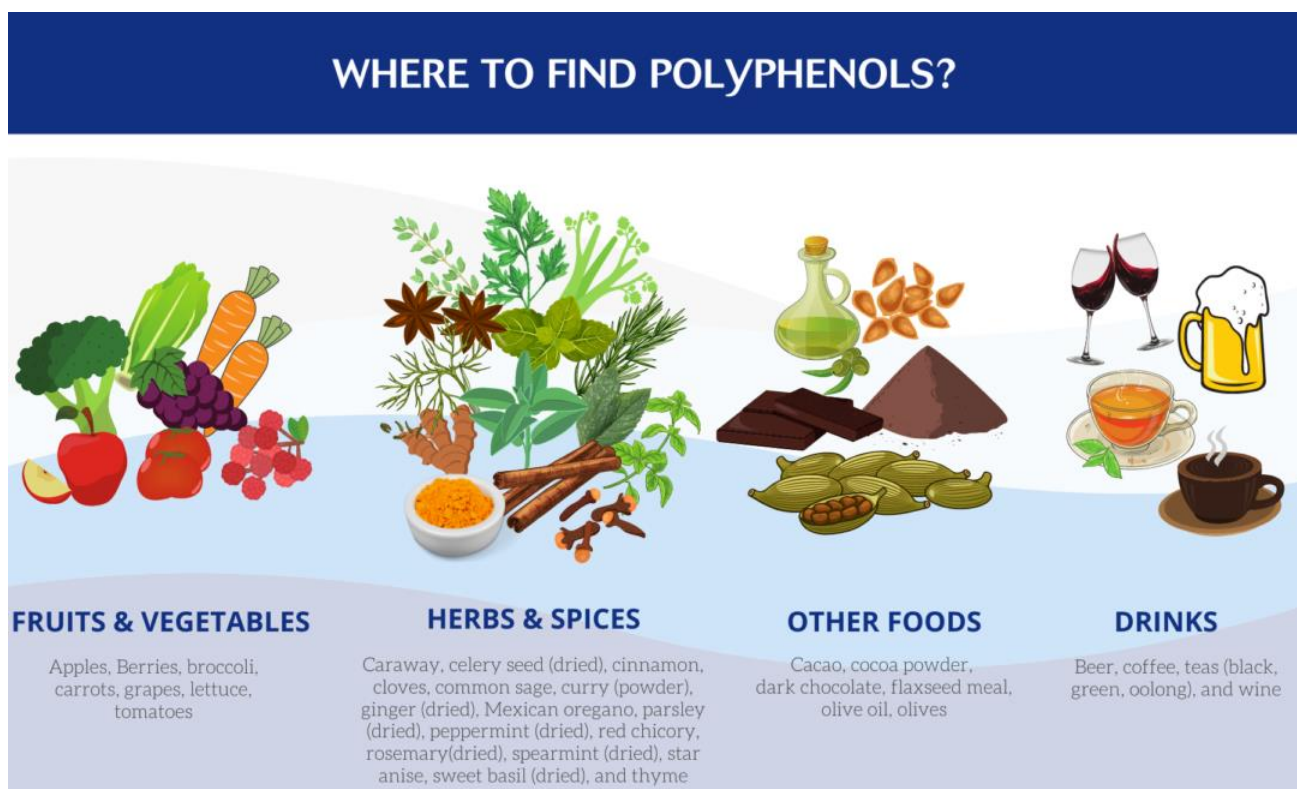
- **Context:** Punjab has come up with a bouquet of crop & vegetable varieties which are rich in nutrients.
- They have been developed by the Punjab Agricultural University (PAU) with support from the **Promotion of University Research & Scientific Excellence (PURSE)** grant provided by the **Department of Science**.

Nutrient rich crops shortlisted for commercialization

- **PAU 1 Chapatti** with low **polyphenols** (plant compounds that offers various health benefits like improved digestion, brain health) & outstanding processing qualities.
- 2 **carotene rich** cherry tomato varieties called **Punjab Sona** & **Punjab Kesar**.
- 2 **anthocyanin** rich brinjal varieties called **Punjab Raunak** & **Punjab Bharpoor** with antioxidant properties.

Polyphenols

- Polyphenols are **micronutrients** that we get through certain plant-based foods.
- They are packed with **antioxidants** & potential health benefits.
- They can help treat **digestion issues**, obesity, diabetes & cardiovascular diseases.



[Source & Credits](#)

Antioxidants

- Antioxidants are substances that can **prevent or slow damage to cells caused by free radicals**.
- They are sometimes called **free-radical scavengers**.

- **Free radicals** are toxins produced by cells as the body processes food & reacts to the environment.
- Certain plant-based foods are thought to be rich in antioxidants.
- The body also produces some antioxidants.



Beta carotene

- Beta carotene is a **red-orange pigment found in fruits**, especially **carrots and colorful vegetables**.
- It is the pigment that gives vegetables and fruits their rich colors.
- **Beta carotene is converted into vitamin A** (its deficiency causes **night blindness**), an essential vitamin.
- Beta carotene in itself is not an essential nutrient, but vitamin A is.
- Beta carotene is also an **antioxidant**.

Anthocyanins

- Anthocyanins are a class of compounds with antioxidant effects.
- **Anthocyanins** are the pigments that give red, purple, and blue plants their **rich colouring**.
- They may offer anti-inflammatory, anti-viral, and anti-cancer benefits.
- Anthocyanins are found in **berries, onions, kidney beans, pomegranates, grapes, tomatoes**, etc.



{S&T – Biotech – 2021/04} Stem Cells

[TH](#) | Prelims | GS3 > Developments & their applications etc.

- **Context:** Researchers at Tufts University have developed **robots from stem cells** of frogs.
- These **biological robots** are named **Xenobots**.
- They can **self-heal after damage**, **record memories** & **work together in groups**.
- They can **record information** about their surroundings.
- They move using **cilia** (minute hair like particles present on their surface).

Stem Cells

- The **blood** collected from the **umbilical cord** of the **new-born** is a **rich source of stem cells**.
- These **stem cells** are **unspecialised cells** (they **do not have a specific predefined function**).
- For instance, a stem cell cannot carry oxygen in the blood as red blood cells nor they can pump blood through the body like heart cells.
- However, they **have the ability to develop into many different cell types** e.g., **nerve cells, heart cells**, etc. during early life & growth.
- The process of unspecialized stem cells giving rise to specialized cells, is called **differentiation**.
- Stem cells can also act as an **internal repair system** in many tissues of the body.
- There are 2 kinds of Stem Cells.
 1. **Embryonic Stem cells** (formed during embryological development).
 2. **Non-embryonic somatic or adult stem cells** (formed in bone marrow & peripheral blood tissue).

Stem cell banking or Cord blood (umbilical cord blood) Banking

- Cord blood is the **blood that remains** in the **umbilical cord** and **placenta** post-delivery.
- **Cord blood at the time of delivery** is a **rich source of stem cells** and other **cells of the immune system**.

- Cord blood banking is the process of collecting the cord blood and **cryogenically freezing its stem cells** and other cells of the immune system for **potential future medical use**.
- In some parts of the world, cord blood banking is more often referred to as **stem cell banking**.
- Cord blood banking is **designed to collect the stem cells** and **not the actual blood cells themselves**.

How long can the stem cells be preserved?

- The stem cells are preserved in **liquid nitrogen** in cord blood banks.
- Technically, there is no expiry date, and these stem cells **can be preserved for a lifetime**.
- Scientifically, evidence exists that they can be stored for **about 20 years**.

What makes stem cells special?

- In some organs, such as the **bone marrow**, stem cells **regularly divide** to **repair and replace damaged tissues**.
- Stem cells taken from **umbilical cord** blood are like those taken from **bone marrow**, **capable of producing all blood cells: red cells, platelets, and immune system cells**.
- That is, they can renew themselves through **cell division** to give rise to **new stem cells** or **specialized cell types (bone cells, muscle cells, etc)**.

What are the uses of stem cells?

- In a patient, they **can be induced to become tissue- or organ-specific cells with special functions**.
- Hence, they offer the **possibility** of a **renewable source of replacement cells and tissues** to treat diseases including muscular degeneration, spinal cord injury, stroke, burns, heart disease, diabetes, etc.
- The stem cells in theory can treat around 70 blood related disorders and genetic disorders including **thalassemia, sickle cell anaemia, leukaemia**, and immune related disorders.
- But given the present state of medicine, they are effective only for around a dozen of them.
- **Bone marrow transplantation (BMT)**
 - ✓ In chemotherapy or radiotherapy (process to eliminate cancer cells), the blood cells get damage.
 - ✓ In bone marrow transplantation, different damaged blood cell types are restored.
- **Skin replacement:**
 - ✓ The skin stem cells are found in the hair follicle & can be removed by plucking the hair.
 - ✓ By using these **skin stem cells**, the scientists can grow skin.
- **Brain cell transplantation:**
 - ✓ Stem cells can be used to treat Parkinson's & Alzheimer's diseases by replenishing the damaged tissue.

- **Organ & tissue regeneration:**
 - ✓ Tissue regeneration is one of the important applications of stem cell therapy.
 - ✓ Stem cells can be used to grow a **particular tissue or the organ**.
- **Treatment for diabetes:**
 - ✓ Recently **insulin expressing cells** have been derived from mouse stem cells.
 - ✓ Future research might aim at providing a stem cell-based therapy to treat diabetes.

Are stem cells useful for family members?

- Body's **immune system does not accept outside stem cells** and other cells of the immune system.
- Cord blood taken from a baby's umbilical cord is always a perfect match for the baby.
- In addition, immediate family members are more likely to also be a match for the banked stem cells.
- Hence, it may sometimes be possible to use the stem cells of the immediate family member to treat certain diseases.

What does Indian Council of Medical Research (ICMR) say about cord blood banking?

- Companies convince parents (emotional marketing) to bank the cells promising future therapeutic use.
- However, the **ICMR does not recommend commercial stem cell banking**.
- According to ICMR, there is no scientific basis for preservation of cord blood for future self-use.
- According to ICMR, cord blood banking is advisable when there is an elder child in the family with a condition treatable with stem cells and the mother is expecting the next baby.

What do experts say?

- Globally, cord blood banking is recommended as a source of **hematopoietic stem cell** (derived **from bone marrow, umbilical cord**) transplantation for **haematological** (diseases related to blood) cancers.
- For all other conditions, the use of cord blood as a source of stem cells is **not yet established**.

Stem Cell Treatments in India

- Stem Cell Treatment is still under research mode in India.
- **Stem cell treatment** is provided to **cancer & thalassemia patients** at **AIIMS**.
- In 2017, **National Guidelines for Stem Cell Research** were released.
- According to these guidelines, **only bone marrow stem cell transplant for blood disorders is permitted**.

{S&T – ICT – 2021/04} NIXI, Internet Protocol (IP) & VPN

- **Context:** MeitY has inaugurated path breaking initiatives of **National Internet Exchange of India (NIXI)**.

National Internet Exchange of India

- It is a not-for-profit organization working since 2003 to **facilitate improved internet services** in India.
- NIXI has also created INRegistry (.in domain) as its autonomous body for **maintenance of .IN domain**.
- It manages the **National Internet Registry** of the country & delegates **Internet Protocol addresses (IPv4 & IPv6)** & Autonomous System numbers to its Affiliates.

The 3 initiatives of NIXI

1. **IPv6 Expert Panel (IP Guru)**
 2. **NIXI Academy**
 3. **NIXI – IP – INDEX**
- With this launch, NIXI has announced to play a supporting role for the **IPv6 awareness** & its adoption.

IPv6 Expert Panel (IP Guru)

- It is a group to **extend support to all the Indian entities** who are finding it technically challenging to **migrate & adopt IPv6**.
- Its services are free of cost.
- It is a joint effort of the **Department of Telecom (DOT) & MeitY**.

NIXI Academy

- It is created to educate technical/non-technical people in India to learn & relearn technologies like IPv6 which are normally not taught in educational institutions.
- Successful candidates (after clearing examination) can take a certificate from NIXI, which will be useful to find/upgrade jobs in the industry.

NIXI – IP – INDEX

- NIXI has developed an IPv6 index portal for the internet community.
- NIXI-IP-INDEX portal will showcase the **IPv6 adoption rate** in India across the world.
- It can be used to compare IPv6 adoption rate of India with other economies of the world.

How an IP address works?

- IP stands for “**Internet Protocol**,” referring to a set of rules which govern how **data packets** are **transmitted across the Internet**.
- **Every device** (computer, mobile, IOT sensor, etc.) **connected to the Internet** needs a **unique numerical IP address** which is used **to identify the device as a destination** for communication with other devices.
- Whenever a device accesses the Internet, it is assigned a unique, numerical IP address (e.g., 99.48.227.227).
- To send data from one computer to another through the web, a **data packet** must be transferred across the network **containing the IP addresses of both devices**.
- Without a unique IP address, the device cannot attempt communication.
- The **IP address can be used to track down a user's physical location**.
- **VPNs are employed to prevent device (IP) tracking**.

IPv6 vs. IPv4

- **IPv6 is the next generation Internet Protocol (IP)** address standard intended to supplement & **eventually replace IPv4**, the protocol many Internet services still use today.
- The original IP address scheme, called **IPv4, is running out of addresses** due to its widespread usage from the proliferation of so many connected devices.
- **IPv6 uses 128-bit IP address** whereas **IPv4 uses a 32-bit address** for its Internet addresses.
- The **number of IPv6 addresses is 1028 times larger than the number of IPv4 addresses**.

IPv4	IPv6
Deployed 1981	Deployed 1998
32-bit IP address	128-bit IP address
4.3 billion addresses	7.9x10 ²⁸ addresses
Addresses must be reused and masked	Every device can have a unique address
Numeric dot-decimal notation	Alphanumeric hexadecimal notation
192.168.5.18	50b2:6400:0000:0000:6c3a:b17d:0000:10a9 (Simplified - 50b2:6400::6c3a:b17d:0:10a9)
DHCP or manual configuration	Supports autoconfiguration

[Source & Credits](#)

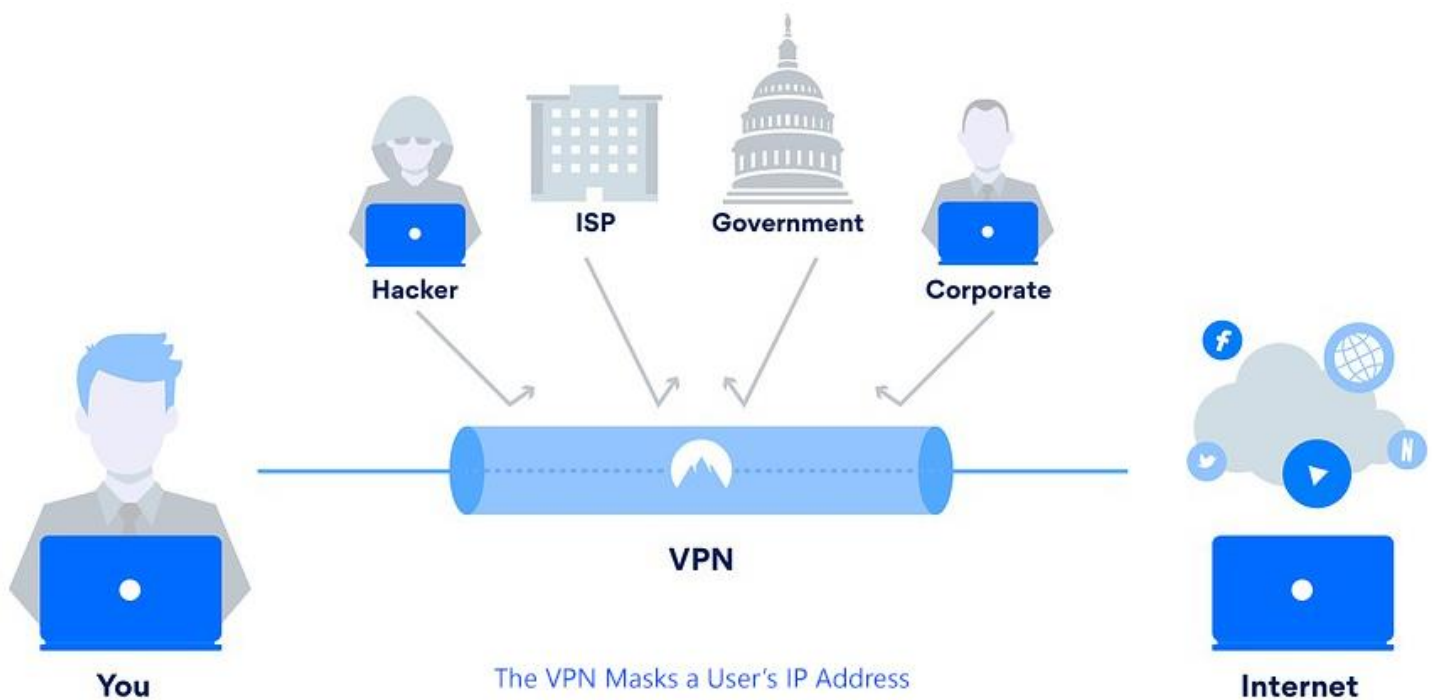
Virtual Private Network (VPN)

- VPNs is a tool designed for large organisations to **securely share their resources** with their employees, as well as connect their employees and branches in a reduced-risk environment.
- To ensure security, the VPN connection is established using an **encrypted layered tunnelling protocol** & users can use a host of authentication methods like passwords, certificates, to gain access to the network.

How a VPN works



EMSISOFT



All of the incoming and outgoing traffic of the user passes through the VPN and is encrypted

- Since the **line is encrypted** between the network & the device connected to it, the **traffic remains private**.

- VPN technology can check whether a connected device meets certain security requirements, thus making the connections secure.

VPN and Privacy

- VPN is also a good tool to **circumvent censorship (IP Tracking)**.
- VPN connects the device securely to a **proxy network**, which in turn, will connect to a destination website.
- Whenever you are connected to the Internet, you are assigned an IP address that is essentially similar to a regular street address.
- With an IP address, you can be tracked down as easily as with a regular street address.
- **VPN replaces a user's real IP addresses with the IP address of the gateway**, which can be **located in a different country**.

You may need a VPN it in the following cases

- You do not want anyone to have access to the data you submit to the internet.
- You do not want your ISP (Internet Service Provider) to know and log your internet activity.
- You do not want various government agencies to track you and your actions on the internet.
- You do not want various sites that you visit, and programs installed on your computer, to collect and send marketing information about you and about what you are doing on the internet.

{S&T – In News – 2021/04} In News Topics for Prelims

[PIB](#) | [PIB](#) | [IE](#) | [IE](#) | [D2E](#) | [IE](#)

Hydrogen Sulphide

- **Context:** Centre for Nano & Soft Matter Sciences (CeNS), Bangalore (Under Department of S&T) have developed **hydrogen sulphide (H₂S)** Gas sensor.
- Hydrogen Sulphide is slightly **denser than air**.
- It is the primary gas produced from the **microbial breakdown of organic matter** in the **absence of oxygen (anaerobic)**, & this necessitates early detection of its emission from **sewers & swamps**.
- It is a **poisonous, corrosive, & flammable gas**.
- **Natural Sources:**
 - ✓ It occurs in **volcanic gases, natural gas**, & in some sources of well water.
 - ✓ The human body produces small amounts of H₂S.

Nano Sniffer

- **Context:** NanoSniffer, a **microsensor based Explosive Trace Detector** was launched recently.
- It is developed by NanoSniff Technologies, an **IIT Bombay** initiative.
- It reduces our dependency on imported explosive trace detector devices.
- It provides **detection of nano-gram quantity of explosives** & delivers result in less than 10 seconds.
- It categorizes explosives into different classes.
- It detects all classes of military, conventional & homemade explosives.



[Source & Credits](#)

Whitest Paint

- **Context:** Engineers in the USA have created what they are calling **whitest paint** yet.
- The older formulation was made of **calcium carbonate**, while the new one is made up of **barium sulphate**, **which makes it whiter**.
- The newer paint keeps the surface cooler than the previous formulation.

Note: The **blackest black** paint is called '**Vantablack**' which is able to **absorb up to 99.9% of visible light**.

What determines the colour of an object?

- Whenever an object is seen by the eye, it is because of sunlight or the artificial light in the room.
- This light is made up of 7 colours (different wavelengths) i.e., VIBGYOR.
- **Colour of any object** is determined by the **wavelength** the **molecules** are **not able to absorb**.
- For ex. a person is able to see a white surface because the molecules that make up the surface are absorbing none of the wavelengths of light (**meaning entire spectrum of VIBGYOR are reflected**).
- Similarly, if an object is black, it means **atoms have absorbed all the wavelengths** & therefore no light is reflected from them.

- This is the reason that **darker objects**, as a result **absorbing all wavelengths** tend to **heat up faster**.

Muon G-2 Experiment

- **Context:** The results from the **Muon G-2 experiment** shows that **fundamental particles** called **muons** behave in a way **that is not predicted by the Standard Model of Particle Physics**.
- The experiment was conducted at the US Department of Energy's Fermi National Accelerator Laboratory.

What is Muon?

- It is an **elementary particle** similar to the **electron**.
- It is heavier cousin of electron & **highly unstable**.
- It is classified as a **lepton**.

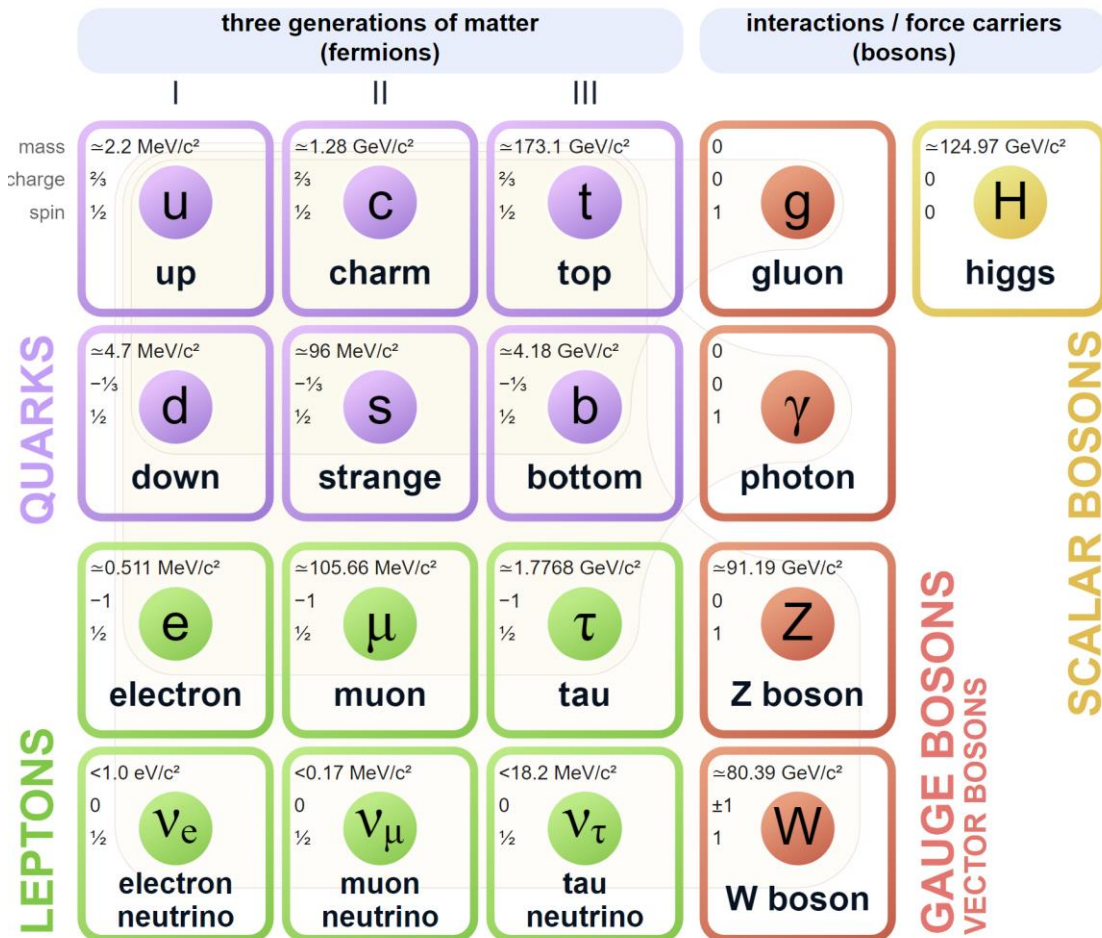
What is G-2?

- A g-factor is a quantity that characterizes the magnetic moment & angular momentum of an atom.
- **Like the electron, the muon acts like a tiny magnet** & therefore gets influenced by magnetic fields.
- When placed in an external magnetic field, the muon wobbles.
- The rate at which the muon wobbles is described by the g-factor.
- This value is known to be close to 2. Hence the name g-2.

What is the Standard Model?

- It is a theory that predicts the behavior of the building blocks of the universe.
- Everything in the universe is made from a **few fundamental particles**, governed by **4 fundamental forces**.
- Standard Model of particle physics deals with the understanding of how these particles and three of the four fundamental forces are related to each other.
- It lays out the rules for
 - ✓ **six types of quarks**,
 - ✓ **six leptons**,
 - ✓ **the Higgs boson**,
 - ✓ **three fundamental forces (the electromagnetic, weak, & strong interactions, & not including gravity)** &
 - ✓ how the **subatomic particles behave under the influence of electromagnetic forces**.
- The g-factor can be calculated precisely using the Standard Model.

Standard Model of Elementary Particles



[Source & Credits](#)

- **Leptons** (e.g., electrons), **quarks** & **Higgs Bosons** are the basic building blocks of matter.
- **Quarks combine** to form particles called **hadrons (made of two or more quarks)** like
 - ✓ **baryons** (made of odd no of quarks, e.g., protons & neutrons) and
 - ✓ **mesons** (composed of an equal number of quarks and antiquarks, usually one of each).
- The **Higgs boson** is the fundamental particle associated with the **Higgs field**.
- The **Higgs field gives mass to other fundamental particles** such as **electrons** and **quarks**.
- A particle's mass determines how much it resists changing its speed or position when it encounters a force.
- Not all fundamental particles have mass.
- The **photon, which is the particle of light** and **carries the electromagnetic force, has no mass at all**.
- The Higgs boson was proposed in 1964. Scientists confirmed its existence in 2012 through the ATLAS and CMS experiments at the **Large Hadron Collider (LHC) at CERN in Switzerland**.

Findings of the G-2 Experiment

- The accepted theoretical value for the muon is slightly deviating from a g-factor of 2.
- This hints at the existence of unknown interactions between the muon & the magnetic field — interactions that could involve new particles or forces.
- In other words, **deviations points to undiscovered subatomic particles existing in nature.**

Opposable thumbs

- Context: Researchers have found a new pterosaur species Monkeydactyl fossil with **opposable thumbs**.



[Source & Credits](#)

- The Pterosaur species were **reptiles, close cousins of dinosaurs** & the **first animals after insects to evolve powered flight.**

What is opposability of the thumb & its significance?

- **Opposable thumb** is a thumb that can be placed opposite the fingers of the same hand.
- Opposable thumbs allow the digits (fingers) to grasp & handle objects & are **characteristic of primates.**
- The grasping hands of primates developed/**evolved because of their life in the trees.**
- This single feature gave primates ability to hold anything tight, ensuring them an **evolutionary advantage.**



- Humans have a relatively longer & distally placed thumb, & larger thumb muscle.
- Hence, humans' tip-to-tip grip when **holding smaller objects** is **superior to non-human primates.**

- This is the reason that humans are able to hold a pen or put a thread through a needle hole.