

Emerging Technologies

Chapter Seven

Other Emerging Technologies

Outline

- **Nanotechnology**
- **Biotechnology**
- **Blockchain Technology**
- **Cloud and Quantum Computing**
- **Autonomic Computing (AC)**
- **Computer Vision**
- **Embedded Systems**
- **Cyber Security**
- **Additive Manufacturing (3D Printing)**

Learning Outcomes

After completion of this lesson, students shall be able to:

- ✓ Explain **nanotechnology** and its applications.
- ✓ Explain **biotechnology** and its applications.
- ✓ Explain **blockchain** technology and its applications.
- ✓ Gain insights about **cloud** and **quantum computing** and applications.
- ✓ Explain how **computer vision** works and

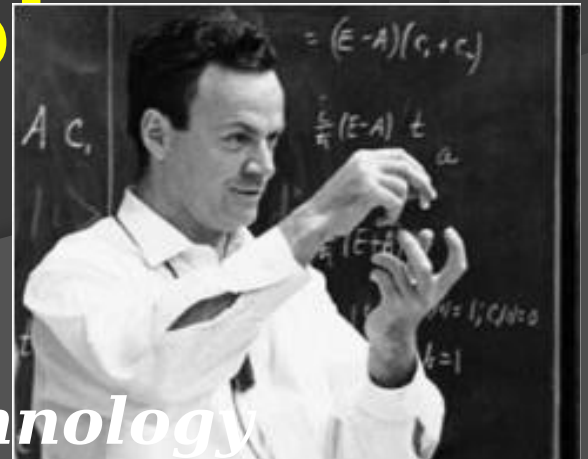
Nanotechnology

- **Nanotechnology** is the application of science, engineering, and technology on materials at the **nanoscale**, roughly within **1 to 100 nanometers**.
- Nanoscience and nanotechnology are the study and application of science & technology on extremely small things and can be used across other science fields, such as chemistry, biology, physics, &

Nanotechnology

- Ideas and concepts behind nanoscience and nanotechnology **started** with a **talk** entitled “**There is plenty of room at the bottom**” by physicist Richard Feynman at a science society meeting in 1959, long **before** the term **nanotechno** used .

Physicist **Richard Feynman**, the father of nanotechnology

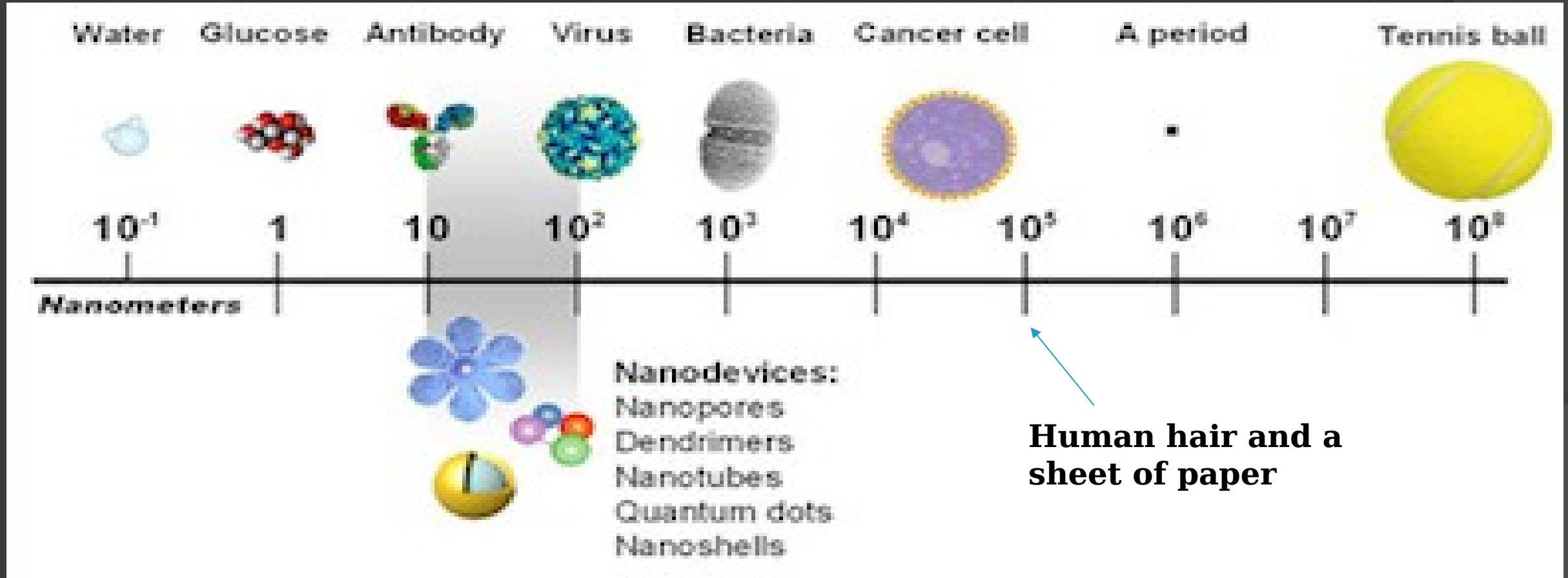


Fundamental concepts in Nanoscience & Nanotechnology

- Can you imagine how small a nanometer is? One **nanometer** is a **billionth** of a meter or **10^{-9}** meters.
- Here are a few illustrative examples:
 - There are **25,400,000 nanometers** in an inch.
 - A **sheet of newspaper** is about **100,000 nanometers** thick.
 - On a comparative scale, **if a marble were a nanometer**, then **one meter** would be the size of the Earth.
- **Nanotechnology** is the application of **nanoscience** leading to the use of **new**

Concepts in Nanoscience & Nanotechnology

How small is a nanometer?



Fundamental concepts in Nanoscience & Nanotechnology

- **Nanoscience** and **Nanotechnology** embrace the ability to see and control individual **atoms** and **molecules**.
- A **nanometer** is large as compared to the **atomic scale**. An atom has a **diameter** of about 0.1 nm. An atom's **nucleus** is much smaller about 0.00001 nm. **Atoms are the building blocks of all matter in the universe.**

Concepts in Nanoscience & Nanotechnology

- According to Dr. Störmer, a Nobel Prize winner, the **nanoscale** is more **interesting** than the **atomic scale** because the **nanoscale** is the **first point** where we can assemble something (by putting atoms together) and make anything useful.

Concepts in Nanoscience & Nanotechnology

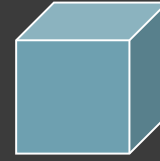
- Based on definitions of nanoscale and atomic scale sizes, we can redefine nanoscience and nanotechnology as follows (**most widely used definition**):
 - **Nanoscience** is the study of phenomena and manipulation of materials at **atomic**, **molecular** and **macromolecular** scales, where properties differ significantly from those at a larger scale.
 - **Nanotechnology** is the design, characterization, production, and application of structures, devices, and systems by controlling shape and size at the

Concepts in Nanoscience & Nanotechnology

What makes technology at the nanoscale different from technology at the macroscale?

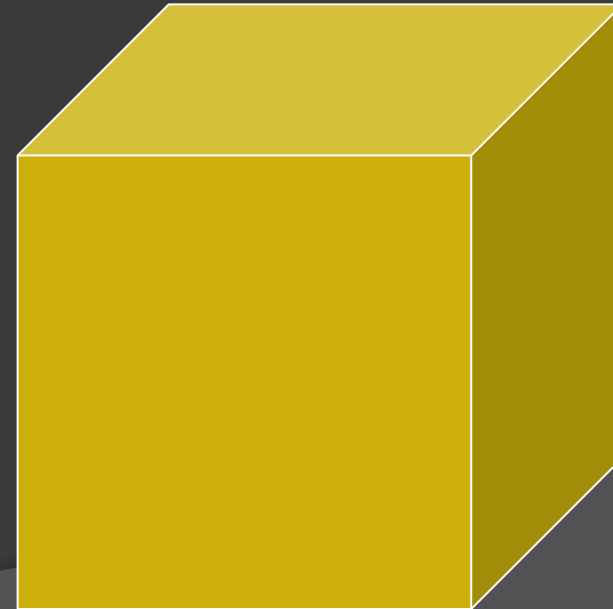
Volume to surface area ratio

- As objects get smaller they have a much greater surface area to volume ratio



2 cm cube has a surface area of 24 cm^2 and a volume of 8 cm^3 (ratio = 3:1)

10 cm cube has a surface area of 600 cm^2 and a volume of 1000 cm^3 (ratio = 0.6:1)



Concepts in Nanoscience & Nanotechnology

- The **properties of materials** can be different at the **nanoscale** for two main reasons:
 - due to the high **surface area to volume ratio** when compared to large-scale materials, which can affect their **strength** or **electrical properties**.
 - **quantum effects** can begin to **dominate** the behavior

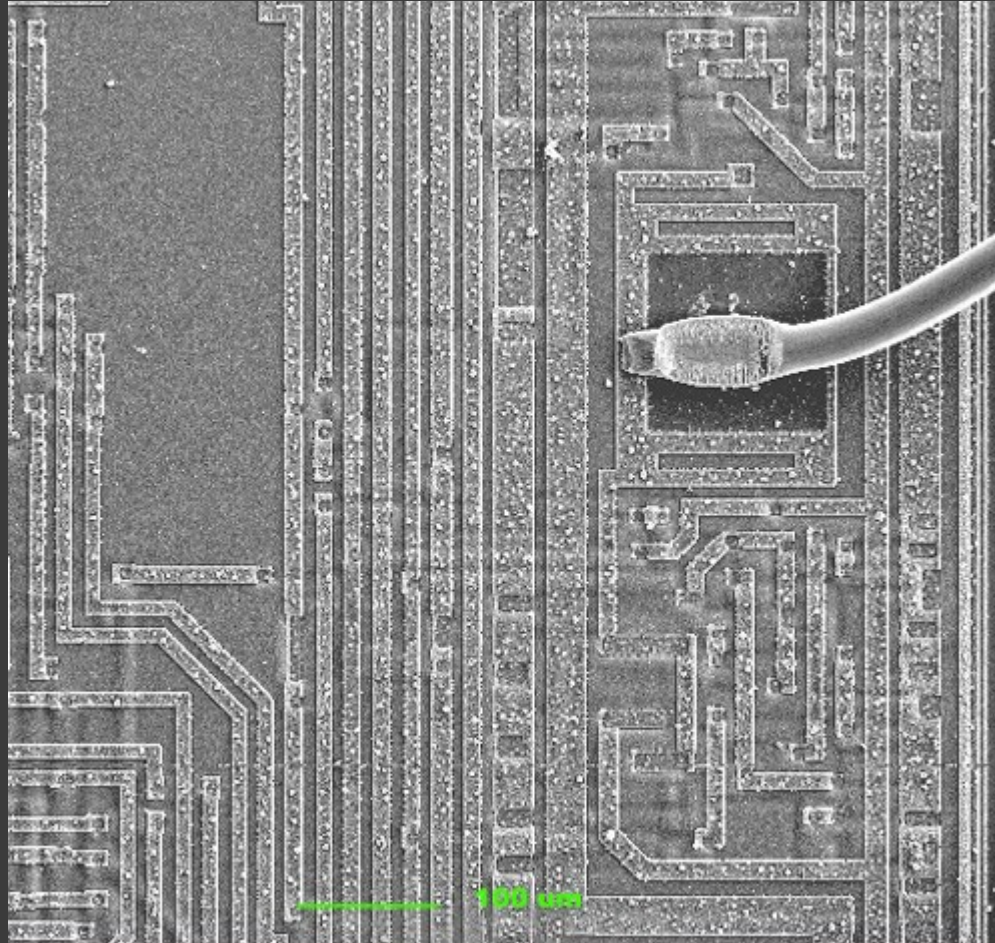
Applications of Nanotechnology

- Coatings - self-cleaning windows and stain proof clothing



Applications of Nanotechnology

- Microchips



Applications

- Catalysts
 - Envirox™ cerium oxide
- Nanoremediation
 - SAMMS technology to remove mercury
- Paper
 - photographic paper
- Filters
 - nanofibres
- Toothpaste
 - to remineralise teeth
- Food
 - packaging
- Paint
 - improved adhesion and anti-fungal qualities/**anti-graffiti**
- Clothes
 - non-staining and anti-radiation
- Batteries
 - (Black & Decker) phosphate nanocrystal technology

Biotechnology

- **Biotechnology** is the use of living systems and **organisms** to **develop** or **make** useful **products**, or "any technological application that uses biological systems, living organisms or derivatives thereof, to make or modify **products** or **processes** for specific use"

Biotechnology

- **Biotechnology** – using living organisms, or the products of living organisms, for human benefit to make a product, a process, or solve a problem.
- **Biotechnology** is the manipulation of living organisms and organic material to serve human needs.

Biotechnology

- **Historical Examples**
 - **Fermentation**
 - **Selective breeding**
 - **Use of antibiotics**
 - **Yeast in bread making and alcohol production**
 - **Use of beneficial bacteria (penicillin) to kill harmful organisms**

Biotechnology

- **Modern Examples**
 - **Cloning of plants and animals**
 - **Artificial insemination**
 - **Genetic engineering**
 - **Recombinant DNA technology**
 - **Human Genome Project**

Biotechnology

- Example of Biotechnology - **Selective Breeding**

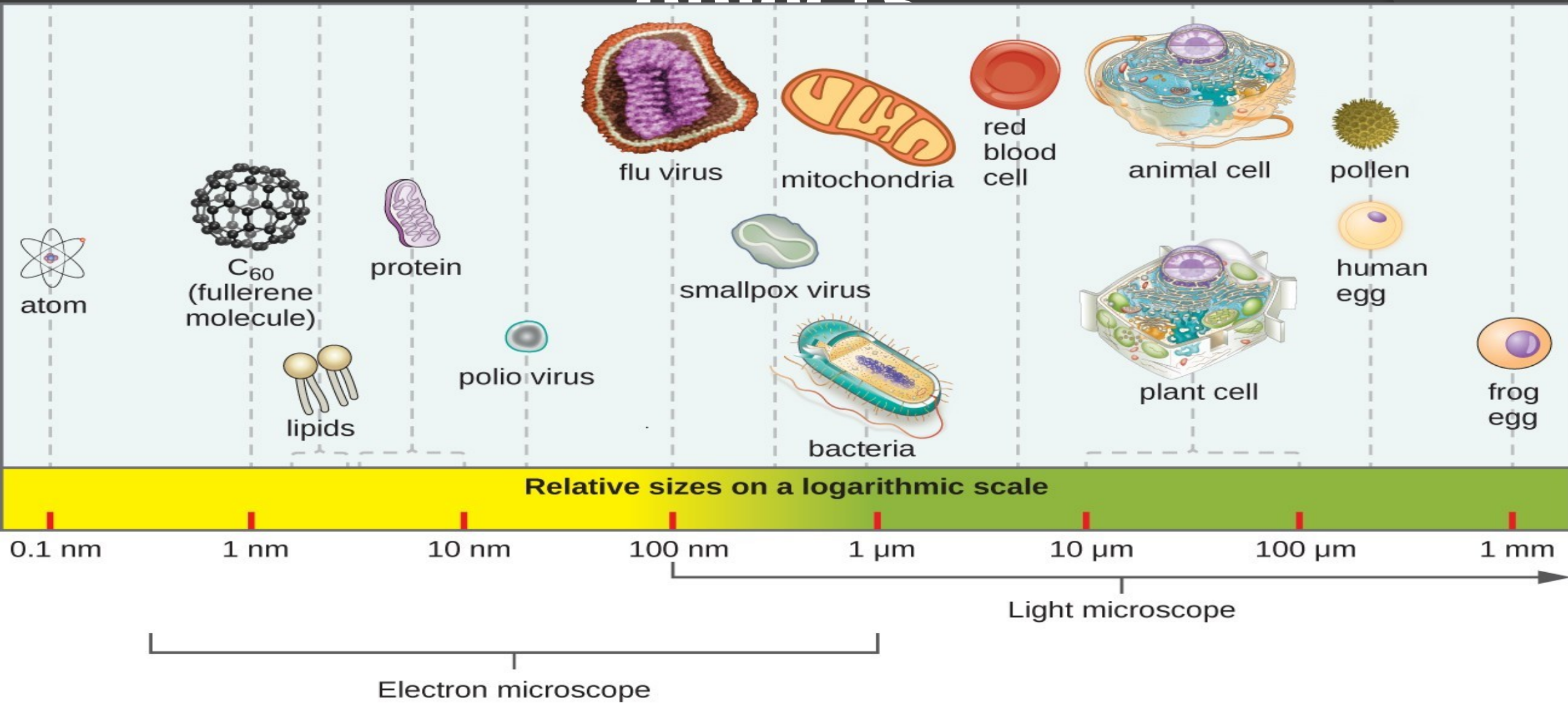


Normal zebrafish



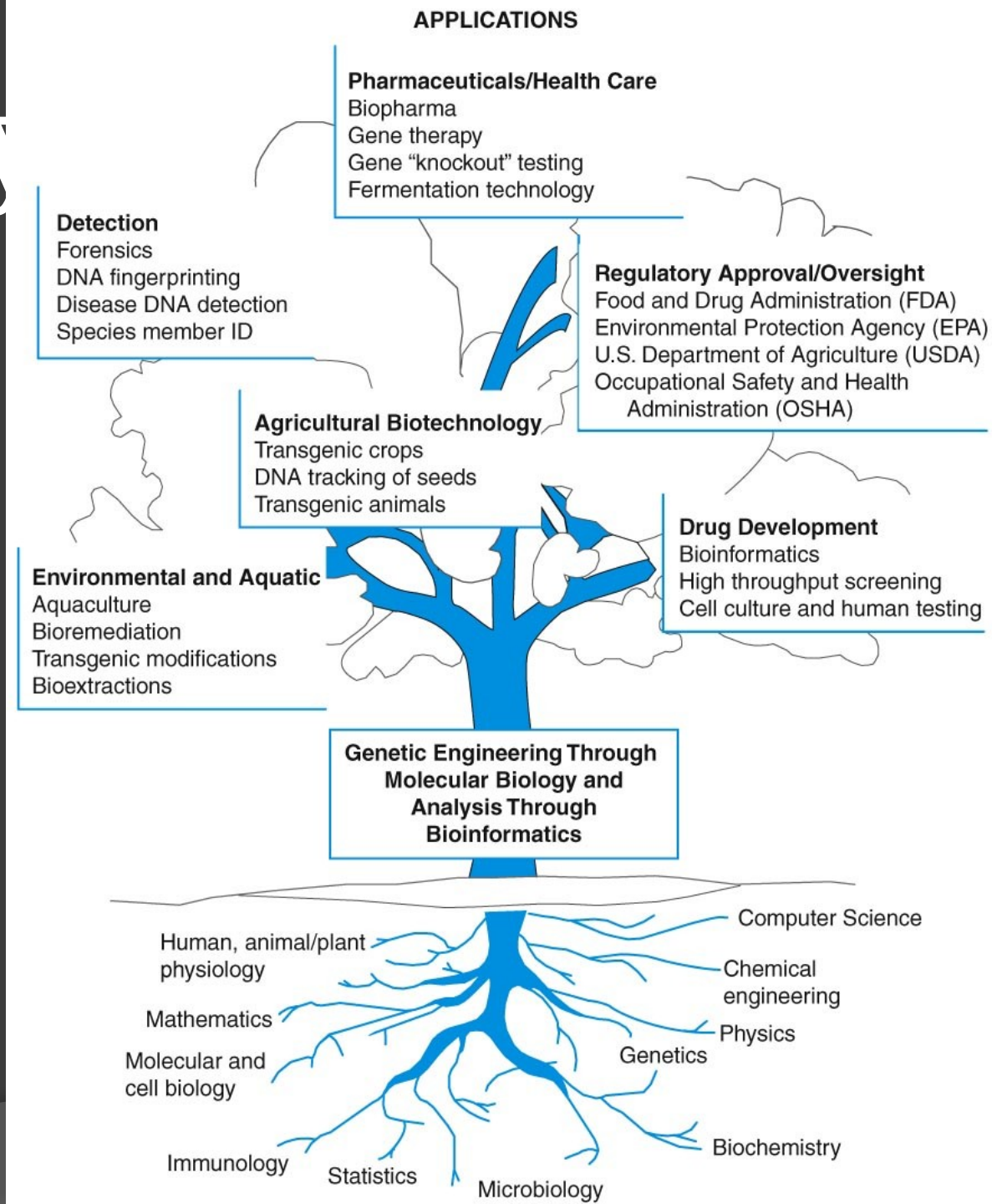
**"Casper" zebrafish -
made
by selective breeding**

The relative sizes of various microscopic and non-microscopic objects



Biotechnology

Based on this tree, can anyone become successful in the biotech industry only studying biology?

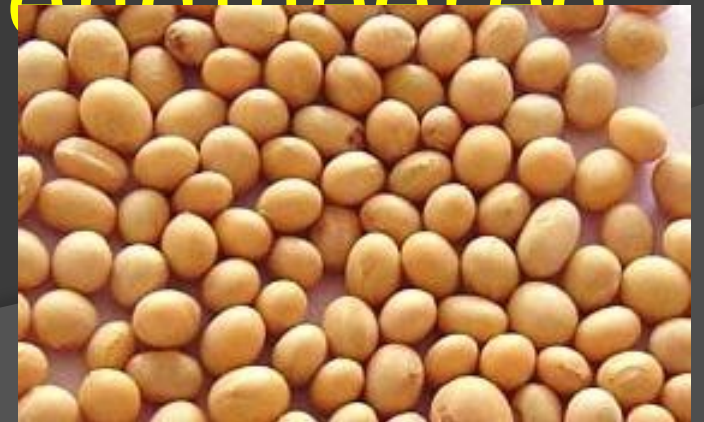


Biotechnology

- Example of "**modern**" biotechnology
 - **recombinant DNA** technology started modern **biotech as an industry**
- Examples of **applications**
 - **development of disease-resistant plants**
 - **food crops that produce greater yields**
 - **"golden rice" engineered to be more nutritious**
 - **genetically engineered bacteria** that can **degrade** environmental **pollutants**

Impact of Biotechnology

- **Genetically modified organisms (GMOs)** are consumed by millions of people.
 - Almost **56%** of **all soybean** plantings worldwide are **genetically engineered** (much higher in the US)



Blockchain Technology

Cloud and Quantum Computing

What is Cloud?

- The term **Cloud** refers to a **Network** or **Internet**. In other words, we can say that Cloud is something, which is present at remote location. Cloud can provide services over a network, i.e., on public networks or on private networks, i.e., WAN, LAN or VPN.
- Applications such as **e-mail, web conferencing, customer relationship management (CRM)**, all run in cloud.

Cloud and Quantum

What is Cloud Computing?

• Internet-based computing?

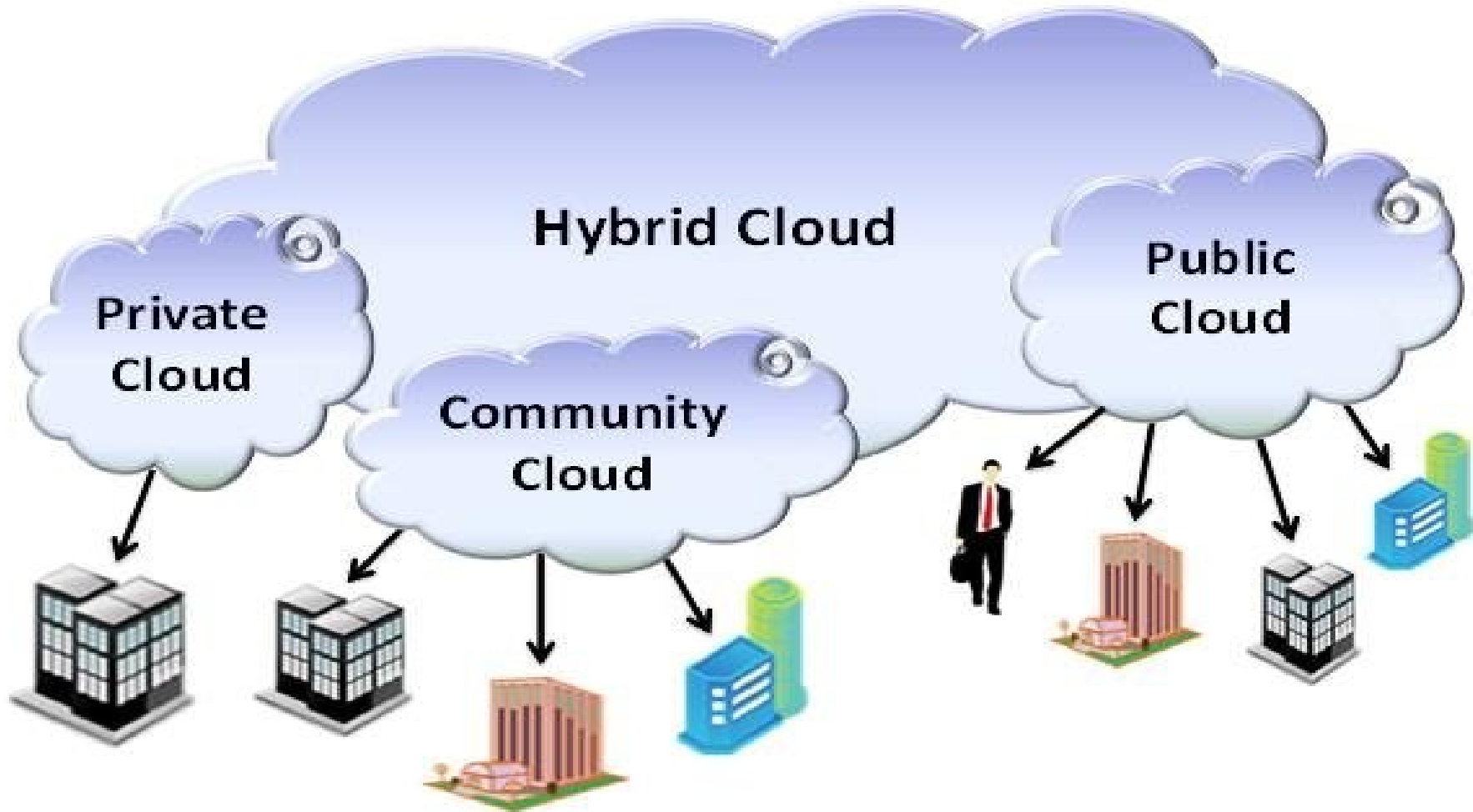
- Internet-based computing in which large groups of remote servers are networked so as to allow sharing of data-processing tasks, centralized data storage, and online access to computer services or resources.
- Any computer related task that is done entirely on the Internet.

Cloud and Quantum Computing

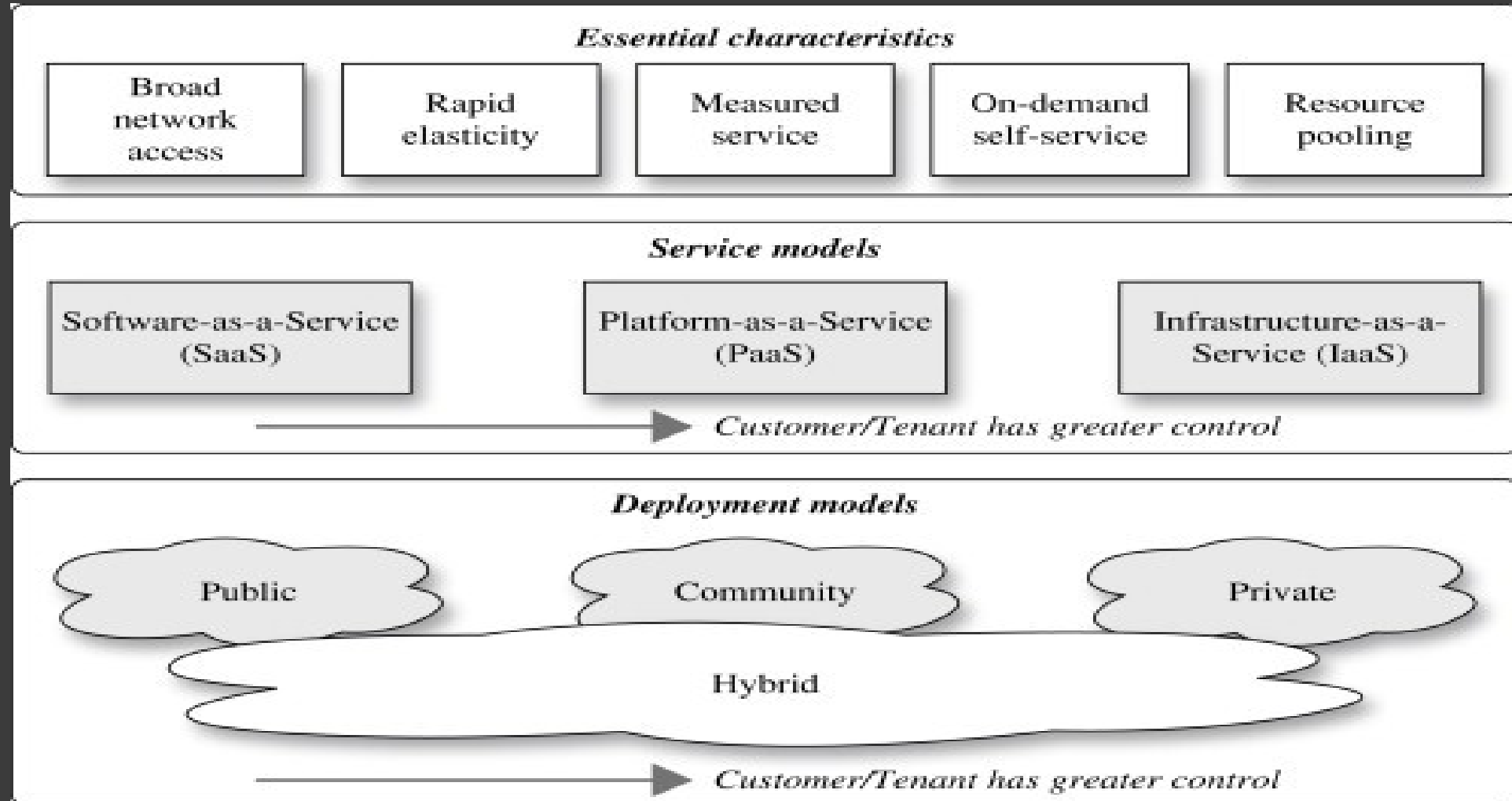
What is Cloud Computing?

- Allows users to deal with software and hardware without having them in their premises.
- Everything is done remotely, nothing is saved locally.
- Is both a combination of software and hardware based computing resources delivered as a network service.

Deployment Models



Cloud Computing Models & Features



Deployment Models

- **PUBLIC CLOUD** : allows systems and services to be easily accessible to the general public. Public cloud may be less secure because of its openness, e.g., e-mail.
- **PRIVATE CLOUD** : allows systems and services to be accessible within an organization. It offers increased security because of its private nature.
- **COMMUNITY CLOUD** : allows systems and services to be accessible by group of organizations.
- **HYBRID CLOUD** : is mixture of public and private cloud. However, the critical activities are performed using private cloud while the non-critical activities are performed using public cloud.

Cloud Computing Advantages

- **Business benefits** from **economies of scale**.
- **Improved performance**
- Reduced software costs
- **Instant** software **updates**
- **Improved** document format **compatibility**
- **Unlimited** storage capacity and other **computing resources**
- **Increased** data **reliability**
- **Universal** document **access**
- **Latest version availability**
- **Easier** group **collaboration**
- **Device independence**

Disadvantages

- Requires a **constant Internet connection**
- **Does not work well** with **low-speed connections**
- **Features** might be **limited**
- **Can be slow**
- Stored **data can be lost**
- Stored **data might not be secure**

Quantum Computing

- **Quantum computers** represent the **next generation of computing**.
- Unlike **classic computers**, they derive their computing power by harnessing the power of **quantum physics** also called **quantum mechanics**.
- **Quantum cloud computing** is the access to a **quantum computer over the internet**.

Introduction to quantum mechanics

- **Quantum mechanics** is a fundamental branch of **theoretical physics** with wide **applications in experimental physics** that **replaces classical mechanics** and classical electromagnetism **at the atomic and subatomic levels.**

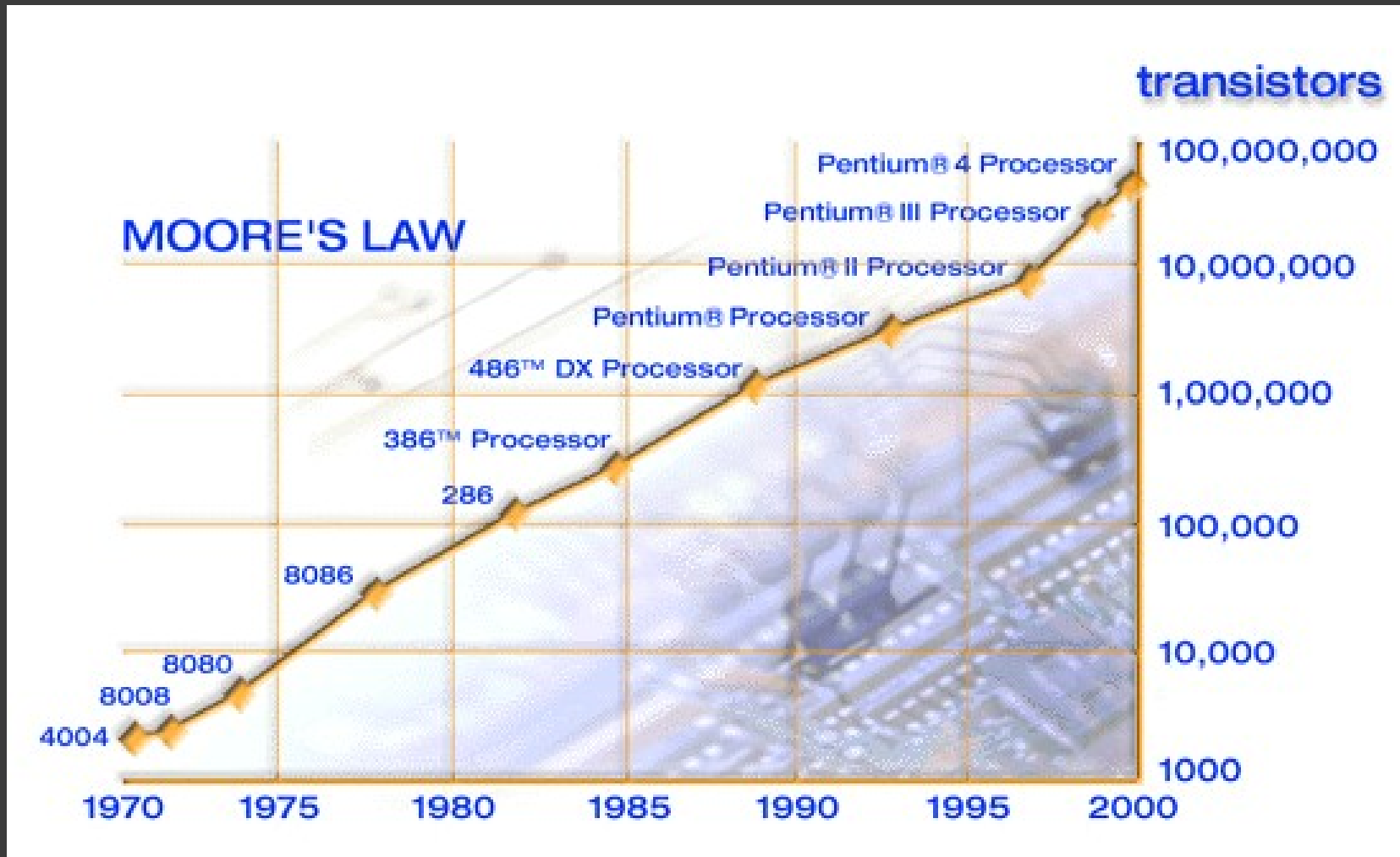
Introduction to quantum mechanics

- **Quantum mechanics** is a more fundamental theory than **Newtonian mechanics** and **classical electromagnetism**.
- It **provides accurate and precise descriptions** for many phenomena that these "**classical**" theories simply cannot explain on the atomic

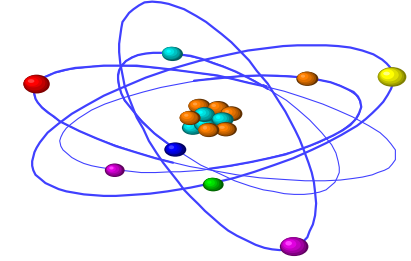
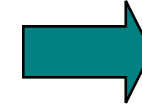
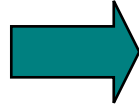
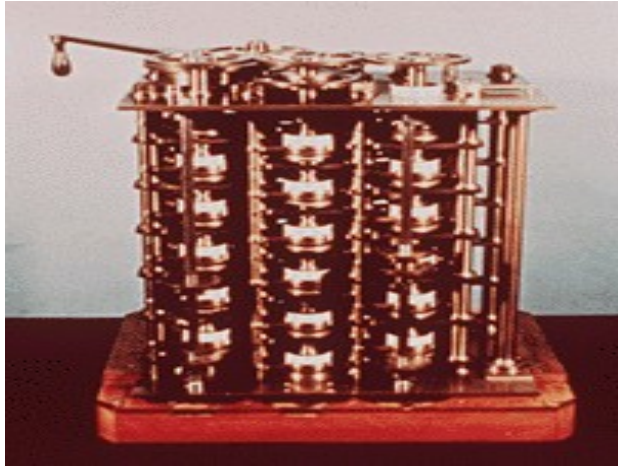
What is a quantum computer?

- A **quantum computer** is a machine that performs calculations based on the **laws of quantum mechanics**, which is the behavior of particles at the **sub-atomic level**.

Why bother with quantum computation?



Moore's Law: We hit the quantum level 2010~2020.



**Computer technology is making
devices **smaller and smaller...****

**...reaching a point where classical
physics is no longer a suitable model
for the laws of physics.**

The design of devices on such a small scale will *require* engineers to control quantum mechanical effects.

Allowing computers to take advantage of quantum mechanical behaviour allows us to do ***more than cram*** increasingly many microscopic components onto a silicon

chip. ... it gives us a whole new framework in which information can be processed in *fundamentally new ways*.

Representation of Data

- Quantum computers would be based on the strange principles of quantum mechanics, in which the smallest particles of light and matter **can be in different places at the same time**.
- In a quantum computer, **one "qubit"** - quantum bit - could be both 0 and 1 at the same time. So with three qubits of data, a quantum computer could store all eight combinations of 0 and 1 simultaneously. That means a three-qubit quantum computer could calculate **eight times faster than a three-bit digital computer**.
- Typical personal computers today calculate 64 bits of data at a time. **A quantum computer with 64 qubits would be 2 to the 64th power faster, or about 18**

A bit of data is represented by a single atom that is in one of two states denoted by $|0\rangle$ and $|1\rangle$. A single bit of this form is known as a *qubit*.

Classical Bit

1 Bit



or

Either 0 or 1

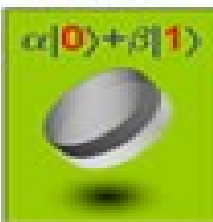
N Bit



One out of 2^N possible permutations

Quantum Bit

1 Bit



Both 0 and 1

N Bit



All of 2^N possible permutations

Autonomic Computing

- **Motivations**
 - Present day **IT environments are complex, heterogeneous** in terms of **software & hardware** from multiple vendors.
 - Computing systems have **evolved** into **millions of interconnected devices** whose interactions create complex web on **increasingly complex architecture**.

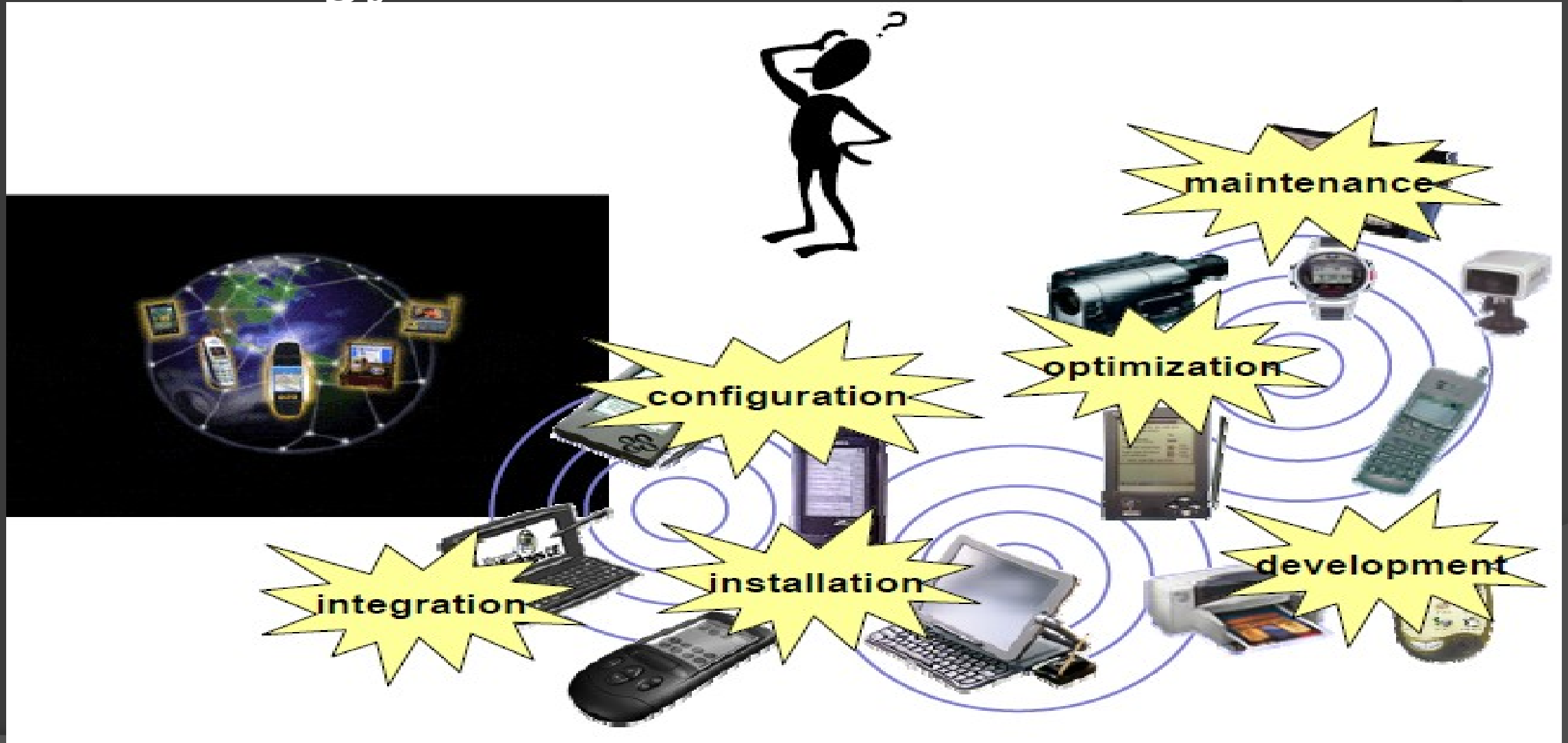
Growing Complexity of IT Systems

- **Very large scales**
 - millions of entities
- **Ad hoc (amorphous) structures/behaviors**
 - p2p, hierarchical architecture
- **Dynamic**
 - entities join, move, change behavior
- **Heterogeneous**
 - capability, connectivity, reliability, guaranties, QoS
- **Unreliable**
 - components, communication
- **Lack of common/complete knowledge**
 - number, type, location, availability, connectivity, protocols, semantics, etc

Convergence of IT and BT

- Our system programming paradigms, methods, and management tools seem to be **inadequate for handling the scale, complexity, dynamism and heterogeneity of emerging future networks and systems.**
- **Biological systems** have evolved strategies to cope with **dynamic, complex, highly uncertain** constraints.
- Recently, some research areas of **IT** are applying

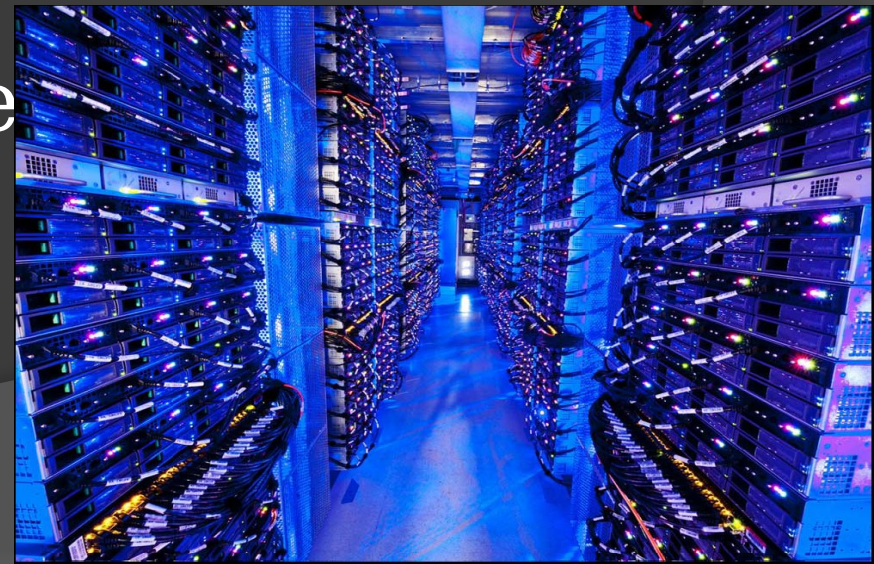
Growing Complexity of Information Technology



Motivation: hardware faults

Question: what is the probability of a hard drive failure?

- In our laptop?
 - Will happen every few years,
 - hopefully not right now...
- In a large supercomputer or data center
 - More than **100k** nodes
 - Will happen during this class!



Autonomic Computing

- **Autonomic**
 - Pertaining to an on demand operating environment that responds **automatically** to problems, security threats, and system failures
 - **Self-adaptive, Self-governing, Self-managing.**
- Is **derived** from human biology, autonomic nervous system
 - ANS **monitors** heartbeat, body temperature, ...
 - Without any conscious effort on our part!
- The **goal** of **autonomic computing** is to **find** appropriate **solutions** based on **current state/context/content** that are **compliant** with

Autonomic option

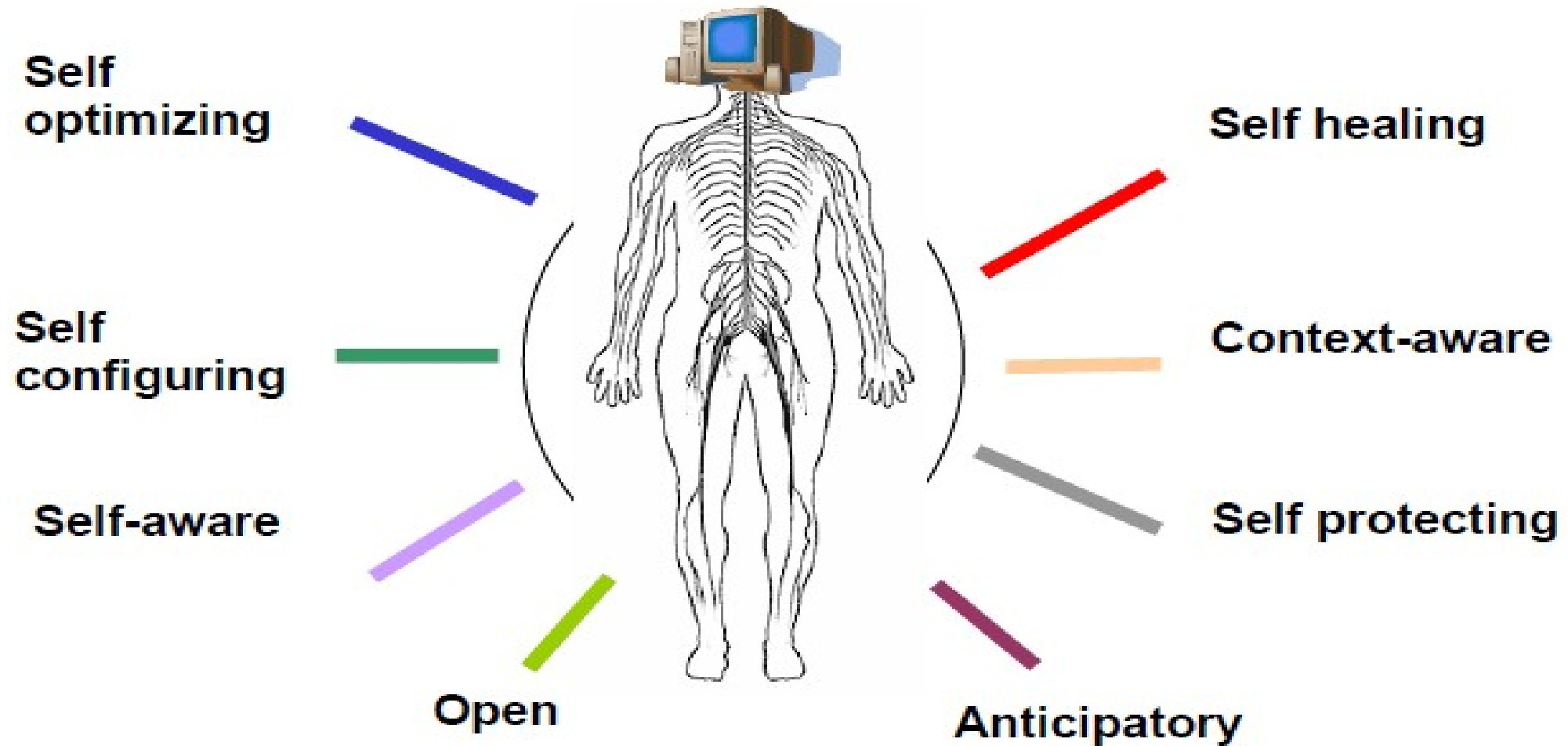
- Autonomic computing
 - Systems **manage themselves** according to admin goals.
 - **Self-governing** operation of entire system, not just parts of it.
 - **New components integrate effortlessly** - as a new cell establishes itself in



The vision for Autonomic Computing

- “**Intelligent**” systems that:
 - **Manage complexity**
 - **Know themselves**
 - Continuously **tune themselves**
 - **Adapt** to unpredictable conditions
 - **Prevent** and **recover** from failures

Characteristics of Autonomic Systems



Autonomic Computing Systems

Systems

They are **Self-managing** systems that deliver:

Increased Responsiveness

Adapt to dynamically changing environments

Operational Efficiency

Tune resources and balance workloads to maximize use of IT resources



Business Resiliency

Discover, diagnose, and act to prevent disruptions

Secure Information and Resources

Anticipate, detect, identify, and protect against attacks

Autonomic Systems **Self-** **management**

- Four aspects of self-management

- **Self-configuration**

- Configure themselves automatically
- High-level policies (**what** is desired, not *how*)

- **Self-optimization**

- Continually seek ways to **improve** their operation
- Hundreds of tunable parameters

- **Self-healing**

- Handle faults and errors
- Analyze information from logs and monitors

- **Self-protection**

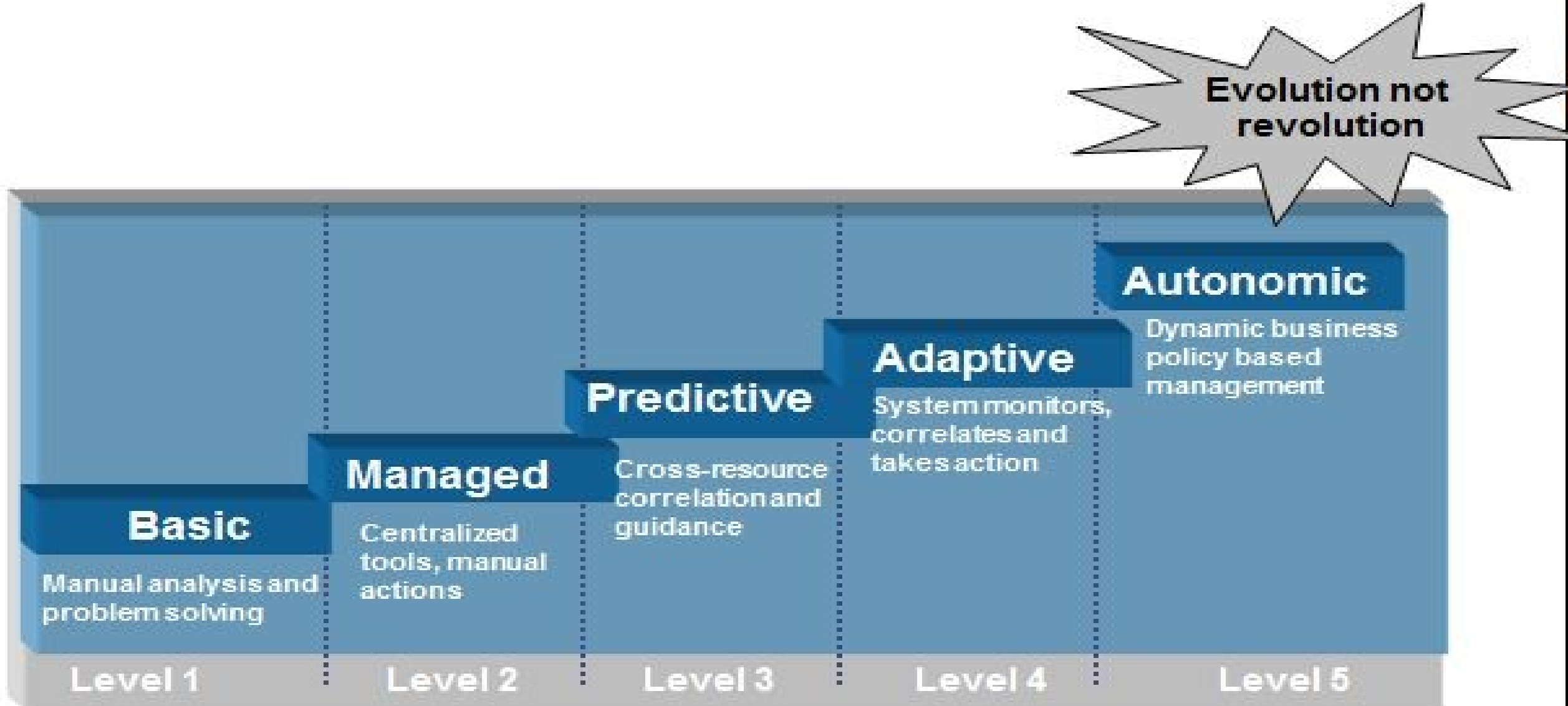
- Malicious attacks, Cascading failures
- Admin mistakes



Self-management Cont..

- **Self-management Issues**
 - Changing components
 - Changing external conditions
 - Hardware/software failures
- **Example, Component Upgrade**
 - Continually check for component upgrades
 - Download and install
 - Reconfigure self
 - Run a regression test
 - If errors are detected, revert to older version

Levels of Autonomic Maturity



Computer Vision

- What is Computer Vision?
 - Make computers **understand images and videos**



- What kind of scene?
- Where are the cars?
- How far is the building?

How Computer Vision Works?

1. **Acquiring an image**: Images, even large sets, can be **acquired in real-time** through video, photos or 3D technology for analysis.
2. **Processing the image**: **Deep learning models automate** much of this process, but the models are often **trained** by first being fed thousands of labeled or pre-identified images.
3. **Understanding the image**: The final step is the **interpretative step**, where an object is identified or classified.

Huge Visual data on the Internet

- Flickr
 - 10+ billion photographs
 - 60 million images uploaded a month
- Facebook
 - 250 billion+ Photographs
 - 300 million a day
- Instagram
 - 55 million a day
- YouTube
 - 100 hours of video uploaded every minute



90% of net traffic will be visual!



History of Computer Vision



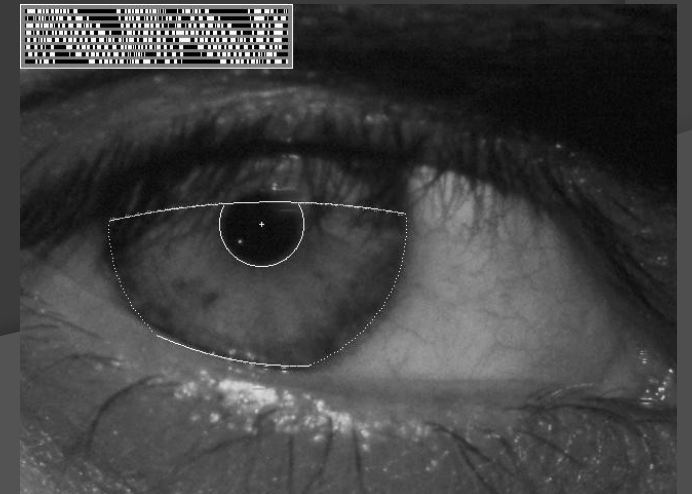
Marvin Minsky, MIT
Turing award, 1969

“In 1966, Minsky hired a first-year undergraduate student and assigned him a problem to solve over the summer:

connect a camera to a computer and get the machine to describe what it sees.”

Examples of Computer Vision Applications

- Face Recognition
 - Facebook face auto-tagging
- Smile detection
- Vision based biometrics
 - Iris patterns



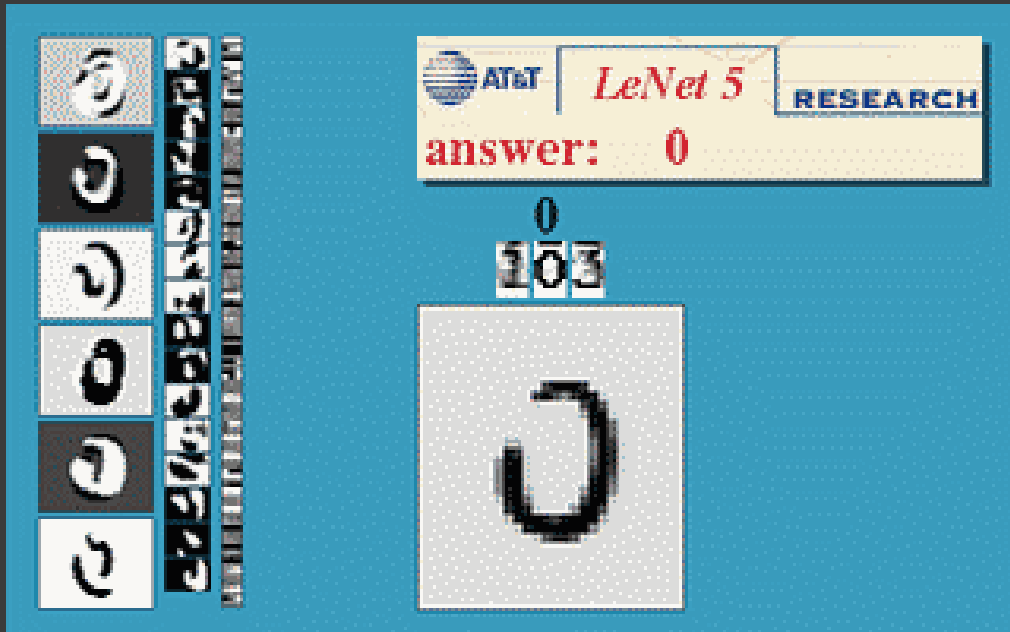
Face detection



- Most digital cameras and smart phones detect faces (and more)
 - Canon, Sony, Fuji, ...
- For smart focus, exposure compensation, and cropping

Optical Character Recognition (OCR)

- ❑ Technology to convert scanned docs to text
- ❑ If you have a scanner, it probably came with OCR software

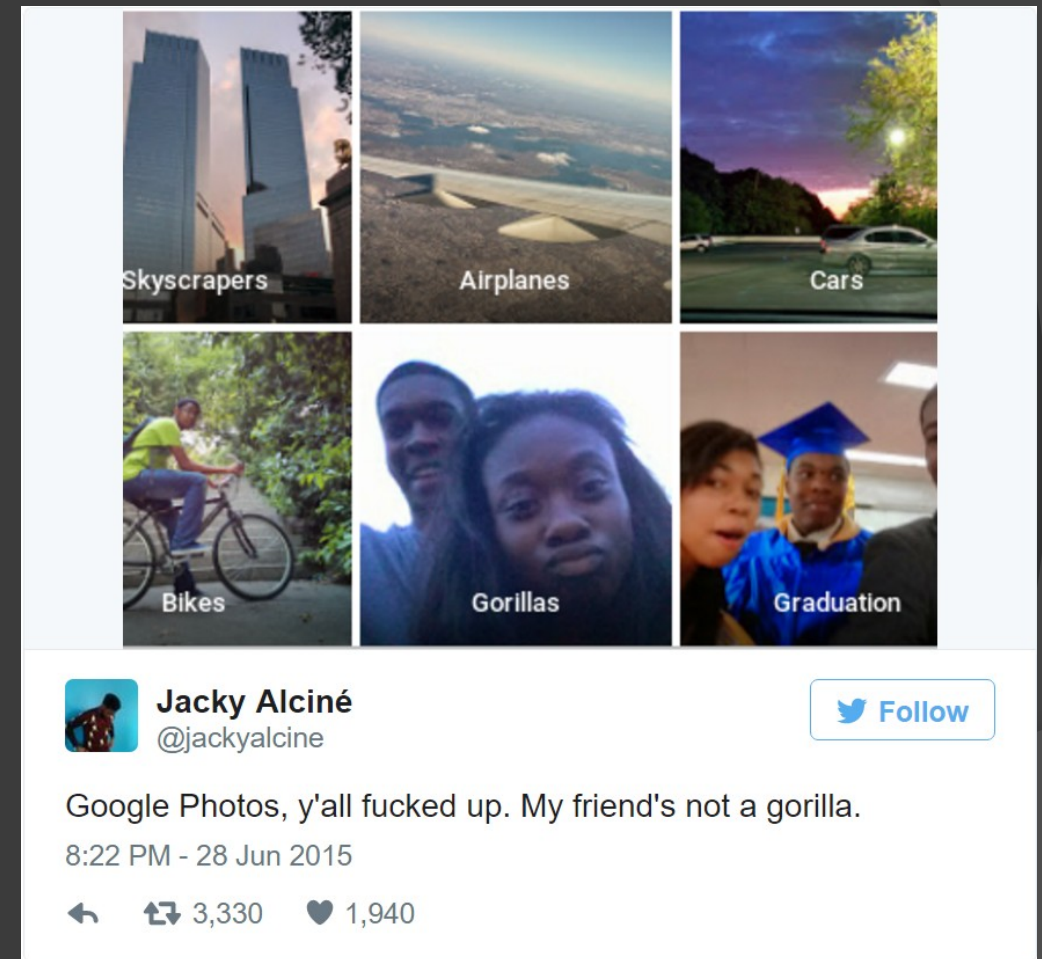
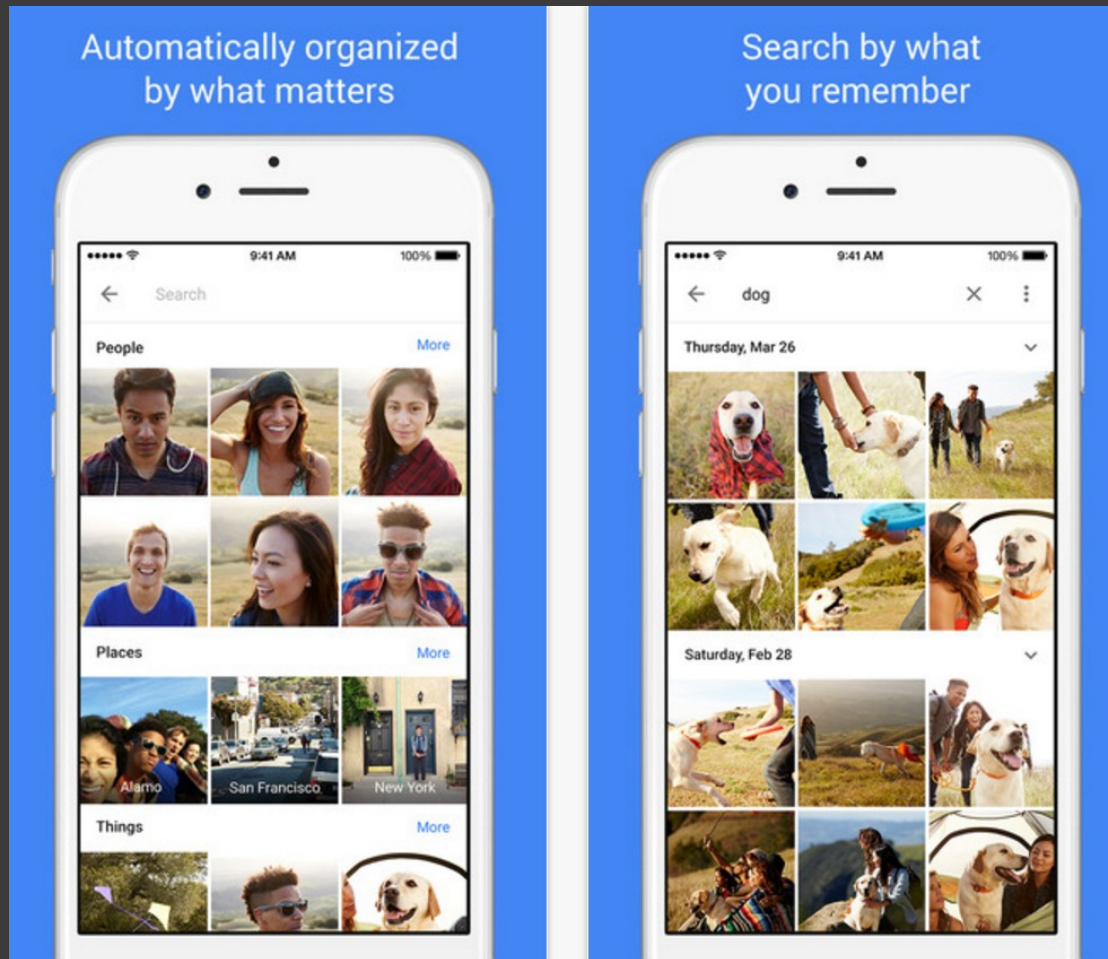


Computer vision in sports



Hawk-Eye: helping/improving referee decisions

Visual recognition for photo organization



Google photo

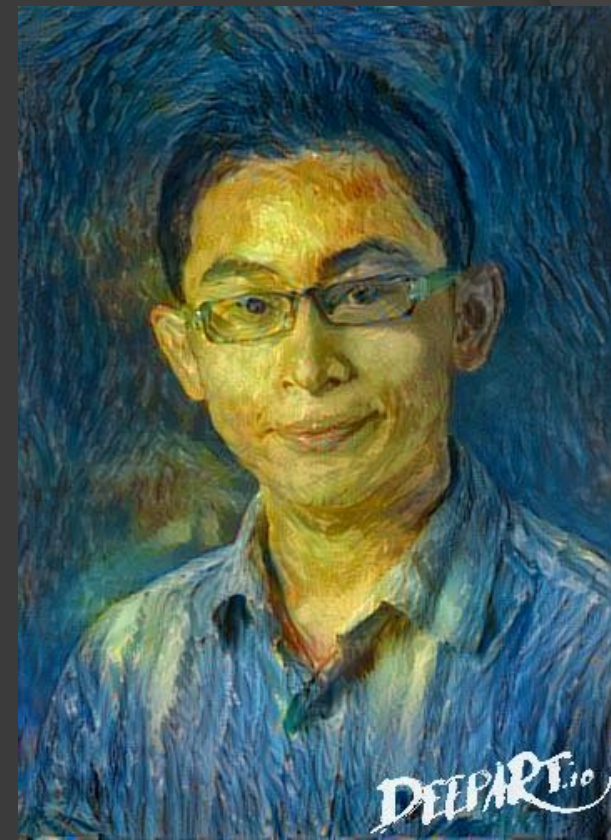
Style transfer



Source image (Style)



Target image (Content)



Output ([deepart](#))

A Neural Algorithm of Artistic Style [[Gatys et al. 2015](#)]

Embedded Systems

Definition

- It is an **Electronic/Electromechanical system** designed to perform a **specific function** and is a combination of both hardware & software.
- A combination of **hardware and software** which together form **a component of a larger machine or system**.

Embedded Systems

Digital System vs. Embedded System

- **Digital System:** **may provide service**
 - as a self-contained unit (e.g., **desktop PC**)
 - as part of a larger system (e.g., digital control system for manufacturing plant)
- **Embedded System**
 - **part of a larger unit**
 - **provides dedicated service to that unit**

Embedded Systems Continued

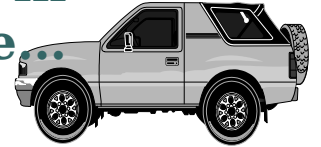
- Computing systems are everywhere
- Most of us think of “desktop” computers
 - PC's 
 - Laptops 
 - Mainframes
 - Servers
- But there's another type of computing system
 - Far more common ... **Embedded computing systems**

••• | Embedded Systems (cont.)

- **Embedded computing systems**

- Computing systems **embedded** within electronic devices.
- Hard to define. Nearly **any computing system other than a desktop computer.**
- **Billions of units produced yearly**, versus **millions of desktop units.**
- Perhaps **100s per household** and **per automobile**

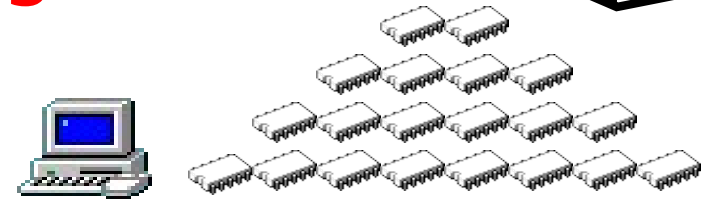
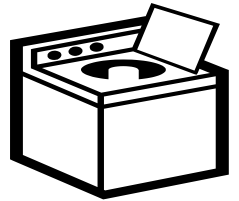
Computers are in here



and here...

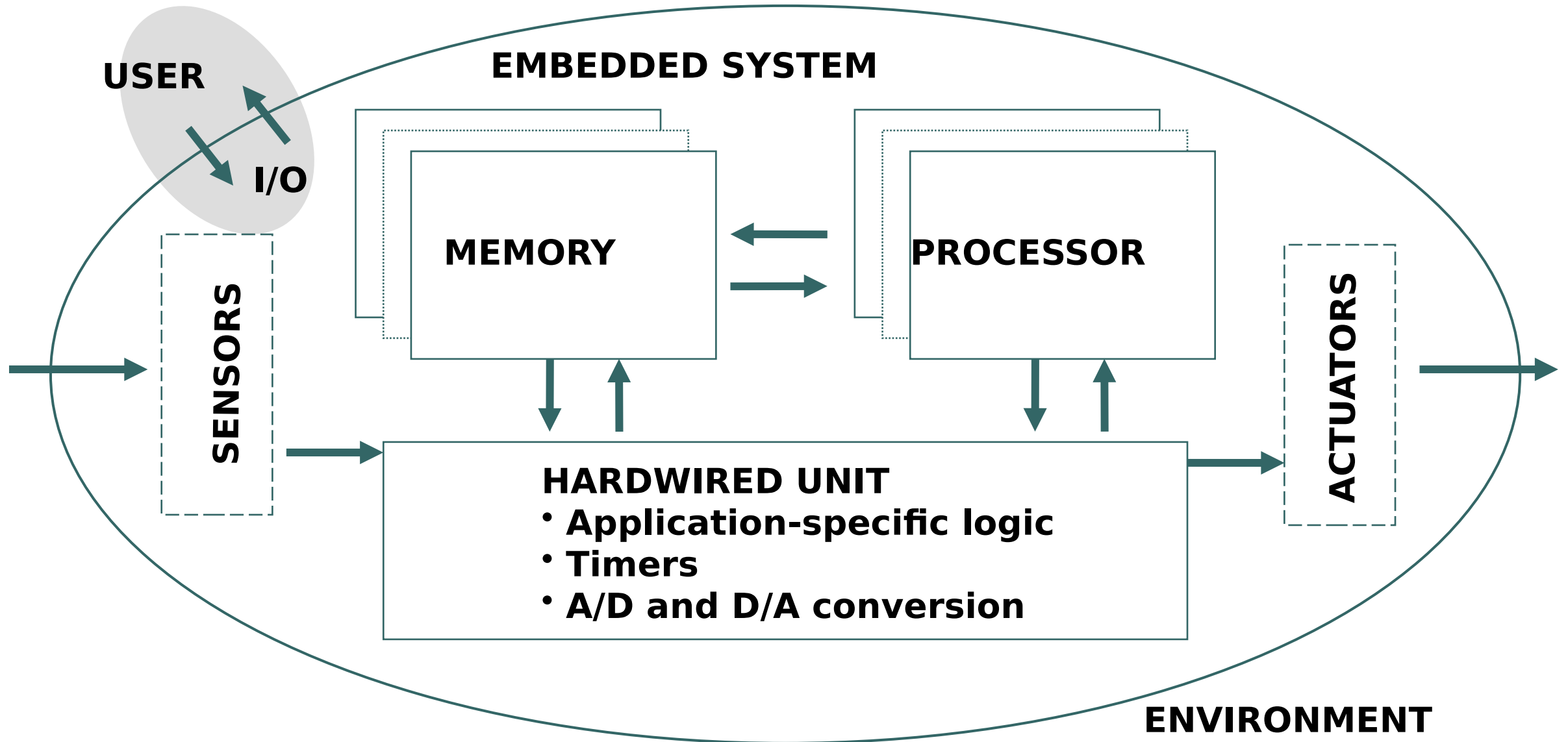


and even here...



Lots more of these, though they cost a lot less each.

Parts of an Embedded System



Parts of an Embedded System (cont.)

- **Actuators** - mechanical components (e.g., valve)
- **Sensors** - input data (e.g., accelerometer for airbag control)
- **Data conversion, storage, processing** - parts
- **Decision-making** - parts



Functions and Design Criteria of Embedded Systems

- **Monitoring** and **control** functions for an overall system (e.g., vehicle control)
- **Information-processing** functions (e.g., telecommunication system -- **data compression, routing**, etc.)
- Criteria: performance, reliability, availability, safety, usability, etc.

Cyber Security

- It is the **protection** of **computer systems** from **theft** and/or **damage** to **hardware**, **software**, or **electronic data**, as well as from the **disruption** or **misdirection** of **services** they provide.
- It is the practice of **defending computers**, **servers**, **mobile devices**, **electronic systems**, **networks**, and **data** from malicious attacks.

Cyber Security

- **Cybersecurity** is meant to **protect attacks** in **cyberspace** such as **data, storage sources, devices, networks**, etc. In contrast, **information security** is intended to protect data from any form of threat regardless of being **analogue or digital**. **Cybersecurity** usually deals with **cybercrimes, cyber frauds and law enforcement**.

Essential cyber security measures

- Use **strong passwords**. Strong passwords are vital to good online security. ...
- **Control access**. ...
- Put up a **firewall** (Inspect encrypted traffic). ...
- Use security software. ...
- **Update programs** and systems regularly. ...
- **Monitor for intrusion**. ...
- **Raise awareness**.
- Use trusted DNS only

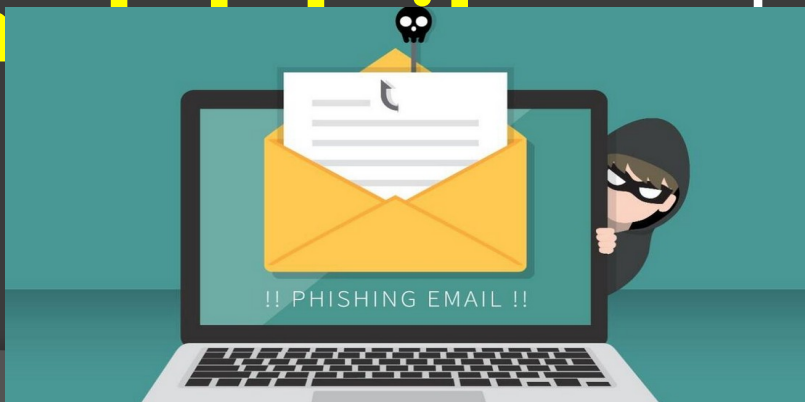
Types of cybersecurity threats

- **Malware** is the collective name for a number of malicious software variants, including **viruses**, **ransomware** and **spyware**. Shorthand for **malicious software**, typically consists of **code developed by cyber-attackers**, designed to cause extensive damage to data and systems or to gain unauthorized access to a network.
- **Social engineering** is the art of **exploiting human psychology**, rather than technical hacking, **to gain access to buildings, systems** and data.



Types of cybersecurity threats

- **Phishing** is a **cybercrime** in which a target or targets are **contacted by email, telephone or text message** by someone **posing as a legitimate** institution to **lure** individuals into providing sensitive data such as **personally identifiable information, banking and credit card numbers, and passwords.**



Advice

- In the **physical world** we're good at protecting ourselves and our property, we need to **replicate** this in the **digital world**.
- **80% of cyber-crime is preventable.**

Additive Manufacturing & 3D Printing

Are they the same?

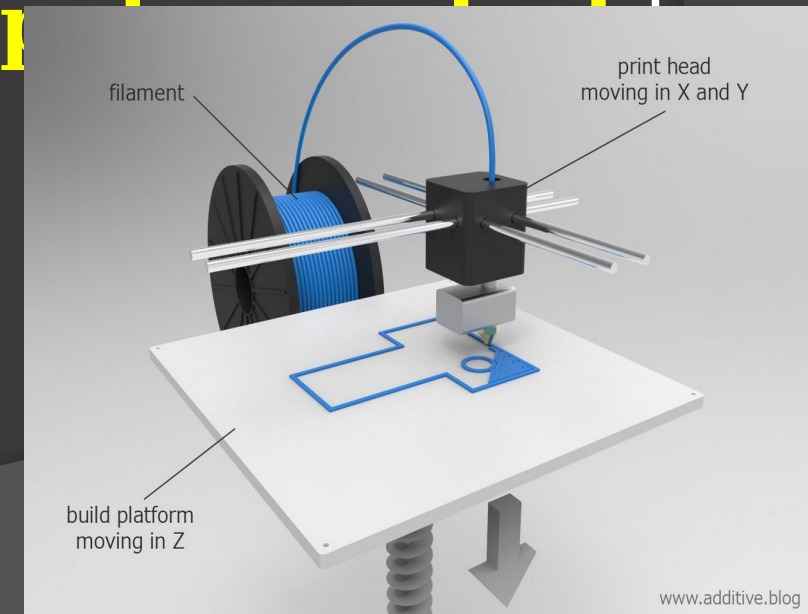
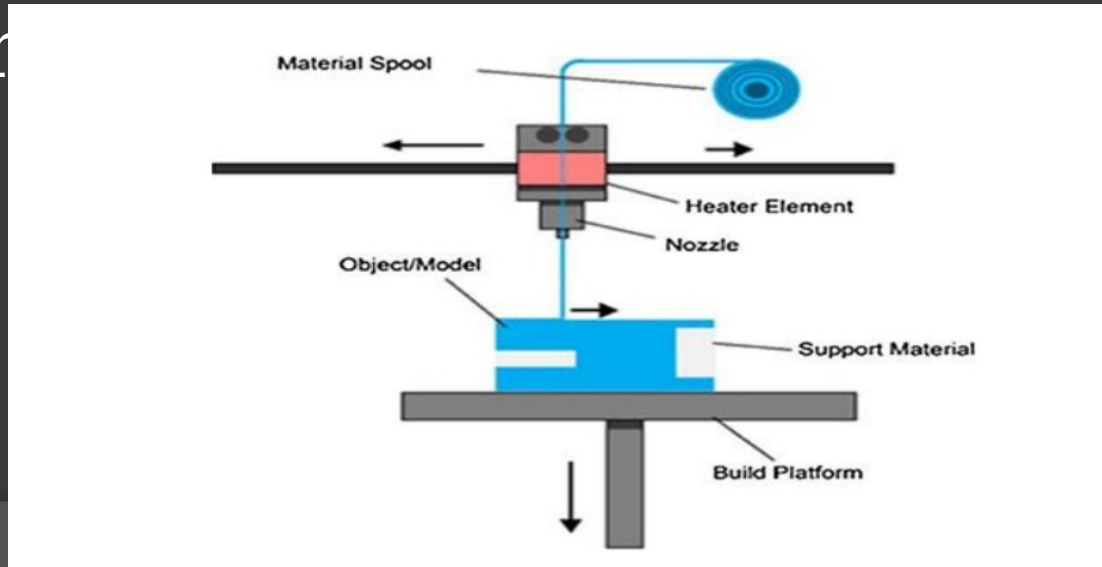
- ASTM **equates** the two terms as: “**Additive manufacturing**, also known as **3D printing**, uses computer-aided design (**CAD**) **to build objects layer by layer.**”
- Wikipedia says, “Today, the precision, repeatability, and material range has increased to the point that **3D printing** is considered as **industrial production technology**, with the name of **additive manufacturing.**”
- In general we can define **additive manufacturing** as

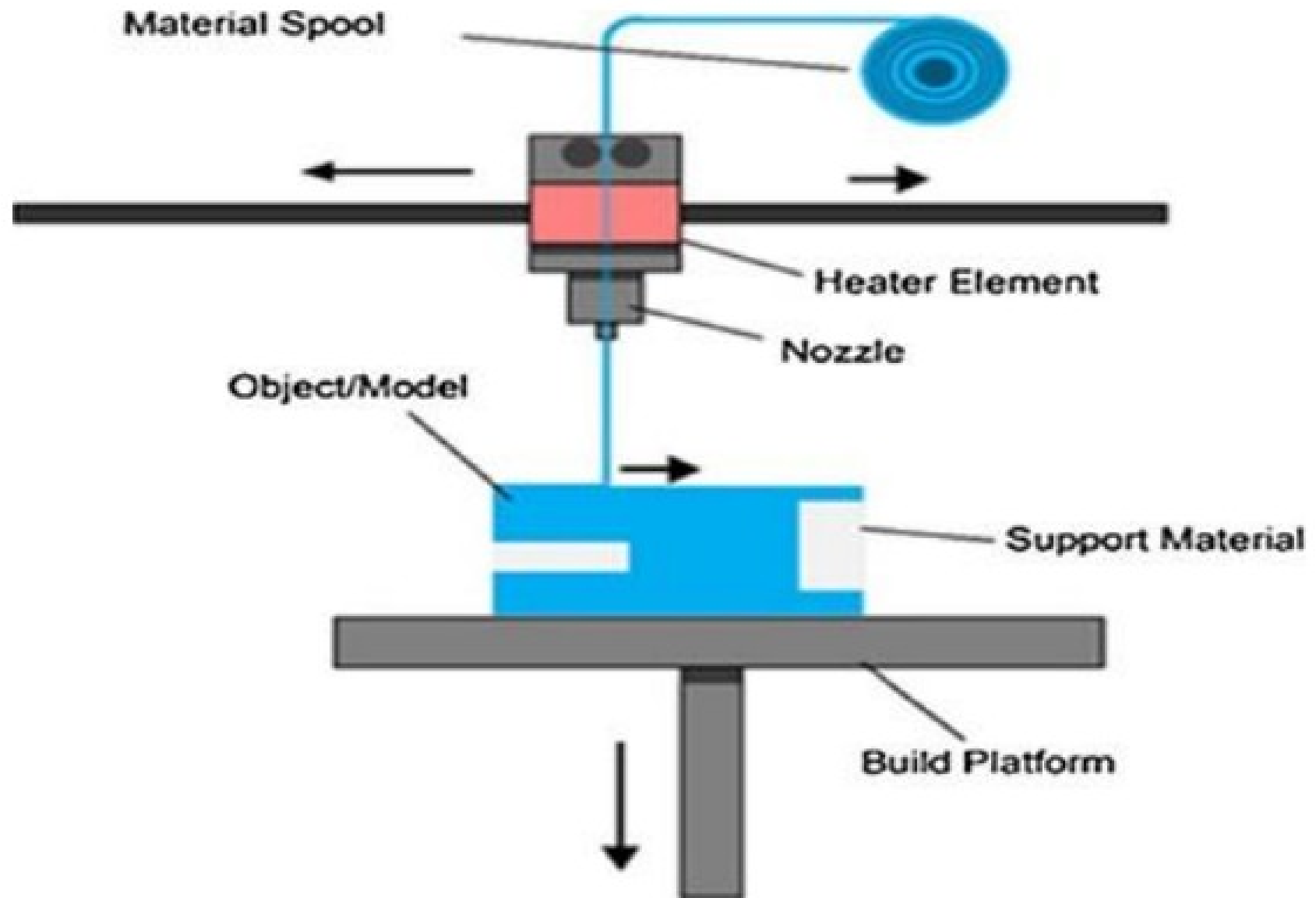
Difference between 3D printing and AM

- **3D printing** is generally used to describe the “**entry level**” processes such as **FDM**, whereas **additive manufacturing** is used to describe the **advanced** and **more precise** techniques like **SLS**.

FDM 3D printing

- **Fused filament fabrication (FFF)**, also known as **fused deposition modeling (FDM)**, or called **filament freeform fabrication**, is a **3D printing** process that uses a continuous filament of a **thermoplastic material**.
- The **print** head is moved under **computer control** to deposit the material layer by layer to define the geometry of the object.





Filament led to the Extruder

Gears control the feed movement of filament

Heater heats and melts the filament

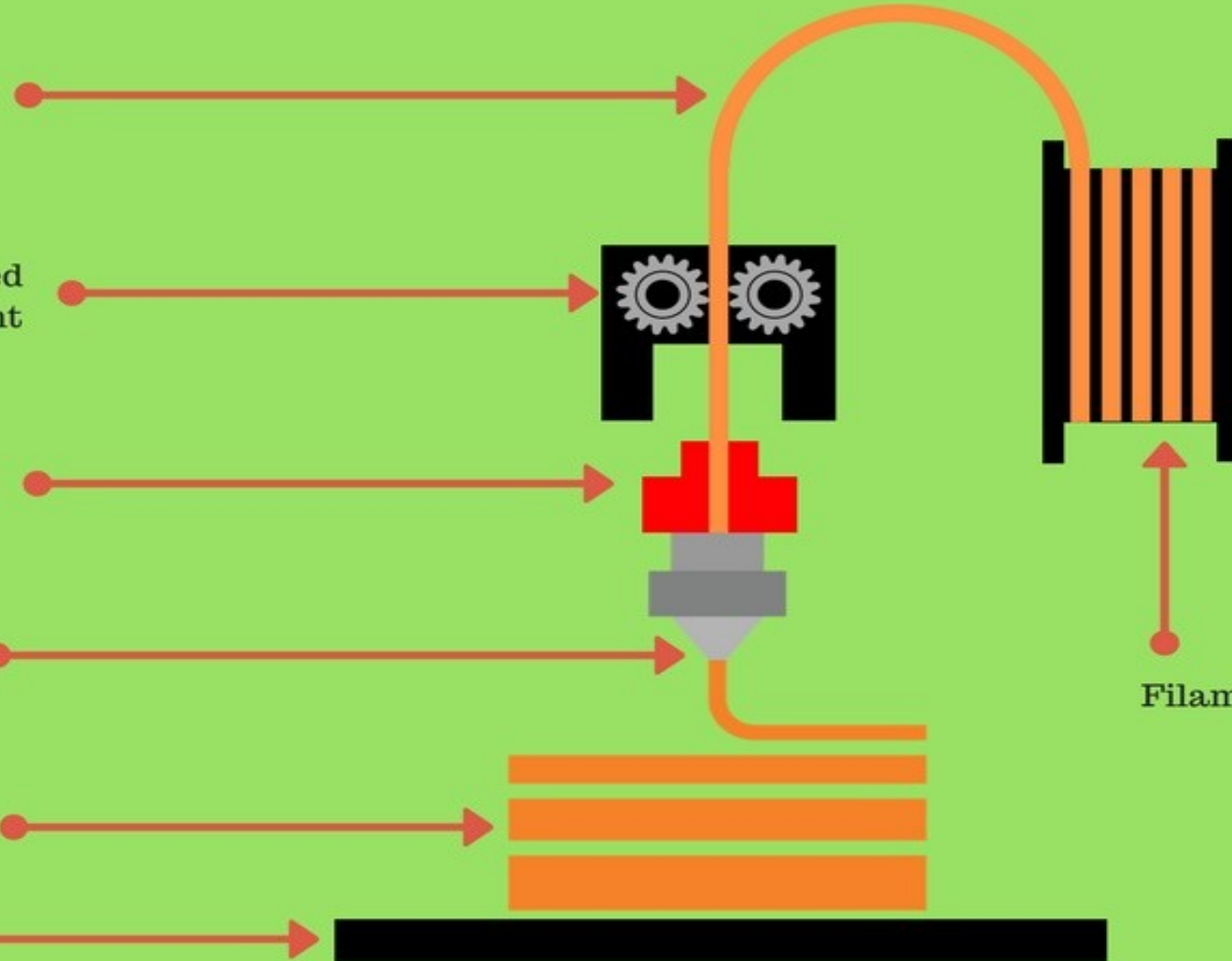
Nozzle extruding the material

Melted material is deposited in layers

FDM Print Bed

Filament Spool

FDM TECHNOLOGY



SLS - Additive Manufacturing

- **Selective laser sintering (SLS)** is an **additive manufacturing (AM)** technique that uses a **laser** as the power source to **sinter** powdered material (typically nylon or polyamide), aiming the laser automatically at points in space defined by a **3D model**, binding the material to create a solid structure.

