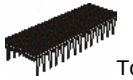
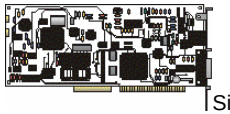
Mission: *To build a powerful desktop computer with a billion processors.*

Transistors are fundamental to modern computers. A transistor is small electronic device containing a semiconductor and having at least three electrical contacts, used in a circuit as an amplifier, detector, or switch. Used as a switch, the transistor can be used to perform logic and numeric computations.



Today's computers have logic circuits with 1,000,000 transistors per square centimeter compactly placed on a single silicon chip. These transistors can switch on and off every 0.000000001 seconds.



Since the 1960's, the number of transistors per unit area has been doubling every 1.5 years. This progression of circuit technology is known as Moore's Law, after Gordon Moore (founder of Intel Corporation).

Researchers at Stanford, Cornell, and Purdue produced a carbon nanotube (CNT) transistor with a zirconium oxide gate insulator that has superior properties to transistors with silicon dioxide gate insulators. CNT transistors might one day continue Moore's Law for packing transistors on chips.

Important Events in Computer History

1886 Charles Pierce circuits based on switches for logic

1890 John Venn invents Venn Diagrams

1890 Herman Hollerith invents tabulating machines

1900 John Ambrose Fleming invents the vacuum tube

1906 Joseph John Thomson awarded Nobel Prize in Physics for his discovery of the electron

1906 Lee de Forest invents the Triode

1937 Alan Turing invents the Turing Machine

1939 John Vincent Atanasoff invents a special-purpose electronic computer

1939 Howard Aiken invents Harvard Mark I

1941 KonrZuse and his Z1, Z3, and Z4

1943 Alan Turing and COLOSSUS

1943 General Purpose Electronic Computer (ENIAC)

1944 Stored program (EDVAC)

1945 The "first" computer bug

1945 Johann (John) Von Neumann writes the "First Draft"

1947 John Bardeen and Walter Brattain (Bell Labs) First point-contact transistor

1948 Commercial computer (UNIVAC)

1949 First assembler (Initial Orders)

1950 First bipolar junction transistor

1952 G.W.A. Dummer conceives integrated circuits

1956 Bardeen and Brattain received the Nobel Prize in Physics together with William Shockley "for their researches on semiconductors and their discovery of the transistor effect."

1957 IBM 610 Auto-Point Computer

1958 First integrated circuit invented by Jack Kilby at Texas Instruments and Robert Noyce at Fairchild Camera to solve problem of many components

1962 First field-effect transistor

1966 FORTRAN

1970 First static and dynamic RAMs

1971 CTC's Datapoint 2200 Computer

1974 The 8080 microprocessor

1974 The Mark-8 microcomputer

1975 The 6502 microprocessor

1975 The Altair 8800 microcomputer

1975 Bill Gates and Paul Allen found Microsoft

1975 The Sphere 1 microcomputer

1976 The Z80 microprocessor

1976 The Apple I and Apple II microcomputers

1977 The Commodore PET microcomputer

1977 The TRS-80 microcomputer

1979 VisiCalc Spreadsheet

1981 IBM PC

2000 Jack Kilby awarded Nobel Prize in Physics for the invention of the integrated circuit.

Solve The Mission: To solve the mission, you need a nanotechnologist with a brilliant idea, scientific advancements like being able to put many CNT transistors on a single chip, and new technologies for competitive manufacturing. What else do you need?

Nanotechnologist

Scientific Advancement

Technology Development

Mission: *To build a nanodevice that will kill cancer cells.*

A lab-on-a-chip miniaturizes all the steps needed to process a medical sample and detect disease. In lab-on-a-chip, a sample travels down tiny channels where nanosized components and sensors identify specific molecules that warn of illness.

Targeted drugs are at the forefront of nanotechnology in medicine. Benefits of targeted drug delivery include:

- Reduce toxicity, side-effects, cost
- Deliver drugs when needed
- Deliver drugs where needed

Also supported cancer treatment is the ability to replace organs that might be removed or partially removed in aggressive cancer surgery. Anticipated benefits of nanotechnology growing organ and tissue replacements include:

- Reduce waiting time
- No shortages
- Less chance of organ rejection

Important Events In Cancer Treatment

1600 BC Edwin Smith Papyrus breast tumors were treated by cauterization.

400 BC Hippocrates invents the terms *carcinos* and *carcinoma* to describe non-ulcer forming and ulcer-forming tumors.

Hippocrates develops the Humoral Theory: the body has 4 humors - blood, phlegm, yellow bile, and black bile. A balance of these fluids resulted in a state of health; cancer results from imbalance.

Doctors in Ancient Rome through the Middle Ages believed Humoral Theory; religious beliefs prohibited the study of body through autopsies.

1628 Harvey explains the circulation of blood through the heart.

1700s Stahl and Hofman theorized that cancer was composed of degenerating lymph.

1761Giovanni Morgagni performed autopsies and laid the foundation for scientific oncology, the study of cancer.

c1760 John Hunter explores surgical procedures for removing tumors.

1779 Paris moves a cancer hospital to prevent spread of cancer.

1838 Johannes Muller showed that cancer is made up of cells and not lymph, and thought it came from blastema (elements between tissue)

c1850 Use of anesthesia results in more aggressive cancer surgery including mastectomy.

1800s Rudolf Virchow invents cellular pathology – studying cells through a microscope. He proposes that cancer is a chronic irritation that spreads like a liquid.

c1860 Karl Thiersch showed that cancers metastasize through the spread of malignant cells.

1800s to 1920 Many thought cancer resulted from trauma.

1940s First chemotherapy.

1946 First NMR

1956 First Bone Marrow Transplant

1972 CT invented by Godfrey Hounsfield.

1974 Damadian patented the design and use of NMR for detecting cancer.

2003 OSU Medical Center performs surgery using robotic instrumentation.

2004 Rice Univ studies nanoshells ability to selectively kill cancer cells.

Fast Facts

DNA is the molecule that controls heredity.

Researchers are exploring ways to modify DNA to prevent cancer.

There are roughly 1 million atoms in a protein molecule.

There are roughly 1 million atoms in a DNA molecule.

The width of a single red blood cell is approximately 7,000 nanometers.

In Nanoshell-Assisted Tumor Ablation, nanoshells attach to cancer cells forming a target for lasers to kill the cancer.

Solve The Mission: To solve the mission, you need a nanotechnologist with a brilliant idea, scientific advancements like being able to create a miniature robot to seek out cancer cells and destroy them without unintended consequences harmful to the patient. What else do you need?

Nanotechnologist

Scientific Advancement

Technology Development

Mission: *To create devices capable of converting sunlight into electricity.*

165,000 TW of sunlight hit the earth every day - 10,000 times more energy than we consume today. To harness this power, nanotechnologists are studying:

- photovoltaics (devices that convert sunlight to electricity),
- photocatalytic reduction of CO_2 to methane,
- photoconversion of light and water to produce hydrogen, and
- sunlight harvesting structures in space.

Richard Smalley envisioned an energy scheme for 30 to 60 TW in 2050 involving a distributed "Store-Gen" Grid in which energy would be transported as electrical energy and produced when and where possible, and consumed as needed.

For such a grid to work, revolutionary photovoltaic devices are needed.

Other Alternative Energy

Hydrogen Fuel Cells: Carbon nanotubes may developed for hydrogen storage in fuel cells that convert hydrogen and oxygen into water and heat.

Energy Efficiency

In addition to new sources of energy, nanotechnology is useful for making current systems more efficient consumers of energy.

Energy efficiency results from:

- improved insulation systems
- efficient lighting
- efficient combustion systems, and
- lighter and stronger materials in the transportation sector

Energy for Lighting

70,000 BC first lamps made of hollow rocks filled with moss soaked with animal fat.

1000 BC. China uses oil for lighting and medicine.

1700s Coal used produce gas for gas lamps.

1752 Franklin proved that lightning and sparks from amber were the same thing

1783 Ami Argand invents oil lamp with a hollow circular wick surrounded by a glass chimney.

1784 Coal used for lighting.

1792 Volta advances study of electricity. Murdoch lights home with natural gas.

1831 Faraday showed that electricity is created through motion from magnetism.

1839 Henri Becquerel discovered the photovoltaic effect

1857 Becquerel theorized about fluorescent lamp.

1859 Edwin Drake drills oil well in Titusville, Pennsylvania - start of modern oil industry and kerosene (petroleum derivative) used for lighting.

1870 Edison invents first practical generator and invents incandescent lightbulb.

1882 Coal-fired electric generating station produces electricity for New York City

1911 Neon lamp

1941 Russell Ohl invented the solar cell.

1960s Oil overtakes coal in the transportation sector. Light Emitting Diodes (LED) are invented.

1970 Passage of Clean Air Act.

1973 Oil embargo.

2003 Coal used for 40% of world's electricity.

Fast Facts

Zinc oxide and Titanium dioxide absorb ultraviolet (UV) light and are useful for sunscreens.

James Clerk Maxwell unified electric and magnetic forces to mathematically derive how waves of light travel through space and time. He showed that light is an electromagnetic wave.

Charles Olk and Joseph Heremans at General Motors Research Laboratory showed that some carbon nanotubes are metallic and others are semiconductors.

Solve The Mission: To solve the mission, you need a nanotechnologist with a brilliant idea and a revolutionary nanocomposite. Will it be a sprayable plastic that converts infrared (heat) light into electricity? Will it convert UV or visible light into electricity? Is it big or small? Portable or permanent?

Nanotechnologist

Scientific Advancement

Technology Development

Mission: *Invent a machine for rapid molecular assembly and fabrication of nano-robots.*

Nanobot Solutions

Imagine an environmental nanobot that uses mechanical means to remove hazards from air, water, or other environment.

Nanofiltration uses nanoporous membranes with pores smaller than 10 nm.

Ultrafiltration uses membranes with pores between 10 and 100 nm.

Magnetic nanoparticles could be used to remove heavy metal contaminants from waste water by magnetic separation techniques.

Researchers are currently addressing design issues of nanorobotics like the environment sensing, power, communication, navigation, manipulation, locomotion, and onboard computation.

For example, scientists at Oxford University are studying how the tails - or 'flagella' - of some bacteria work to make a nanorobot rotor.

Fast Facts

In Top-down assembly, a bulk material is reduced in size to nanoscale pattern.

Dendrimers are branching molecules usually created by self-assembly.

Self-assembly is one bottom-up technique.

In Bottom-up assembly larger structures are built or grown atom by atom or molecule by molecule.

Used to make ceramic and glass materials, involving the transition from a liquid 'sol' phase to a solid 'gel' phase is called a sol-gel process. Nanoelectrodeposition is used to create films, a single layer of a material is placed on a surface in a very controlled way

Devices for moving atoms and molecules

Atomic Force Microscopes (AFM) and cryogenic scanning tunneling microscope (STM) can move atoms.

A nanomanipulator is a device that connects a computer virtual-reality interface to a scanning-probe microscope that allows a human user to see and manipulate individual molecules.

Nanotweezers are devices for picking up atoms and molecules that use Carbon Nanotubes at the end of an atomic force microscope with voltages to open and close the nanotube end allowing individual atoms or molecules to be selected and moved.

Making Carbon Nanotube (CNT) components…

Plasma arching is useful for forming CNT. A plasma (ionized gas) is created by making gas conduct electricity by applying a large external voltage.

Chemical vapor deposition is useful for forming CNT. A material is heated to form a gas then allowed to form a solid deposit on a surface.

Sumio Iijima discovered CNT in 1991 at the NEC laboratory in Tsukuba, Japan.

Donald Bethune's group at IBM Almaden Research Center and Sumio Iijima's group both were the first to synthesize single-walled CNT.

Making other nanobot components…

A Sol-Gel process is used for forming nanoholes in materials, a colloidal liquid is transitioned to a solid. Nanoholes can be filled with metals using electroplating techniques, making nanowires when the porous material is removed.

First Nanobots

In 2005, Rice University researchers created the world's smallest car, only 4 nm wide with wheels made of buckyballs.

Solve The Mission: To solve the mission, you need a nanotechnologist with a brilliant idea, scientific advancements like being able to create a miniature robot to seek out cancer cells and destroy them without unintended consequences harmful to the patient. What else do you need?

Nanotechnologist

Scientific Advancement

Technology Development

Mission: *To create devices for measuring at atomic levels.*

Nanotechnology is "the art of manipulating materials on a very small scale in order to build microscopic devices."

Light is not useful for "seeing" atoms because wavelengths of visible light are larger than atomic structures. At the atomic level, the way objects behave and interact is completely different from the macroscale or bulk objects we know everyday. Classical mechanics doesn't work.

The observation that electrons ejected from metal were dependent on the color of light but not the intensity, which could not be explained by classical physics resulted in development of quantum mechanics to explain the atomic world. Heisenberg showed that the more precisely the position of a particle is known, the less precisely its speed is known. The link between Heisenberg's Quantum Mechanics world and Newton's Classical Mechanics world is called the **Correspondence Principle**.

In quantum mechanics particles behave like waves, and waves behave like particles. The assumption that particles may be regarded as countable packets of wave is known as **wave-particle duality**. A photon is a packet of electromagnetic energy (light) that behaves like a wave and a particle at the same time. Electrons are charged particles that behave like waves.

Devices are needed to measure nanoscale…

in One Dimension

Thin films.

Coatings.

There are 8 to 10 atoms in a line that is 1 nanometer long.

in Two Dimensions

Nanowires

Long carbon nanotubes

in Three Dimensions

Quantum Nanodots

Buckyballs (fullerenes)

Nanopowders

The width of a water molecule is about three tenths of a nanometer.

Nanocomposites

Although ceramics are hard, brittle and difficult to machine, at nanoscales, ceramics become more plastic (ductile).

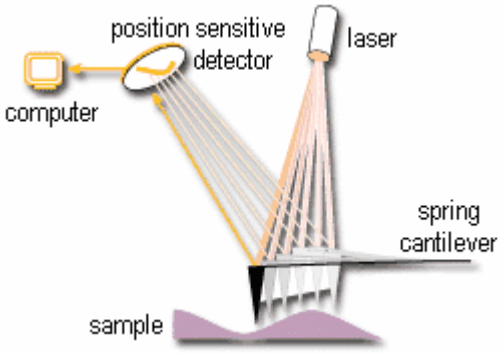
Measurement Devices

Conventional microscopes use a series lenses to bend light to create a larger image of an object. Isaac Newton used lenses to study light.

An Atomic Force Microscope (AFM) is a device that creates topographic maps of the surface of a material by measuring the reflection of light from a deflected cantilever while its a cone-shaped probe at the tip is dragged across the surface.

SEM stands for scanning electron microscope. An SEM makes pictures by moving a beam of focused electrons across an object and reading the scattered electrons.

A nanomanipulator is a device that connects a computer virtual-reality interface to a scanning-probe microscope that allows a human user to see and manipulate individual molecules.



Atomic Force Microscope

Fast Facts

There are one billion nanometers in a meter.

There are roughly 100 distinct types of atoms, each with a unique number of protons.

There are 60 carbon atoms in a buckyball (fullerene) **–** this was determined by looking at the structures spectrum.

From the spectrum, Smalley and Curl determined that the buckyball structure was like a soccer ball with 12 pentagons and 20 hexagons.

A human hair is about 75,000 nm in diameter.

Today's devices image the atom, but not internal structure like the central core of an atom is a cluster of protons and neutrons known as the nucleus.

Solve The Mission: To solve the mission, you need a nanotechnologist with a brilliant idea for how to measure size and physical properties of materials, and scientific advancements. What else do you need? Will your device also move atoms? Does you device use light or magnetism? Does it involve many probes?


Nanotechnologist


Scientific Advancement


Technology Development

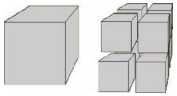
Mission: *To use nanoparticles for catalysis.*

A catalyst is a substance, usually used in small amounts relative to the reactants, that modifies and increases the rate of a reaction without being consumed in the process.

When the surface area of matter is increased, it can become more chemically reactive. Consider that as a spherical snowball melts, the surface area to volume ratio increases inversely proportional to its radius. The smaller radius has a larger fraction of its atoms at the surface – where they can react with the environment the snowball is in. When any bulk material is cut into smaller pieces, there is a greater chance that atoms of that material will react or interact with the substances in contact with that material.

That is why materials that are nanoscale are more efficient catalysts.

Scientists are researching adding cerium oxide to diesel fuel to improve fuel economy by reducing the degradation of fuel consumption over time.



Whenever a cube is divided, its total surface area is doubled – can you see why?

Surface area to volume ratio…

A gram of carbon black has a *smaller* surface area when in bulk form than when formed as nanoparticles.

Nanoparticles are *more* chemically reactive than when in macroscopic form.

On the surface of a particle of size 30 nm are 5% of the total number of atoms, at 10 nm are 20% of its atoms, and at 3 nm are 50% of its atoms.

Buckyballs, or C60, are named for architect Buckminister Fuller. They have 100% of their atoms on the surface. Robert Curl, Harold Kroto and Richard Smalley share the Nobel Prize for their discovery of C60.

Challenges

Composites of plastics with carbon nanotubes are difficult to manufacture because the nanotubes don't disperse easily. This is because CNTs tend to bundle.

Uniform dispersion of nanoparticles into the mixture or solution where they are being used for catalysis sometimes is a huge challenge.

Nanotechnology is used to create self-cleaning windows with glass coated in highly activated titanium dioxide, to be water repelling, antibacterial, and to catalytically destroy chemical agents.

Quantum Mechanics dominates…

Optical Properties

Carbon forms different structures **–** diamonds are transparent while graphite and carbon black are opaque and black.

Copper, which is opaque in bulk structures, becomes transparent at nanoscales.

Electrical Properties

At room temperature gold is solid, except at nanoscales **–** it becomes a liquid.

In bulk silicon is an insulator; nanoscale Silicon is a conductor.

Magnetic Properties

One possible application of nano-scaled magnetic devices is data storage.

Fast Facts

Sodium, an element in the compound sodium-chloride (table salt), is a metal that reacts violently in air.

Chlorine, an element in the compound sodium-chloride (table salt), by itself forms a lethal gas.

Some materials are inert in large form and reactive in nanoscale form because at nanoscale they are more chemically reactive.

Bulk platinum is inert **–** meaning it doesn't react with other materials. But at nanoscales it becomes a catalyst.

Aluminum is a stable bulk solid, but it readily combusts at nanoscales.

Solve The Mission: To solve the mission, you need a nanotechnologist with a brilliant idea, and scientific advancements in creation of nanoparticles and their dispersion. What else do you need? What sort of catalytic reaction do you want? For better fuel burning? For a microfluidics medical lab on a chip?

Nanotechnologist

Scientific Advancement

Technology Development