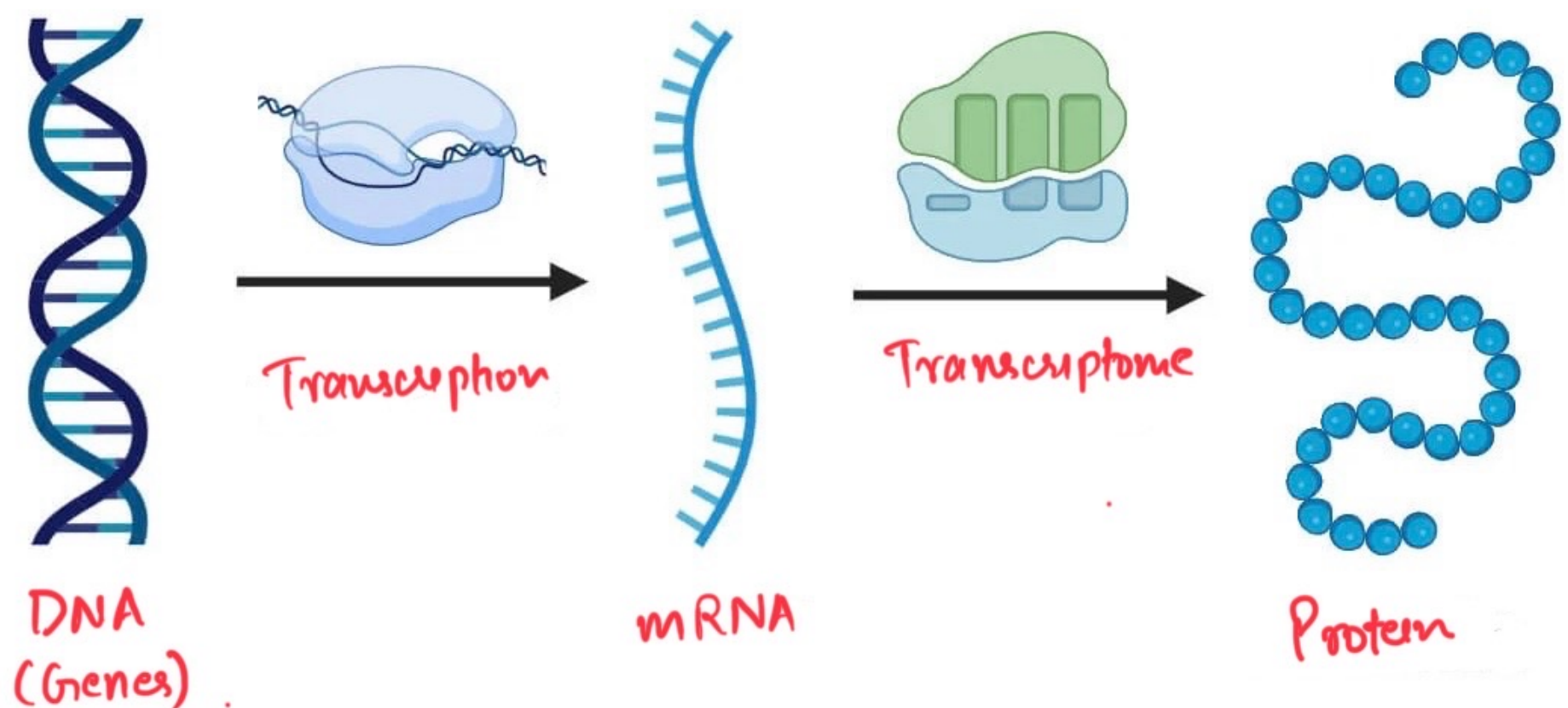# Gene Expression

Gene Expression is basically how the information contained in a gene is used to make a protein

Example: Eye Colour

- **Gene:** There is a gene in our DNA that determines your eye colour
- **Transcription:** The gene is copied into mRNA (like writing down the recipe for eye colour)
- **Translation:** The mRNA is sent to the ribosome where the body uses it to create the protein responsible for the colour of your eyes
- **Protein:** The protein that is made will give your eyes their specific colour

DNA (Genes) → Transcription → mRNA → Transcriptome → Protein

Gene Expression is a fundamental force behind everything that is happening inside our body. Every cell relies on the expression of genes to make the necessary proteins that carry out various body functions

Examples: Immune Response to any disease, Tissue Repair and Healing, Cell Growth and Division, etc.

Gene Silencing

The primary purpose of genes is to store and transmit the information necessary for the synthesis of various proteins and to regulate biological processes

But sometimes it may happen that some genes are not needed or undesirable. For Ex: Cancer causing genes (oncogenes) are obviously undesirable

To regulate and silence the expression of these genes, Biotechnology has given a technique of Gene Silencing

Hence, Gene Silencing refers to the process of turning off or suppressing the expression of specific genes.

2 ways for Gene Silencing
- Preventing the Gene from being transcribed into mRNA or
- Blocking the mRNA before it is translated into a protein (RNAi)

RNA Interference (RNAi)

It is one of the most widely used techniques of Gene Silencing

How it works?

Genes and mRNA:
- In our cells, genes are instructions (DNA) that our copied into mRNA(Transcription).
- The mRNA then acts as a blueprint to make proteins (Translation)

Role of RNAi:
- RNAi involves use of small RNA molecules (like siRNA or miRNA) that can bind to mRNA. Once they are bind to mRNA, the mRNA is destroyed or it's translation into proteins is blocked
- This means that the protein from the gene can't be made which effectively means silencing the gene

RNAi technique is also known as Post Transcriptional Gene Silencing because it involves silencing the gene after the gene has been transcribed into mRNA but before the mRNA is translated into a protein

DNA Methylation

DNA Methylation adds small methyl groups (which are just tiny chemical tags) to the DNA

How it works?

- These methyl groups usually attach to a part of the DNA called the promoter which is like the on switch for a gene
- When the methyl groups are added, they act like a "stop signal". This shuts down the gene preventing it from being turned on or making proteins

This technique is considered as part of transcriptional gene silencing because it works before the gene is transcribed into mRNA affecting the transcription process itself

Histone Modification

What are Histones? Histones are basically proteins that DNA wraps around like thread around spools

How it works?

- Under this technique, Histones are chemically modified (like adding or removing small groups) which causes DNA to tighten or loosen
- Tightening the DNA makes it harder for the cell to read or access the gene which silences that gene

It is also a part of transcriptional gene silencing because it works before the gene is transcribed into mRNA affecting the transcription process itself

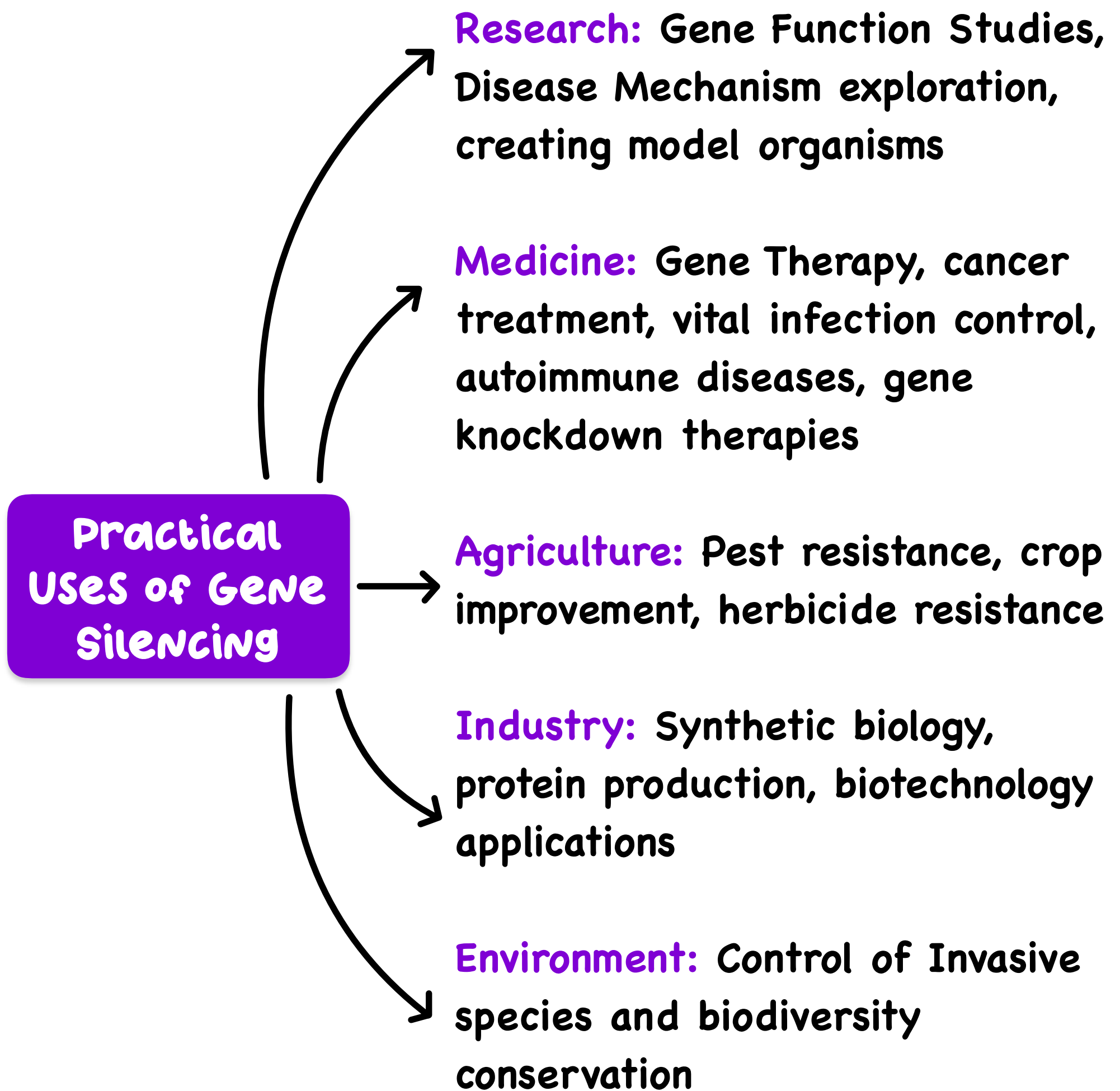## Practical Uses of Gene Silencing

Research: Gene Function Studies, Disease Mechanism exploration, creating model organisms

Medicine: Gene Therapy, cancer treatment, vital infection control, autoimmune diseases, gene knockdown therapies

Agriculture: Pest resistance, crop improvement, herbicide resistance

Industry: Synthetic biology, protein production, biotechnology applications

**Environment:** Control of Invasive species and biodiversity conservation

Genome Sequencing

#1. What is a Genome?

- A Genome is a complete set of DNA in an organism including all of its genes
- It carries the entire set of genetic instructions required for the growth, development, functioning and reproduction of the organism
- DNA is made up of 4 chemical bases: Adenine (A), Thymine (T), Cytosine (C) and Guanine (G)

#2. Genome Sequencing

- Genome Sequencing is the process of determine the precise order of the nucleotides (A, T, C, G) in the entire genome of an organism
- It provides a comprehensive map of the genetic material allowing researchers to identify the structure, function and variation of genes
- Scientists use special machines to figure out the exact order of the letters (A,T,C,G) in our DNA. It is basically like using a scanner to read every page and word in the instruction manual of life
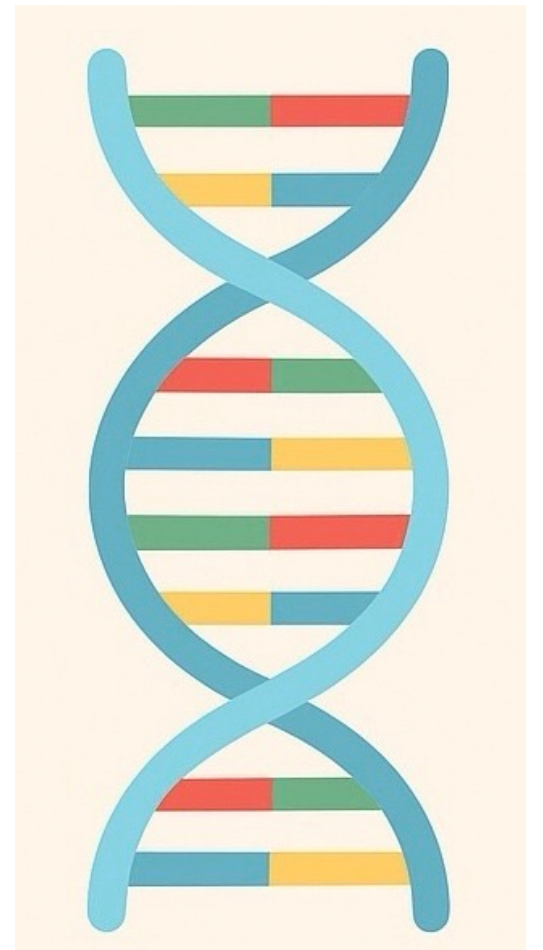
Applications of Genome Sequencing

Personalised Medicine

- By sequencing an individual's genome, doctors can tailor medical treatments based on genetic predispositions
- This helps in identifying most effective drugs, dosages, treatment plans

Disease Diagnosis and Risk Prediction

- Genome Sequencing can identify genetic mutations that cause hereditary diseases such as sickle cell anaemia
- It can also help in assessing risks for conditions like diabetes and cancer

Understanding of Diseases

- It helps in advance research in understanding genetic causes of diseases

Agriculture

- In agriculture, it helps in o roving crop yield, resistance diseases and pests and stress tolerance by genetically modifying specific genes

Forensic Science

- It is used in criminal investigations for DNA profiling helping identifying suspects or victims

Metagenomics

- It helps in genome sequencing of microbes like bacteria, fungi, virus which helps in identifying pathogenic strains, understanding their behaviour, and tracking outbreaks
- This helps in developing vaccines, antibiotics and other treatments

Ancestry and Genealogy

- It allows individuals to trace their genetic lineage and ancestral origins by comparing their DNA to global genetic databases

Genome Sequencing Projects

Human Genome Project (2003): First successful sequencing of the complete human genome

Genome India Project: Launched by Dept of Biotechnology; Aims to sequence 10,000 Indian genomes which will help in building Indian reference genome for better healthcare solutions

INSACOG (Indian SARS-Cov-2 Genomics Consortium): Tracks virus mutations via genome sequencing

INDigen Project: Sequencing the genome of Indian individuals to create a genetic database that reflects India's diversity
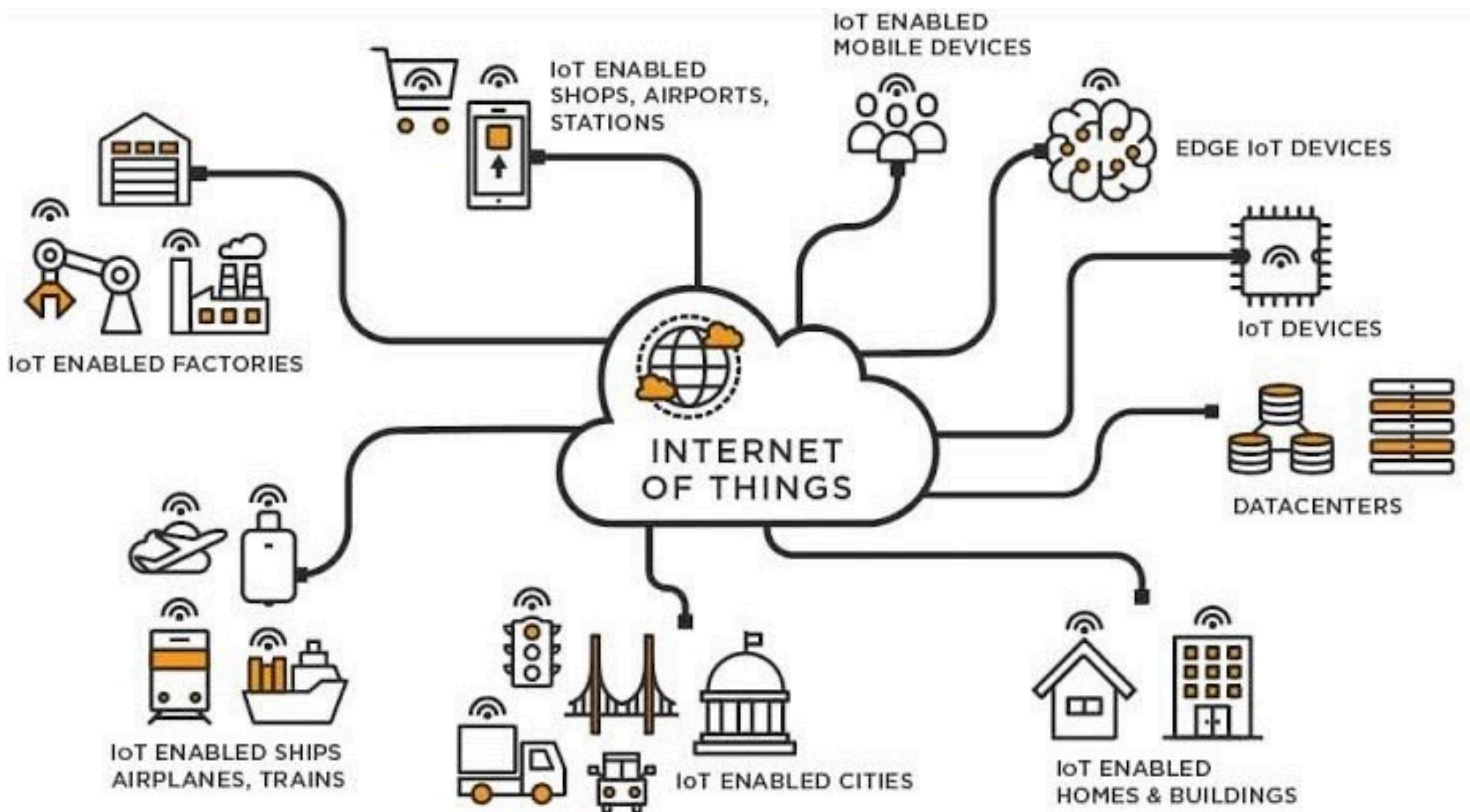
Internet of Things

IoT is a network of physical objects embedded with sensors, software and connectivity that enables them to collect and exchange data with other devices or systems over the Internet

It is the backbone of a connected ecosystem where everyday devices becomes smart through real time data exchange revolutionising sectors like health, agriculture, manufacturing, etc.

Ex: Your refrigerator senses that the milk is low and sends a message to your smartphone with a reminder to buy it

Ex: When you step out of your house, your smart home assistant turns off the lights, fans and ACs automatically saving electricity

IoT ENABLED SHOPS, AIRPORTS, STATIONS

IoT ENABLED MOBILE DEVICES

EDGE IoT DEVICES

IoT ENABLED FACTORIES

IoT DEVICES

INTERNET OF THINGS

DATACENTERS

IoT ENABLED SHIPS AIRPLANES, TRAINS

IoT ENABLED CITIES

IoT ENABLED HOMES & BUILDINGS

IoT is not just a technological advancement but a transformative force shaping a smarter, more connected world. It holds immense potential for inclusive and sustainable development

Virtual Private Network

VPN is a secure, encrypted connection over a public network (like the Internet) that allows users to access private networks securely. It basically masks the user's IP address making online activities untraceable

It prevents unauthorised people from eavesdropping on the traffic and allows the user to conduct work remotely. This ensures that sensitive data is safely transmitted

User

Secure connection to VPN

Hacker

VPN
(masks User's IP Address)
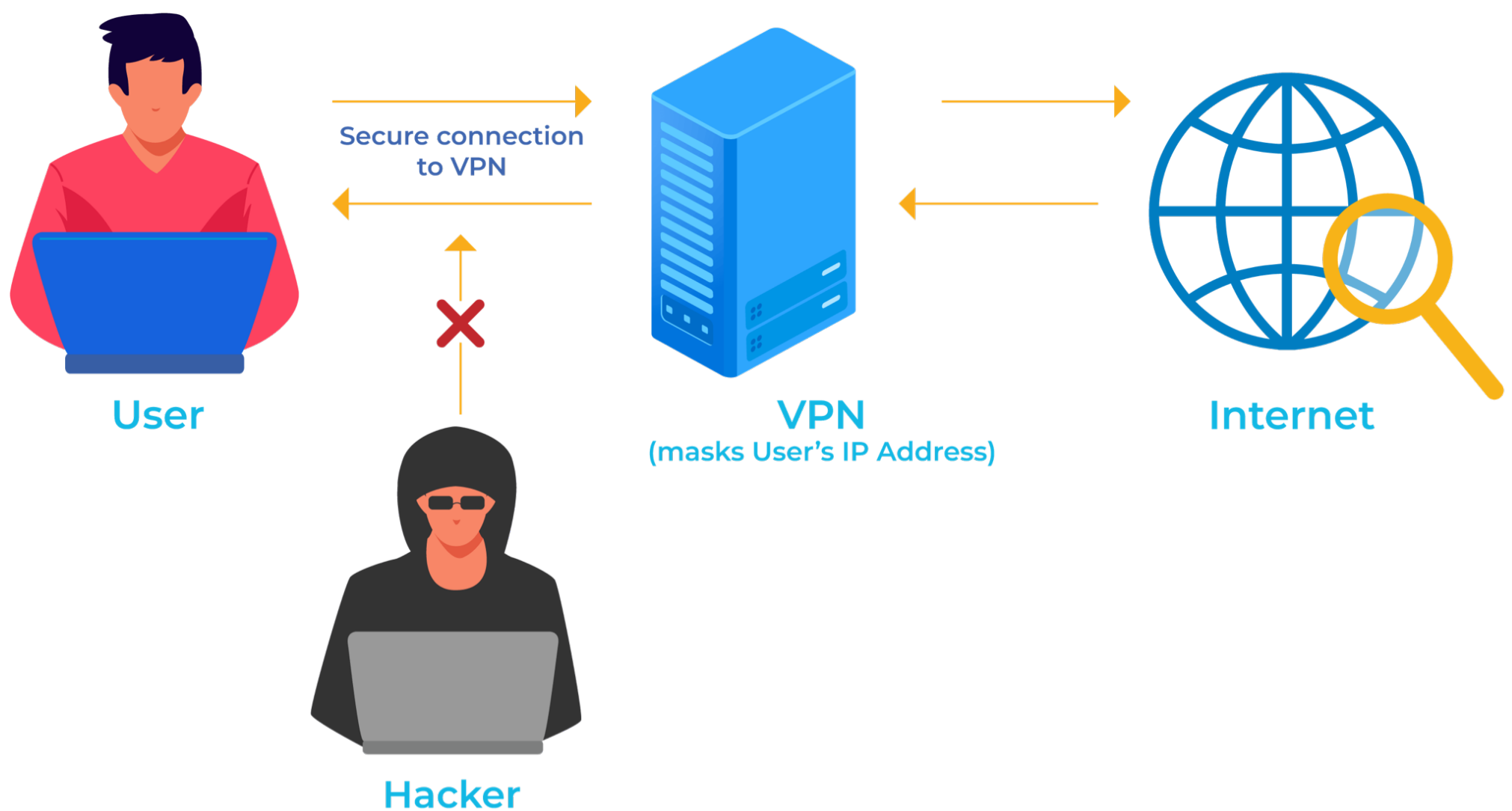
Internet

#1. Encryption
Data is encrypted before being sent over the Internet

#2. Secure Tunneling
Data travels through a VPN tunnel hiding it from hackers, ISPs, government, etc.

#3. IP Masking
VPN replaces a user's real IP address with a VPN server IP making the user appear in a different location

Types of VPN

Remote Access VPN: Used by individuals to securely access the Internet

Site to Site VPN: Used by businesses to connect branch offices securely

Mobile VPN: Used for secure browsing on mobile networks

Applications of VPN

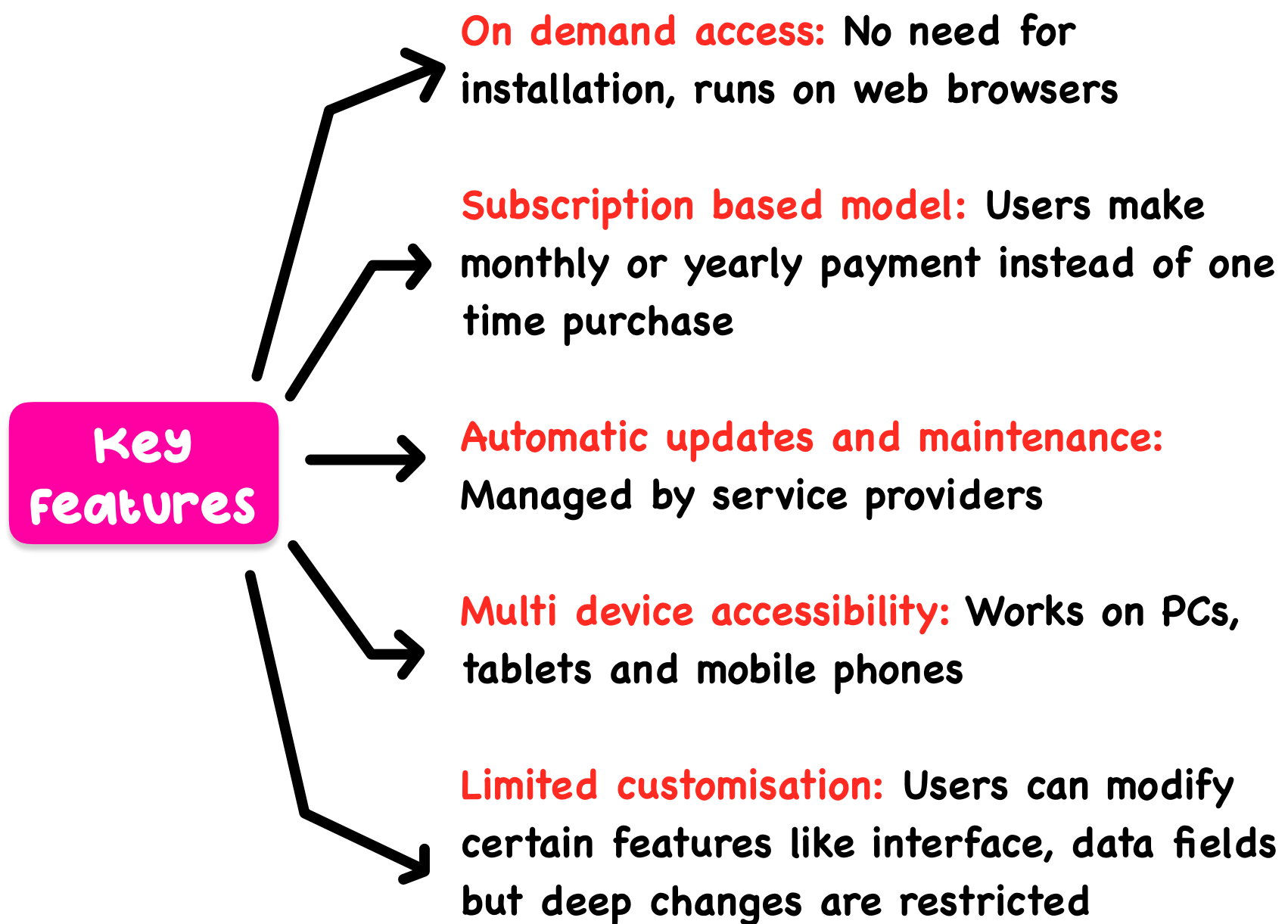**Privacy and Security:** Protects adapt from hackers and surveillance

Bypassing Geo Restrictions: Helps to access blocked websites in some countries like China, North Korea, etc.

Safe Public Wi-Fi use: Prevents data theft on open networks like in cafés, airports, etc.

Corporate Use: Secure remote work from home for employees

Software as a Service

SaaS is a cloud based software delivery model where applications are accessed via the Internet without local installation. In this, users purchase subscription of the software instead of purchasing it outright

Key Features

On demand access: No need for installation, runs on web browsers

Subscription based model: Users make monthly or yearly payment instead of one time purchase

Automatic updates and maintenance: Managed by service providers

Multi device accessibility: Works on PCs, tablets and mobile phones

Limited customisation: Users can modify certain features like interface, data fields but deep changes are restricted
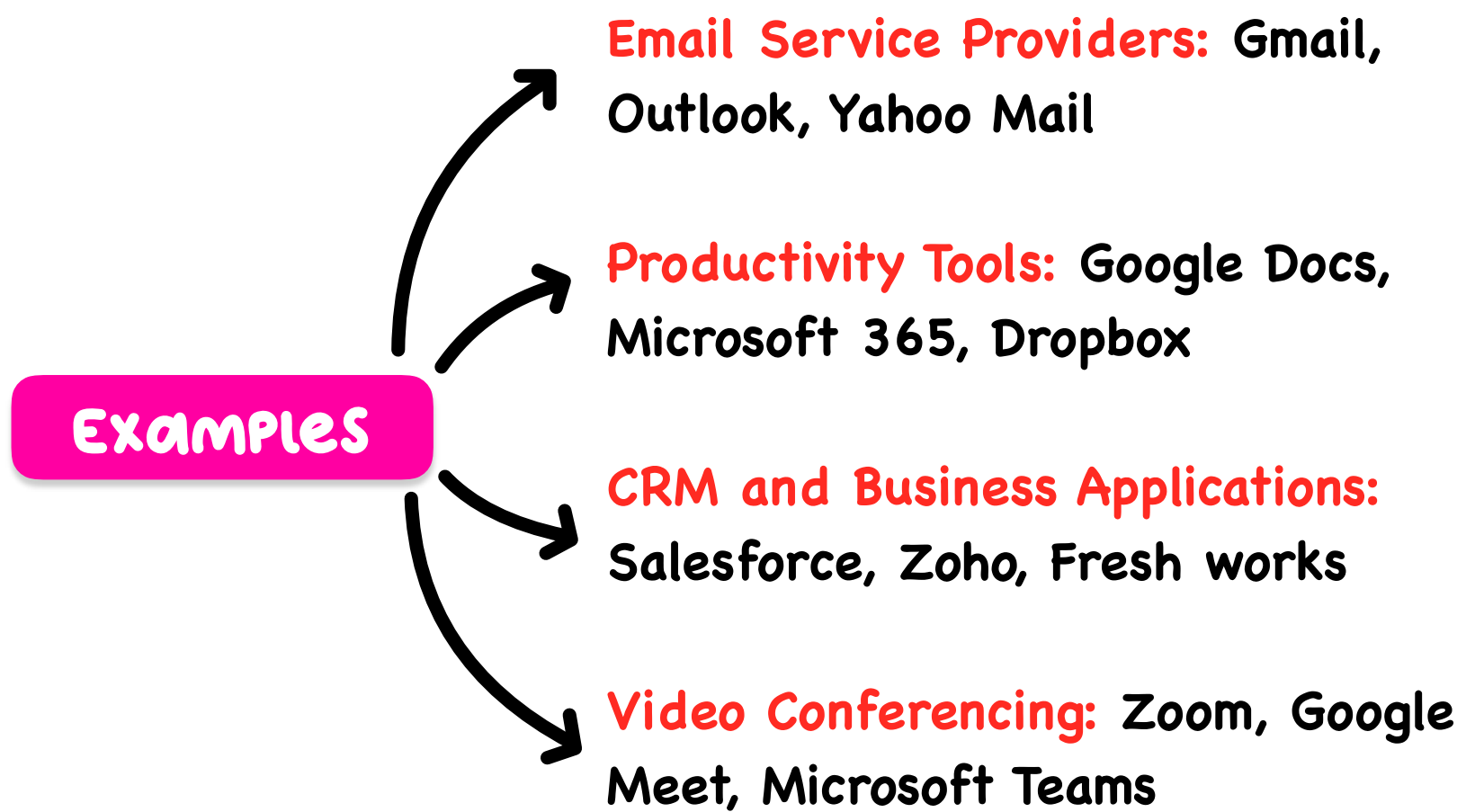
Benefits of SaaS

- **Cost Effective:** No need for expensive hardware or software installation
- **Remote Accessibility:** Access data from anywhere via the Internet
- **Security and Backups:** Service providers manage data security and backups
- **Scalability:** Users can upgrade based on needs

Challenges

- **Data Security Risks:** Data is stored on third party servers
- **Internet Dependency:** Requires a stable connection for smooth functioning
- **Limited Control:** Users rely on service provider configurations

Examples

Email Service Providers: Gmail, Outlook, Yahoo Mail

Productivity Tools: Google Docs, Microsoft 365, Dropbox

CRM and Business Applications: Salesforce, Zoho, Fresh works

Video Conferencing: Zoom, Google Meet, Microsoft Teams

Is Excel a SaaS?

Excel as a SaaS
If you are accessing web version of Excel through a browser, then it will be considered SaaS. Ex: Microsoft 365

Excel as Traditional Software
If you are accessing installed version of Excel on your computer without using any Internet, then it will considered as a traditional software
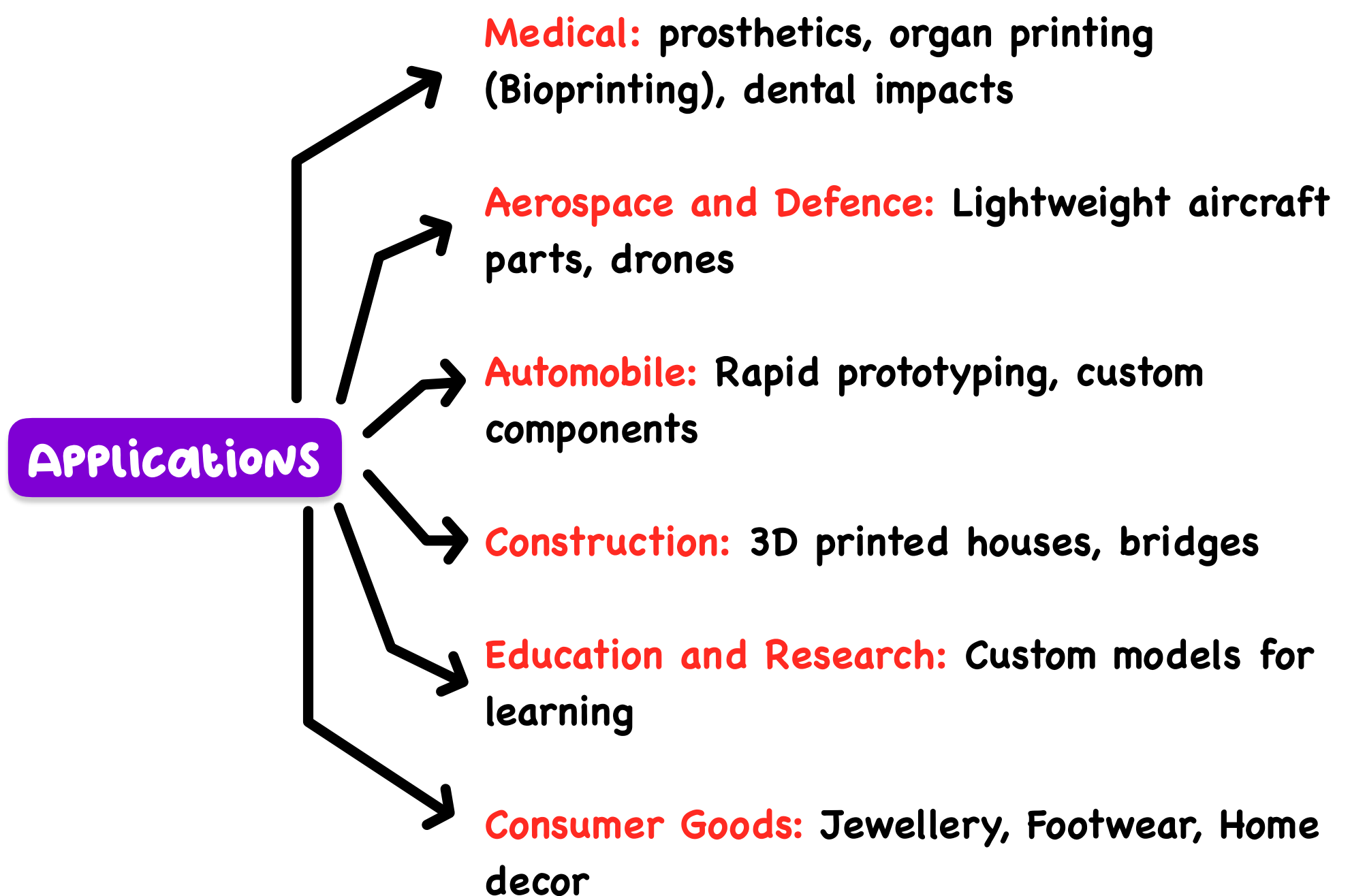
3D Printing

3D Printing or Additive Manufacturing is a process of joining materials to make objects from 3D model data usually layer upon layer

It is different from conventional manufacturing. In 3D printing, the object is made from a CAD model usually by successively adding materials in a layer by layer fashion

The addition of materials can happen in multiple ways like power deposition, resin curing, filament fusing, etc.

Thermoplastics, Metals, Ceramics as well as biomaterials can be used for 3D printing

Applications

Medical: prosthetics, organ printing (Bioprinting), dental impacts

Aerospace and Defence: Lightweight aircraft parts, drones

Automobile: Rapid prototyping, custom components

Construction: 3D printed houses, bridges

Education and Research: Custom models for learning

Consumer Goods: Jewellery, Footwear, Home decor

Non Fungible Tokens

NFTs is a unique digital asset stored on a blockchain that certifies ownership and authenticity of items like art, music, videos and virtual goods
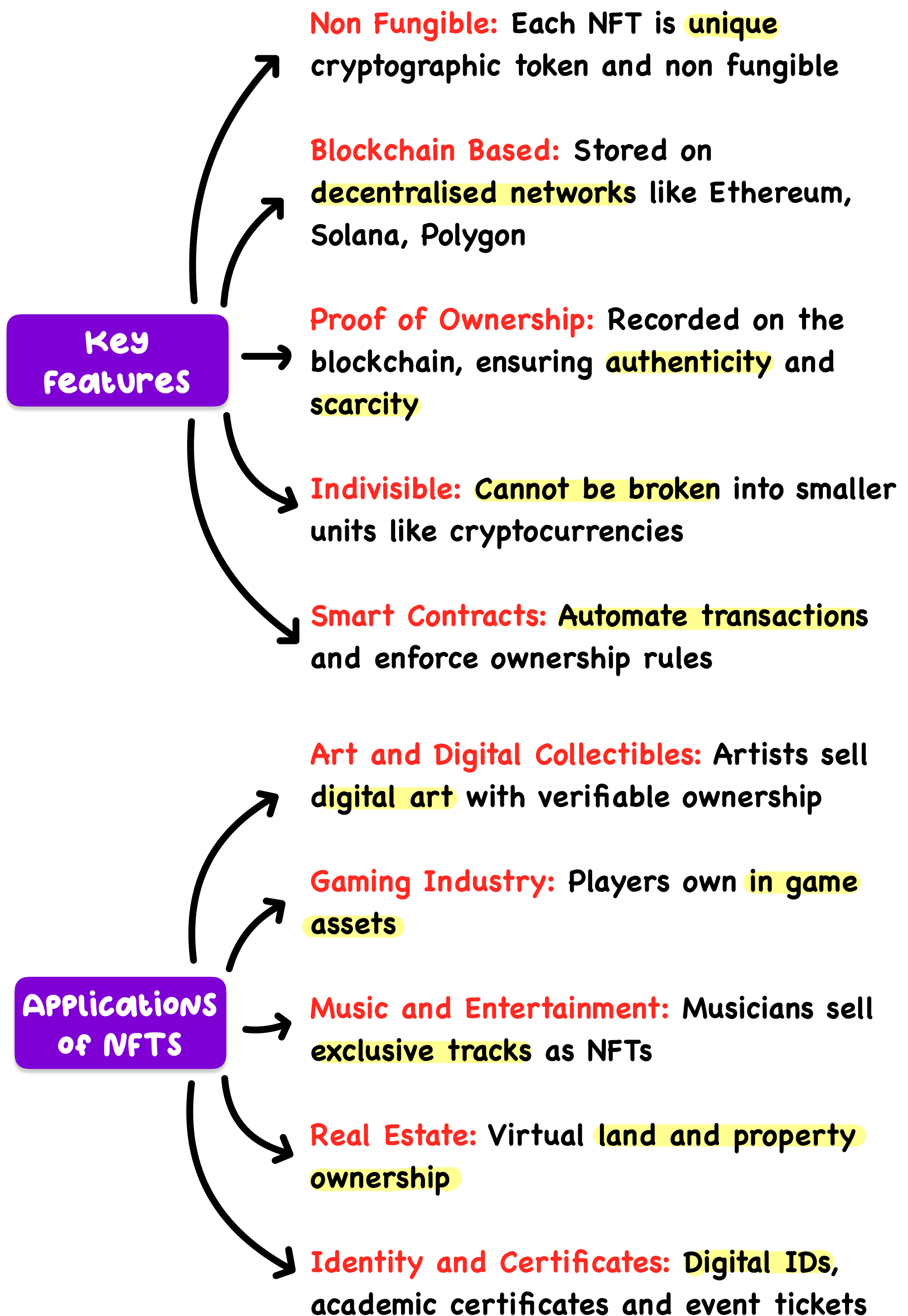
Unlike cryptocurrencies, NFTs are indivisible, irreplaceable and one of a kind making digital equivalent of rare collectibles

What is Fungibility?

- Fungibility refers to an asset's ability to be exchanged for another of the same kind without losing value
- Fungible Assets: Identical and Interchangeable and Subdivision into Units is possible (Ex: Rs 100 note = another Rs 100 note; Rs 500 = five Rs. 100 notes; 1 Bitcoin = another Bitcoin). Hence, Bitcoin and Currency are fungible
- Non Fungible Assets: Unique and not Interchangeable and Subdivision into Units is not possible (Ex: 1 artwork by Pikaso is not equal to another artwork by Pikaso)

What is NFT?

- NFT is a digital file such as photo file (JPEG), animated image (GIF), music file (MP3)
- Stored using blockchain technology
- They cannot be subdivided and it cannot be exchanged with one another because their values are different based on buyer's preferences. So, NFTs are non fungible
- Hence, they cannot be traded or exchanged at equivalency and cannot be used as a medium of commercial transactions

Key Features

Non Fungible: Each NFT is unique cryptographic token and non fungible

Blockchain Based: Stored on decentralised networks like Ethereum, Solana, Polygon

Proof of Ownership: Recorded on the blockchain, ensuring authenticity and scarcity

Indivisible: Cannot be broken into smaller units like cryptocurrencies

Smart Contracts: Automate transactions and enforce ownership rules

Applications of NFTS

Art and Digital Collectibles: Artists sell digital art with verifiable ownership

Gaming Industry: Players own in game assets

Music and Entertainment: Musicians sell exclusive tracks as NFTs

Real Estate: Virtual land and property ownership

Identity and Certificates: Digital IDs, academic certificates and event tickets

Advantages

Ensues authenticity: Reduces counterfeit products

Empowers creators: Artists get direct payments without intermediaries

Immutable Ownership: Cannot be altered once recorded on blockchain

Programmability: Smart contracts enable royalty payments to creators

Challenges

Environmental Impact: High energy consumption

Speculative Market: Prone to price volatility and scams

Copyright Issues: Ownership of NFT does not imply copyright of underlying asset

Regulatory Uncertainty: Legal framework still evolving globally