Advanced High Technology and Engineering

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Chapter- 1

High Tech

High tech is technology that is at the cutting edge: the most advanced technology currently available. The adjective form is hyphenated: **high-tech** or **high-technology**. (There is also an architectural style known as high tech.)

There is no specific class of technology that is high tech — the definition shifts over time — so products hyped as high tech in the 1960s would now be considered, if not exactly low tech, then at least somewhat obsolete. This fuzzy definition has led to marketing departments describing nearly all new products as high tech.

Origin of the term

In a search of the best *New York Times* articles, the first occurrence of the phrase "high tech" occurs in a 1950s story advocating "atomic energy" for Europe: "...Eastern Europe, with its dense population and its high technology..." The twelfth occurrence, in 1968, is, significantly, in a story about Route 128, described as Boston's "Golden Semicircle":

It is not clear whether the term comes from the high technologies flourishing in the glass rectangles along the route or from the Midas touch their entrepreneurs have shown in starting new companies.

By April 1969, Robert Metz was using it in a financial column—Arthur H. Collins of Collins Radio "controls a score of high technology patents in variety of fields." Metz used the term frequently thereafter; a few months later he was using it with a hyphen, saying that a fund "holds computer peripheral... business equipment, and high-technology stocks." Its first occurrence in the abbreviated form "high tech" occurred in a Metz in 1971.

Economy

Because the high-tech sector of the economy develops or uses the most advanced technology known, it is often seen as having the most potential for future growth. This perception has led to high investment in high-tech sectors of the economy. High-tech startup enterprises receive a large portion of venture capital. However, if, as has happened in the past, investment exceeds actual potential, then investors can lose all or most of their investment. High tech is often viewed as high risk, but offering the opportunity for high profits.

Like Big Science, high technology is an international phenomenon, spanning continents, epitomized by the worldwide communication of the Internet. Thus a multinational corporation might work on a project 24 hours a day, with teams waking and working with the advance of the sun across the globe; such projects might be in software development or in the development of an integrated circuit. The help desks of a multinational corporation might thus employ, successively, teams in Kenya, Brazil, the Philippines, or India, with the only requirement fluency in the mother tongue, be it Spanish, Portuguese or English.

OECD has two different approaches: sector and product (industry) approaches.

High-tech sectors

The sector approach classifies industries according their technology intensity, product approach according to finished products.

- Aerospace technology
- Artificial intelligence
- Biotechnology
- Energy
- Instrumentation
- Nanotechnology
- Nuclear physics
- Optoelectronics
- Robotics
- Telecommunications
- Electrical Engineering

It can be noted that technologies which are not seen as high-tech, like Information technology, may also be considered in the scope of being part of higher technological developments.

High-tech industries

Further analysis from OECD has indicated that using research intensity as only industry classification indicator is also possible. The OECD does not only take the manufacturing but also the usage rate of technology into account. The OECD's classification is following (stable since 1973):

Industry name	Total R&D-intensity (1999, in %)	ISIC Rev. 3
High-Technology		
Pharmaceuticals	10.46	2423
Aircraft & spacecraft	10.29	353
Medical, precision & optical instruments	9.69	33
Radio, television & communication equipment	7.48	32
Office, accounting & computing machinery	7.21	30
Medium-High-Technology		
Electrical machinery & apparatus	3.60	31
Motor vehicles, trailers & semi-trailers	3.51	34
Railroad & transport equipment	3.11	352+359
Chemical & chemical products	2.85	24 (excl. 2423)
Machinery & equipment	2.20	29

Furthermore, OECD's product-based classification supports the technology intensity approach. It can be concluded, that companies in a high-technology industry do not necessary produce high-technology products and vice versa. This creates a problem of aggregation.

High-tech society

An overall society based in high-tech is something generally unattainable by the definition comprising its scarcity among every technology available. Many countries and regions like United States, Canada, Italy, Denmark, Belgium, the Netherlands, Israel, Japan, the United Kingdom, Estonia, Australia, Germany, South Korea, Taiwan, Hong Kong, Finland, Spain, Sweden, Brazil and France can be in general considered high-tech societies in relation to other countries, since it is common for its citizens having access to technology that is presently at the cutting edge, in consumer's terms, as can parts of India (Bangalore, Mumbai) and China (Shanghai, Beijing). Research oriented institutions such as ESA, MITRE, NASA, CERN, and universities with high research activity such as MIT and the Technion might be considered high-tech microsocieties in relation to the general surrounding socio-economic region or overall activity sector.

Some geographical areas can be consider as a high-tech startups society like for instance the Silicon Valley:

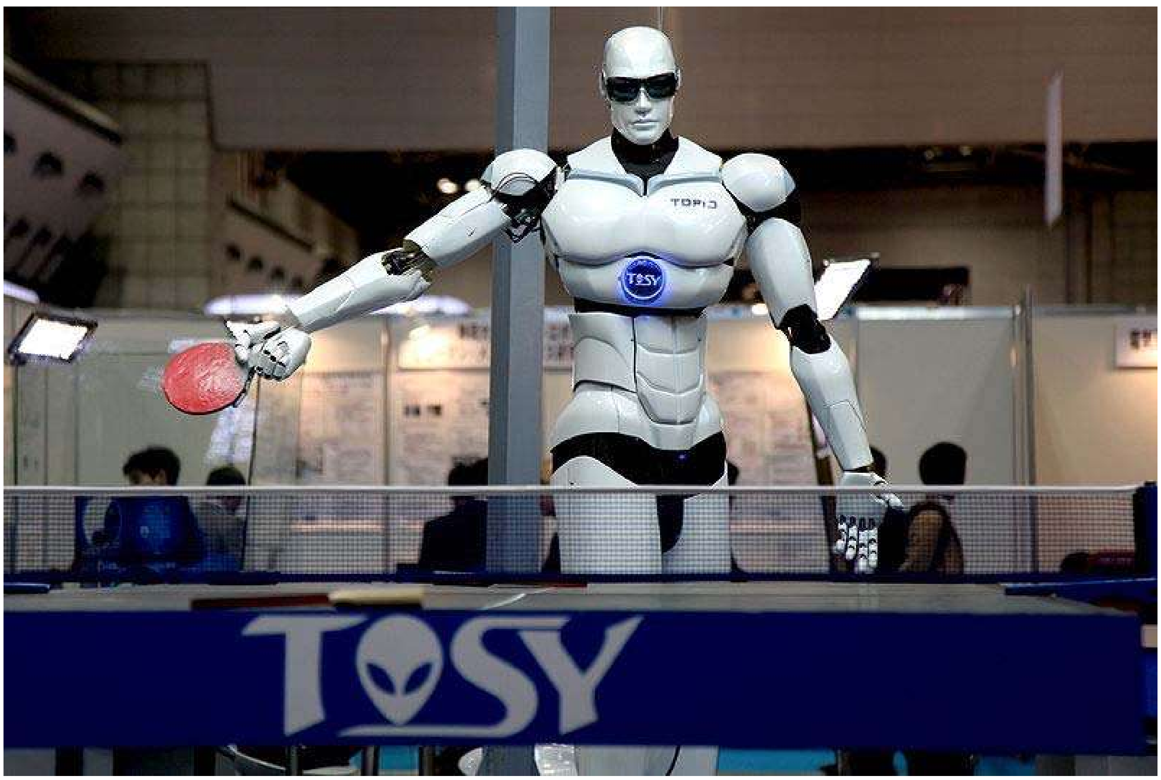
The spark that set off the explosive boom of "Silicon startups" in Stanford Industrial Park was a personal dispute in 1957 between employees of Shockley Semiconductor and the company's namesake and founder, Nobel laureate and co-inventor of the transistor

William Shockley... (His employees) formed Fairchild Semiconductor immediately following their departure... After several years, Fairchild gained its footing, becoming a formidable presence in this sector. Its founders began to leave to start companies based on their own, latest ideas and were followed on this path by their own former leading employees... The process gained momentum and what had once began in a Stanford's research park became a veritable startup avalanche... Thus, over the course of just 20 years, a mere eight of Shockley's former employees gave forth 65 new enterprises, which then went on to do the same...

An organization's department dealing with the latest technology in their projects, may also be considered a high-tech microsociety within the organization's and partners' scope. Students and faculty related with ENAEE or ABET accredited programs might be considered high-tech society members, regarding other traditional degrees. In industry, companies working in the leading edge may be considered high-tech societies along with its main competitors, regarding the rest of the sectorial competition.

Chapter- 2

Artificial Intelligence



TOPIO, a humanoid robot, played ping pong at Tokyo International Robot Exhibition (IREX) 2009.

Artificial intelligence (**AI**) is the intelligence of machines and the branch of computer science that aims to create it. AI textbooks define the field as "the study and design of intelligent agents" where an intelligent agent is a system that perceives its environment and takes actions that maximize its chances of success. John McCarthy, who coined the term in 1956, defines it as "the science and engineering of making intelligent machines."

The field was founded on the claim that a central property of humans, intelligence—the sapience of *Homo sapiens*—can be so precisely described that it can be simulated by a machine. This raises philosophical issues about the nature of the mind and the ethics of creating artificial beings, issues which have been addressed by myth, fiction and philosophy since antiquity. Artificial intelligence has been the subject of optimism, but has also suffered setbacks and, today, has become an essential part of the technology industry, providing the heavy lifting for many of the most difficult problems in computer science.

AI research is highly technical and specialized, deeply divided into subfields that often fail to communicate with each other. Subfields have grown up around particular institutions, the work of individual researchers, the solution of specific problems, longstanding differences of opinion about how AI should be done and the application of widely differing tools. The central problems of AI include such traits as reasoning, knowledge, planning, learning, communication, perception and the ability to move and manipulate objects. General intelligence (or "strong AI") is still among the field's long term goals.

History

Thinking machines and artificial beings appear in Greek myths, such as Talos of Crete, the bronze robot of Hephaestus and Pygmalion's Galatea. Human likenesses believed to have intelligence were built in every major civilization: animated cult images were worshipped in Egypt and Greece and humanoid automatons were built by Yan Shi, Hero of Alexandria and Al-Jazari. It was also widely believed that artificial beings had been created by Jābir ibn Hayyān, Judah Loew and Paracelsus. By the 19th and 20th centuries, artificial beings had become a common feature in fiction, as in Mary Shelley's *Frankenstein* or Karel Čapek's *R.U.R. (Rossum's Universal Robots)*. Pamela McCorduck argues that all of these are examples of an ancient urge, as she describes it, "to forge the gods". Stories of these creatures and their fates discuss many of the same hopes, fears and ethical concerns that are presented by artificial intelligence.

Mechanical or "formal" reasoning has been developed by philosophers and mathematicians since antiquity. The study of logic led directly to the invention of the programmable digital electronic computer, based on the work of mathematician Alan Turing and others. Turing's theory of computation suggested that a machine, by shuffling symbols as simple as "0" and "1", could simulate any conceivable act of mathematical deduction. This, along with recent discoveries in neurology, information theory and cybernetics, inspired a small group of researchers to begin to seriously consider the possibility of building an electronic brain.

The field of AI research was founded at a conference on the campus of Dartmouth College in the summer of 1956. The attendees, including John McCarthy, Marvin Minsky, Allen Newell and Herbert Simon, became the leaders of AI research for many decades. They and their students wrote programs that were, to most people, simply astonishing: computers were solving word problems in algebra, proving logical theorems and speaking English. By the middle of the 1960s, research in the U.S. was heavily funded by the Department of Defense and laboratories had been established around the world. AI's founders were profoundly optimistic about the future of the new field: Herbert Simon predicted that "machines will be capable, within twenty years, of doing any work a man can do" and Marvin Minsky agreed, writing that "within a generation ... the problem of creating 'artificial intelligence' will substantially be solved".

They had failed to recognize the difficulty of some of the problems they faced. In 1974, in response to the criticism of England's Sir James Lighthill and ongoing pressure from Congress to fund more productive projects, the U.S. and British governments cut off all undirected, exploratory research in AI. The next few years, when funding for projects was hard to find, would later be called an "AI winter".

In the early 1980s, AI research was revived by the commercial success of expert systems, a form of AI program that simulated the knowledge and analytical skills of one or more human experts. By 1985 the market for AI had reached over a billion dollars. At the same time, Japan's fifth generation computer project inspired the U.S and British governments to restore funding for academic research in the field. However, beginning with the collapse of the Lisp Machine market in 1987, AI once again fell into disrepute, and a second, longer lasting AI winter began.

In the 1990s and early 21st century, AI achieved its greatest successes, albeit somewhat behind the scenes. Artificial intelligence is used for logistics, data mining, medical diagnosis and many other areas throughout the technology industry. The success was due to several factors: the increasing computational power of computers, a greater emphasis on solving specific subproblems, the creation of new ties between AI and other fields working on similar problems, and a new commitment by researchers to solid mathematical methods and rigorous scientific standards.

Problems

The general problem of simulating (or creating) intelligence has been broken down into a number of specific sub-problems. These consist of particular traits or capabilities that researchers would like an intelligent system to display. The traits described below have received the most attention.

Deduction, reasoning, problem solving

Early AI researchers developed algorithms that imitated the step-by-step reasoning that humans were often assumed to use when they solve puzzles, play board games or make logical deductions. By the late 1980s and '90s, AI research had also developed highly successful methods for dealing with uncertain or incomplete information, employing concepts from probability and economics.

For difficult problems, most of these algorithms can require enormous computational resources — most experience a "combinatorial explosion": the amount of memory or computer time required becomes astronomical when the problem goes beyond a certain size. The search for more efficient problem solving algorithms is a high priority for AI research.

Human beings solve most of their problems using fast, intuitive judgments rather than the conscious, step-by-step deduction that early AI research was able to model. AI has made some progress at imitating this kind of "sub-symbolic" problem solving: embodied agent approaches emphasize the importance of sensorimotor skills to higher reasoning; neural net research attempts to simulate the structures inside human and animal brains that give rise to this skill.

Knowledge representation

Knowledge representation and knowledge engineering are central to AI research. Many of the problems machines are expected to solve will require extensive knowledge about the world. Among the things that AI needs to represent are: objects, properties, categories and relations between objects; situations, events, states and time; causes and effects; knowledge about knowledge (what we know about what other people know); and many other, less well researched domains. A complete representation of "what exists" is an ontology (borrowing a word from traditional philosophy), of which the most general are called upper ontologies.

Among the most difficult problems in knowledge representation are:

Default reasoning and the qualification problem

Many of the things people know take the form of "working assumptions." For example, if a bird comes up in conversation, people typically picture an animal that is fist sized, sings, and flies. None of these things are true about all birds. John McCarthy identified this problem in 1969 as the qualification problem: for any commonsense rule that AI researchers care to represent, there tend to be a huge number of exceptions. Almost nothing is simply true or false in the way that abstract logic requires. AI research has explored a number of solutions to this problem.

The breadth of commonsense knowledge

The number of atomic facts that the average person knows is astronomical. Research projects that attempt to build a complete knowledge base of commonsense knowledge (e.g., Cyc) require enormous amounts of laborious ontological engineering — they must be built, by hand, one complicated concept at a time. A major goal is to have the computer understand enough concepts to be able to learn by reading from sources like the internet, and thus be able to add to its own ontology.

The subsymbolic form of some commonsense knowledge

Much of what people know is not represented as "facts" or "statements" that they could express verbally. For example, a chess master will avoid a particular chess position because it "feels too exposed" or an art critic can take one look at a statue and instantly realize that it is a fake. These are intuitions or tendencies that are represented in the brain non-consciously and sub-symbolically. Knowledge like this informs, supports and provides a context for symbolic, conscious knowledge. As with the related problem of sub-symbolic reasoning, it is hoped that situated

AI or computational intelligence will provide ways to represent this kind of knowledge.

Planning

Intelligent agents must be able to set goals and achieve them. They need a way to visualize the future (they must have a representation of the state of the world and be able to make predictions about how their actions will change it) and be able to make choices that maximize the utility (or "value") of the available choices.

In classical planning problems, the agent can assume that it is the only thing acting on the world and it can be certain what the consequences of its actions may be. However, if this is not true, it must periodically check if the world matches its predictions and it must change its plan as this becomes necessary, requiring the agent to reason under uncertainty.

Multi-agent planning uses the cooperation and competition of many agents to achieve a given goal. Emergent behavior such as this is used by evolutionary algorithms and swarm intelligence.

Learning

Machine learning has been central to AI research from the beginning. Unsupervised learning is the ability to find patterns in a stream of input. Supervised learning includes both classification and numerical regression. Classification is used to determine what category something belongs in, after seeing a number of examples of things from several categories. Regression takes a set of numerical input/output examples and attempts to discover a continuous function that would generate the outputs from the inputs. In reinforcement learning the agent is rewarded for good responses and punished for bad ones. These can be analyzed in terms of decision theory, using concepts like utility. The mathematical analysis of machine learning algorithms and their performance is a branch of theoretical computer science known as computational learning theory.

Natural language processing

ASIMO uses sensors and intelligent algorithms to avoid obstacles and navigate stairs

Natural language processing gives machines the ability to read and understand the languages that humans speak. Many researchers hope that a sufficiently powerful natural language processing system would be able to acquire knowledge on its own, by reading the existing text available over the internet. Some straightforward applications of natural language processing include information retrieval (or text mining) and machine translation.

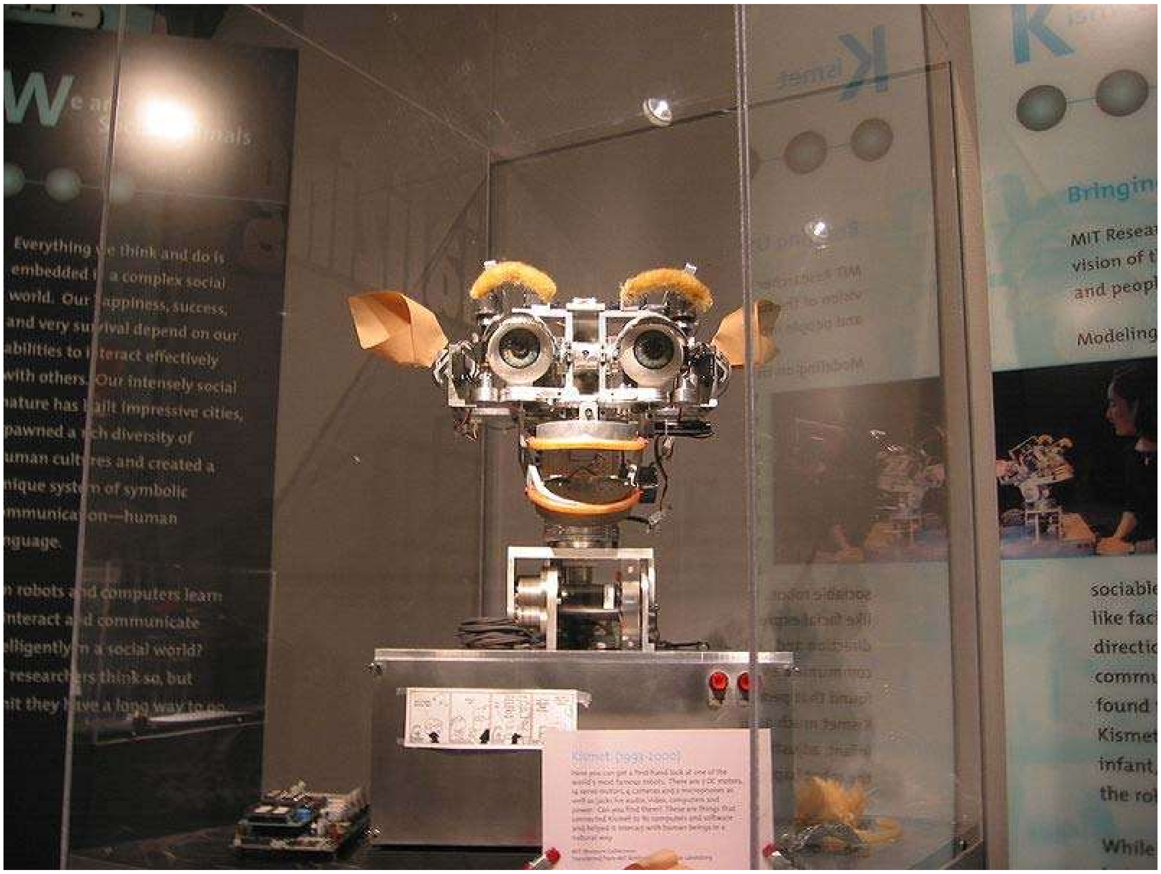
Motion and manipulation

The field of robotics is closely related to AI. Intelligence is required for robots to be able to handle such tasks as object manipulation and navigation, with sub-problems of localization (knowing where you are), mapping (learning what is around you) and motion planning (figuring out how to get there).

Perception

Machine perception is the ability to use input from sensors (such as cameras, microphones, sonar and others more exotic) to deduce aspects of the world. Computer vision is the ability to analyze visual input. A few selected subproblems are speech recognition, facial recognition and object recognition.

Social intelligence



Kismet, a robot with rudimentary social skills

Emotion and social skills play two roles for an intelligent agent. First, it must be able to predict the actions of others, by understanding their motives and emotional states. (This involves elements of game theory, decision theory, as well as the ability to model human emotions and the perceptual skills to detect emotions.) Also, for good human-computer interaction, an intelligent machine also needs to *display* emotions. At the very least it must appear polite and sensitive to the humans it interacts with. At best, it should have normal emotions itself.

Creativity

A sub-field of AI addresses creativity both theoretically (from a philosophical and psychological perspective) and practically (via specific implementations of systems that generate outputs that can be considered creative, or systems that identify and assess creativity). A related area of computational research is Artificial Intuition and Artificial Imagination.

General intelligence

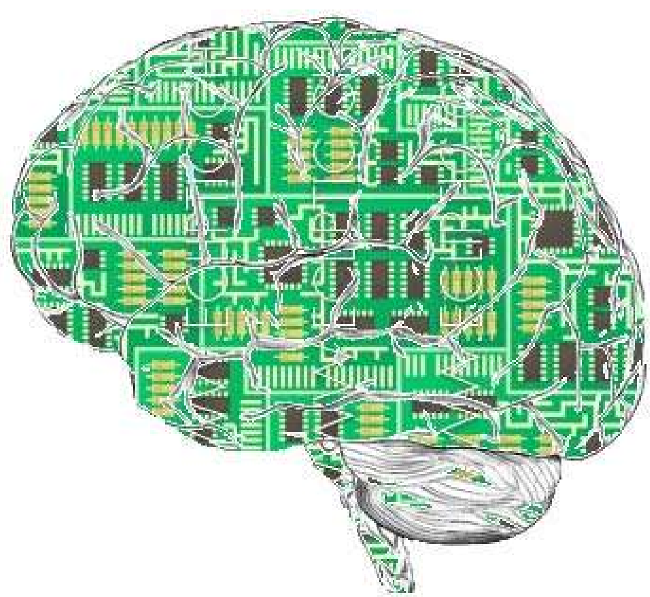
Most researchers hope that their work will eventually be incorporated into a machine with *general* intelligence (known as strong AI), combining all the skills above and exceeding human abilities at most or all of them. A few believe that anthropomorphic features like artificial consciousness or an artificial brain may be required for such a project.

Many of the problems above are considered AI-complete: to solve one problem, you must solve them all. For example, even a straightforward, specific task like machine translation requires that the machine follow the author's argument (reason), know what is being talked about (knowledge), and faithfully reproduce the author's intention (social intelligence). Machine translation, therefore, is believed to be AI-complete: it may require strong AI to be done as well as humans can do it.

Approaches

There is no established unifying theory or paradigm that guides AI research. Researchers disagree about many issues. A few of the most long standing questions that have remained unanswered are these: should artificial intelligence simulate natural intelligence, by studying psychology or neurology? Or is human biology as irrelevant to AI research as bird biology is to aeronautical engineering? Can intelligent behavior be described using simple, elegant principles (such as logic or optimization)? Or does it necessarily require solving a large number of completely unrelated problems? Can intelligence be reproduced using high-level symbols, similar to words and ideas? Or does it require "sub-symbolic" processing?

Cybernetics and brain simulation



There is currently no consensus on how closely the brain should be simulated.

In the 1940s and 1950s, a number of researchers explored the connection between neurology, information theory, and cybernetics. Some of them built machines that used electronic networks to exhibit rudimentary intelligence, such as W. Grey Walter's turtles and the Johns Hopkins Beast. Many of these researchers gathered for meetings of the Teleological Society at Princeton University and the Ratio Club in England. By 1960, this approach was largely abandoned, although elements of it would be revived in the 1980s.

Symbolic

When access to digital computers became possible in the middle 1950s, AI research began to explore the possibility that human intelligence could be reduced to symbol manipulation. The research was centered in three institutions: CMU, Stanford and MIT, and each one developed its own style of research. John Haugeland named these approaches to AI "good old fashioned AI" or "GOFAI".

Cognitive simulation
: Economist Herbert Simon and Allen Newell studied human problem solving skills and attempted to formalize them, and their work laid the foundations of the field of artificial intelligence, as well as cognitive science, operations research and management science. Their research team used the results of psychological experiments to develop programs that simulated the techniques that people used to solve problems. This tradition, centered at Carnegie Mellon University would eventually culminate in the development of the Soar architecture in the middle 80s.

Logic based
: Unlike Newell and Simon, John McCarthy felt that machines did not need to simulate human thought, but should instead try to find the essence of abstract reasoning and problem solving, regardless of whether people used the same algorithms. His laboratory at Stanford (SAIL) focused on using formal logic to solve a wide variety of problems, including knowledge representation, planning and learning. Logic was also focus of the work at the University of Edinburgh and elsewhere in Europe which led to the development of the programming language Prolog and the science of logic programming.

"Anti-logic" or "scruffy"
: Researchers at MIT (such as Marvin Minsky and Seymour Papert) found that solving difficult problems in vision and natural language processing required ad-hoc solutions – they argued that there was no simple and general principle (like logic) that would capture all the aspects of intelligent behavior. Roger Schank described their "anti-logic" approaches as "scruffy" (as opposed to the "neat" paradigms at CMU and Stanford). Commonsense knowledge bases (such as Doug Lenat's Cyc) are an example of "scruffy" AI, since they must be built by hand, one complicated concept at a time.

Knowledge based
: When computers with large memories became available around 1970, researchers from all three traditions began to build knowledge into AI applications. This

"knowledge revolution" led to the development and deployment of expert systems (introduced by Edward Feigenbaum), the first truly successful form of AI software. The knowledge revolution was also driven by the realization that enormous amounts of knowledge would be required by many simple AI applications.

Sub-symbolic

During the 1960s, symbolic approaches had achieved great success at simulating high-level thinking in small demonstration programs. Approaches based on cybernetics or neural networks were abandoned or pushed into the background. By the 1980s, however, progress in symbolic AI seemed to stall and many believed that symbolic systems would never be able to imitate all the processes of human cognition, especially perception, robotics, learning and pattern recognition. A number of researchers began to look into "sub-symbolic" approaches to specific AI problems.

Bottom-up, embodied, situated, behavior-based or nouvelle AI

Researchers from the related field of robotics, such as Rodney Brooks, rejected symbolic AI and focused on the basic engineering problems that would allow robots to move and survive. Their work revived the non-symbolic viewpoint of the early cybernetics researchers of the 50s and reintroduced the use of control theory in AI. This coincided with the development of the embodied mind thesis in the related field of cognitive science: the idea that aspects of the body (such as movement, perception and visualization) are required for higher intelligence.

Computational Intelligence

Interest in neural networks and "connectionism" was revived by David Rumelhart and others in the middle 1980s. These and other sub-symbolic approaches, such as fuzzy systems and evolutionary computation, are now studied collectively by the emerging discipline of computational intelligence.

Statistical

In the 1990s, AI researchers developed sophisticated mathematical tools to solve specific subproblems. These tools are truly scientific, in the sense that their results are both measurable and verifiable, and they have been responsible for many of AI's recent successes. The shared mathematical language has also permitted a high level of collaboration with more established fields (like mathematics, economics or operations research). Stuart Russell and Peter Norvig describe this movement as nothing less than a "revolution" and "the victory of the neats."

Integrating the approaches

Intelligent agent paradigm

An intelligent agent is a system that perceives its environment and takes actions which maximizes its chances of success. The simplest intelligent agents are programs that solve specific problems. The most complicated intelligent agents are rational, thinking humans. The paradigm gives researchers license to study isolated problems and find solutions that are both verifiable and useful, without agreeing on one single approach. An agent that solves a specific problem can use any approach that works — some agents are symbolic and logical, some are sub-symbolic neural networks and others may use new approaches. The paradigm also gives researchers a common language to communicate with other fields—such as decision theory and economics—that also use concepts of abstract agents. The intelligent agent paradigm became widely accepted during the 1990s.

Agent architectures and cognitive architectures

Researchers have designed systems to build intelligent systems out of interacting intelligent agents in a multi-agent system. A system with both symbolic and sub-symbolic components is a hybrid intelligent system, and the study of such systems is artificial intelligence systems integration. A hierarchical control system provides a bridge between sub-symbolic AI at its lowest, reactive levels and traditional symbolic AI at its highest levels, where relaxed time constraints permit planning and world modelling. Rodney Brooks' subsumption architecture was an early proposal for such a hierarchical system.

Tools

In the course of 50 years of research, AI has developed a large number of tools to solve the most difficult problems in computer science. A few of the most general of these methods are discussed below.

Search and optimization

Many problems in AI can be solved in theory by intelligently searching through many possible solutions: Reasoning can be reduced to performing a search. For example, logical proof can be viewed as searching for a path that leads from premises to conclusions, where each step is the application of an inference rule. Planning algorithms search through trees of goals and subgoals, attempting to find a path to a target goal, a process called means-ends analysis. Robotics algorithms for moving limbs and grasping objects use local searches in configuration space. Many learning algorithms use search algorithms based on optimization.

Simple exhaustive searches are rarely sufficient for most real world problems: the search space (the number of places to search) quickly grows to astronomical numbers. The result is a search that is too slow or never completes. The solution, for many problems, is to use "heuristics" or "rules of thumb" that eliminate choices that are unlikely to lead to the goal (called "pruning the search tree"). Heuristics supply the program with a "best guess" for what path the solution lies on.

A very different kind of search came to prominence in the 1990s, based on the mathematical theory of optimization. For many problems, it is possible to begin the search with some form of a guess and then refine the guess incrementally until no more refinements can be made. These algorithms can be visualized as blind hill climbing: we begin the search at a random point on the landscape, and then, by jumps or steps, we keep moving our guess uphill, until we reach the top. Other optimization algorithms are simulated annealing, beam search and random optimization.

Evolutionary computation uses a form of optimization search. For example, they may begin with a population of organisms (the guesses) and then allow them to mutate and recombine, selecting only the fittest to survive each generation (refining the guesses). Forms of evolutionary computation include swarm intelligence algorithms (such as ant colony or particle swarm optimization) and evolutionary algorithms (such as genetic algorithms and genetic programming).

Logic

Logic is used for knowledge representation and problem solving, but it can be applied to other problems as well. For example, the satplan algorithm uses logic for planning and inductive logic programming is a method for learning.

Several different forms of logic are used in AI research. Propositional or sentential logic is the logic of statements which can be true or false. First-order logic also allows the use of quantifiers and predicates, and can express facts about objects, their properties, and their relations with each other. Fuzzy logic, is a version of first-order logic which allows the truth of a statement to be represented as a value between 0 and 1, rather than simply True (1) or False (0). Fuzzy systems can be used for uncertain reasoning and have been widely used in modern industrial and consumer product control systems. Subjective logic models uncertainty in a different and more explicit manner than fuzzy-logic: a given binomial opinion satisfies belief + disbelief + uncertainty = 1 within a Beta distribution. By this method, ignorance can be distinguished from probabilistic statements that an agent makes with high confidence.

Default logics, non-monotonic logics and circumscription are forms of logic designed to help with default reasoning and the qualification problem. Several extensions of logic have been designed to handle specific domains of knowledge, such as: description logics; situation calculus, event calculus and fluent calculus (for representing events and time); causal calculus; belief calculus; and modal logics.

Probabilistic methods for uncertain reasoning

Many problems in AI (in reasoning, planning, learning, perception and robotics) require the agent to operate with incomplete or uncertain information. AI researchers have devised a number of powerful tools to solve these problems using methods from probability theory and economics.

Bayesian networks are a very general tool that can be used for a large number of problems: reasoning (using the Bayesian inference algorithm), learning (using the expectation-maximization algorithm), planning (using decision networks) and perception (using dynamic Bayesian networks). Probabilistic algorithms can also be used for filtering, prediction, smoothing and finding explanations for streams of data, helping perception systems to analyze processes that occur over time (e.g., hidden Markov models or Kalman filters).

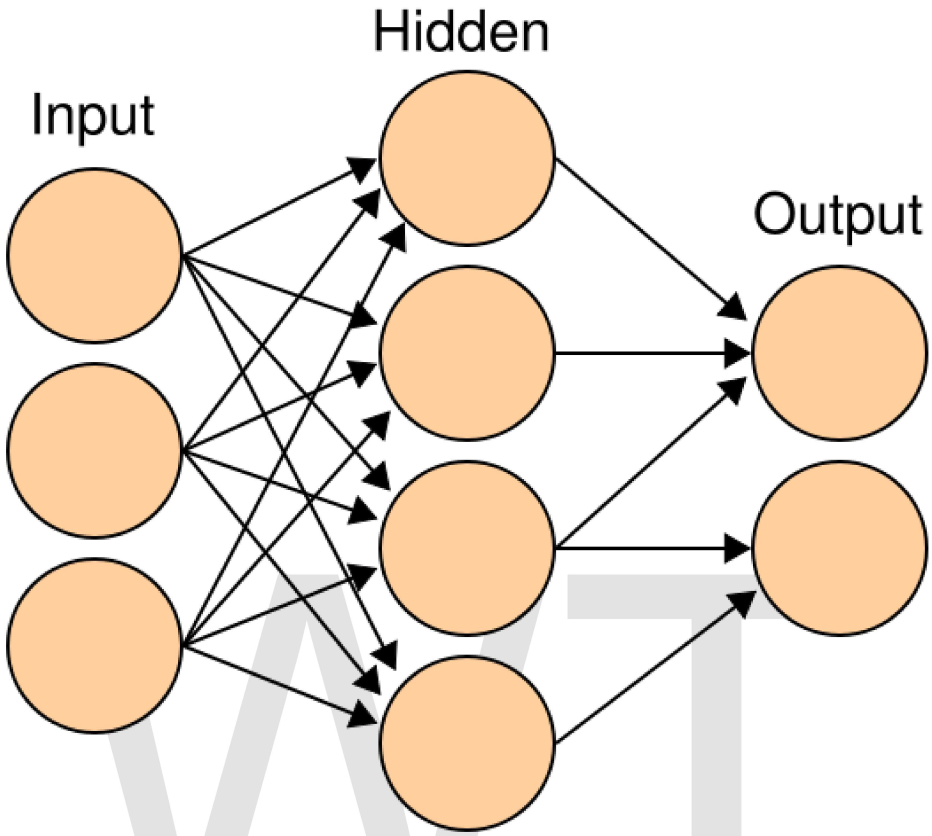
A key concept from the science of economics is "utility": a measure of how valuable something is to an intelligent agent. Precise mathematical tools have been developed that analyze how an agent can make choices and plan, using decision theory, decision analysis, information value theory. These tools include models such as Markov decision processes, dynamic decision networks, game theory and mechanism design.

Classifiers and statistical learning methods

The simplest AI applications can be divided into two types: classifiers ("if shiny then diamond") and controllers ("if shiny then pick up"). Controllers do however also classify conditions before inferring actions, and therefore classification forms a central part of many AI systems. Classifiers are functions that use pattern matching to determine a closest match. They can be tuned according to examples, making them very attractive for use in AI. These examples are known as observations or patterns. In supervised learning, each pattern belongs to a certain predefined class. A class can be seen as a decision that has to be made. All the observations combined with their class labels are known as a data set. When a new observation is received, that observation is classified based on previous experience.

A classifier can be trained in various ways; there are many statistical and machine learning approaches. The most widely used classifiers are the neural network, kernel methods such as the support vector machine, k-nearest neighbor algorithm, Gaussian mixture model, naive Bayes classifier, and decision tree. The performance of these classifiers have been compared over a wide range of tasks. Classifier performance depends greatly on the characteristics of the data to be classified. There is no single classifier that works best on all given problems; this is also referred to as the "no free lunch" theorem. Determining a suitable classifier for a given problem is still more an art than science.

Neural networks



A neural network is an interconnected group of nodes, akin to the vast network of neurons in the human brain.

The study of artificial neural networks began in the decade before the field AI research was founded, in the work of Walter Pitts and Warren McCullough. Other important early researchers were Frank Rosenblatt, who invented the perceptron and Paul Werbos who developed the backpropagation algorithm.

The main categories of networks are acyclic or feedforward neural networks (where the signal passes in only one direction) and recurrent neural networks (which allow feedback). Among the most popular feedforward networks are perceptrons, multi-layer perceptrons and radial basis networks. Among recurrent networks, the most famous is the Hopfield net, a form of attractor network, which was first described by John Hopfield in 1982. Neural networks can be applied to the problem of intelligent control (for robotics) or learning, using such techniques as Hebbian learning and competitive learning.

Jeff Hawkins argues that research in neural networks has stalled because it has failed to model the essential properties of the neocortex, and has suggested a model (Hierarchical Temporal Memory) that is loosely based on neurological research.

Control theory

Control theory, the grandchild of cybernetics, has many important applications, especially in robotics.

Languages

AI researchers have developed several specialized languages for AI research, including Lisp and Prolog.

Evaluating progress

In 1950, Alan Turing proposed a general procedure to test the intelligence of an agent now known as the Turing test. This procedure allows almost all the major problems of artificial intelligence to be tested. However, it is a very difficult challenge and at present all agents fail.

Artificial intelligence can also be evaluated on specific problems such as small problems in chemistry, hand-writing recognition and game-playing. Such tests have been termed subject matter expert Turing tests. Smaller problems provide more achievable goals and there are an ever-increasing number of positive results.

The broad classes of outcome for an AI test are: (1) Optimal: it is not possible to perform better. (2) Strong super-human: performs better than all humans. (3) Super-human: performs better than most humans. (4) Sub-human: performs worse than most humans. For example, performance at draughts is optimal, performance at chess is super-human and nearing strong super-human and performance at many everyday tasks (such as recognizing a face or crossing a room without bumping into something) is sub-human.

A quite different approach measures machine intelligence through tests which are developed from *mathematical* definitions of intelligence. Examples of these kinds of tests start in the late nineties devising intelligence tests using notions from Kolmogorov Complexity and data compression. Two major advantages of mathematical definitions are their applicability to nonhuman intelligences and their absence of a requirement for human testers.

Applications

Artificial intelligence techniques are pervasive and are too numerous to list. Frequently, when a technique reaches mainstream use, it is no longer considered artificial intelligence; this phenomenon is described as the AI effect.

Competitions and prizes

There are a number of competitions and prizes to promote research in artificial intelligence. The main areas promoted are: general machine intelligence, conversational behavior, data-mining, driverless cars, robot soccer and games.

Platforms

A platform (or "computing platform")is defined as "some sort of hardware architecture or software framework (including application frameworks), that allows software to run." As Rodney Brooks pointed out many years ago, it is not just the artificial intelligence software that defines the AI features of the platform, but rather the actual platform itself that affects the AI that results, i.e., we need to be working out AI problems on real world platforms rather than in isolation.

A wide variety of platforms has allowed different aspects of AI to develop, ranging from expert systems, albeit PC-based but still an entire real-world system to various robot platforms such as the widely available Roomba with open interface.

Philosophy

Artificial intelligence, by claiming to be able to recreate the capabilities of the human mind, is both a challenge and an inspiration for philosophy. Are there limits to how intelligent machines can be? Is there an essential difference between human intelligence and artificial intelligence? Can a machine have a mind and consciousness? A few of the most influential answers to these questions are given below. Philosophy of AI. All of these positions below are mentioned in standard discussions of the subject, such as:

Turing's "polite convention"

> *If a machine acts as intelligently as a human being, then it is as intelligent as a human being.* Alan Turing theorized that, ultimately, we can only judge the intelligence of a machine based on its behavior. This theory forms the basis of the Turing test.

The Dartmouth proposal

> *"Every aspect of learning or any other feature of intelligence can be so precisely described that a machine can be made to simulate it."* This assertion was printed in the proposal for the Dartmouth Conference of 1956, and represents the position of most working AI researchers.

Newell and Simon's physical symbol system hypothesis

> *"A physical symbol system has the necessary and sufficient means of general intelligent action."* Newell and Simon argue that intelligences consists of formal operations on symbols. Hubert Dreyfus argued that, on the contrary, human expertise depends on unconscious instinct rather than conscious symbol manipulation and on having a "feel" for the situation rather than explicit symbolic knowledge.

Gödel's incompleteness theorem

A formal system (such as a computer program) can not prove all true statements. Roger Penrose is among those who claim that Gödel's theorem limits what machines can do.

Searle's strong AI hypothesis

"The appropriately programmed computer with the right inputs and outputs would thereby have a mind in exactly the same sense human beings have minds." John Searle counters this assertion with his Chinese room argument, which asks us to look *inside* the computer and try to find where the "mind" might be.

The artificial brain argument

The brain can be simulated. Hans Moravec, Ray Kurzweil and others have argued that it is technologically feasible to copy the brain directly into hardware and software, and that such a simulation will be essentially identical to the original.

Prediction

Artifcial Intelligence is a common topic in both science fiction and projections about the future of technology and society. The existence of an artificial intelligence that rivals human intelligence raises difficult ethical issues, and the potential power of the technology inspires both hopes and fears.

In fiction, Artificial Intelligence has appeared fulfilling many roles, including a servant (R2D2 in *Star Wars*), a law enforcer (K.I.T.T. "Knight Rider"), a comrade (Lt. Commander Data in *Star Trek: The Next Generation*), a conqueror/overlord (*The Matrix*), a dictator (*With Folded Hands*), an assassin (*Terminator*), a sentient race (*Battlestar Galactica*/Transformers), an extension to human abilities (*Ghost in the Shell*) and the savior of the human race (R. Daneel Olivaw in the *Asimov's Robot Series*).

Mary Shelley's *Frankenstein* considers a key issue in the ethics of artificial intelligence: if a machine can be created that has intelligence, could it also *feel*? If it can feel, does it have the same rights as a human? The idea also appears in modern science fiction, including the films *I Robot*, *Blade Runner* and *A.I.: Artificial Intelligence*, in which humanoid machines have the ability to feel human emotions. This issue, now known as "robot rights", is currently being considered by, for example, California's Institute for the Future, although many critics believe that the discussion is premature.

Andrew Kennedy, in his musing on the evolution of the human personality, considered that artificial intelligences or 'new minds' are likely to have severe personality disorders, and identifies four particular types that are likely to arise: the autistic, the collector, the ecstatic, and the victim. He suggests that they will need humans because of our superior understanding of personality and the role of the unconscious.

Martin Ford and others argue that specialized artificial intelligence applications, robotics and other forms of automation will ultimately result in significant unemployment as machines begin to match and exceed the capability of workers to perform most routine and repetitive jobs. Ford predicts that many knowledge-based occupations—and in particular entry level jobs—will be increasingly susceptible to automation via expert systems and other AI-enhanced applications. AI-based applications may also be used to amplify the capabilities of low-wage offshore workers, making it more feasible to outsource knowledge work. Evidence to support this contention may be found in the fact that real wages for new college graduates have been flat or even declining since 2000.

Joseph Weizenbaum wrote that AI applications can not, by definition, successfully simulate genuine human empathy and that the use of AI technology in fields such as customer service or psychotherapy was deeply misguided. Weizenbaum was also bothered that AI researchers (and some philosophers) were willing to view the human mind as nothing more than a computer program (a position now known as computationalism). To Weizenbaum these points suggest that AI research devalues human life.

Many futurists believe that artificial intelligence will ultimately transcend the limits of progress. Ray Kurzweil has used Moore's law (which describes the relentless exponential improvement in digital technology) to calculate that desktop computers will have the same processing power as human brains by the year 2029. He also predicts that by 2045 artificial intelligence will reach a point where it is able to improve *itself* at a rate that far exceeds anything conceivable in the past, a scenario that science fiction writer Vernor Vinge named the "technological singularity".

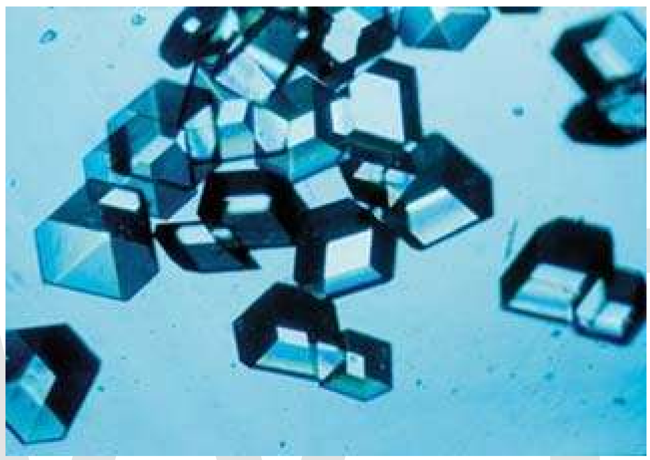
Robot designer Hans Moravec, cyberneticist Kevin Warwick and inventor Ray Kurzweil have predicted that humans and machines will merge in the future into cyborgs that are more capable and powerful than either. This idea, called transhumanism, which has roots in Aldous Huxley and Robert Ettinger, has been illustrated in fiction as well, for example in the manga *Ghost in the Shell* and the science-fiction series *Dune*.

Edward Fredkin argues that "artificial intelligence is the next stage in evolution," an idea first proposed by Samuel Butler's "Darwin among the Machines" (1863), and expanded upon by George Dyson in his book of the same name in 1998.

Pamela McCorduck writes that all these scenarios are expressions of the ancient human desire to, as she calls it, "forge the gods".

Chapter- 3

Biotechnology



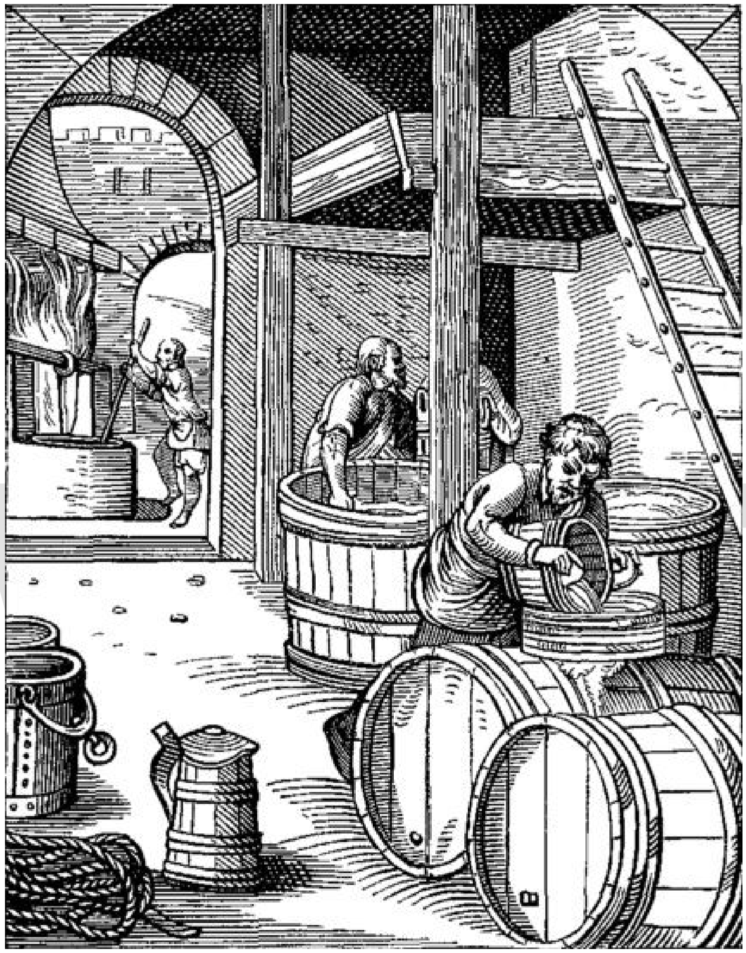
Insulin crystals

Biotechnology is a field of applied biology that involves the use of living organisms and bioprocesses in engineering, technology, medicine and other fields requiring bioproducts. Modern use of similar terms includes genetic engineering as well as cell- and tissue culture technologies. The concept encompasses a wide range of procedures (and history) for modifying living organisms according to human purposes - going back to domestication of animals, cultivation of plants, and "improvements" to these through breeding programs that employ artificial selection and hybridization. By comparison to biotechnology, bioengineering is generally thought of as a related field with its emphasis more on higher systems approaches (not necessarily altering or using biological materials *directly*) for interfacing with and utilizing living things. The United Nations Convention on Biological Diversity defines biotechnology as:

"Any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use."

Biotechnology draws on the pure biological sciences (genetics, microbiology, animal cell culture, molecular biology, biochemistry, embryology, cell biology) and in many instances is also dependent on knowledge and methods from outside the sphere of biology (chemical engineering, bioprocess engineering, information technology, biorobotics). Conversely, modern biological sciences (including even concepts such as molecular ecology) are intimately entwined and dependent on the methods developed through biotechnology and what is commonly thought of as the life sciences industry.

History



Brewing was an early application of biotechnology

Biotechnology is not limited to medical/health applications (*unlike* Biomedical Engineering, which includes much biotechnology). Although not normally thought of as biotechnology, agriculture clearly fits the broad definition of "*using a biotechnological system to make products*" such that the cultivation of plants may be viewed as the earliest biotechnological enterprise. Agriculture has been theorized to have become the dominant way of producing food since the Neolithic Revolution. The processes and methods of agriculture have been refined by other mechanical and biological sciences since its inception. Through early biotechnology, farmers were able to select the best suited crops, having the highest yields, to produce enough food to support a growing population. Other uses of biotechnology were required as the crops and fields became increasingly large and difficult to maintain. Specific organisms and organism by-products were used to fertilize, restore nitrogen, and control pests. Throughout the use of agriculture, farmers have inadvertently altered the genetics of their crops through introducing them to new environments and breeding them with other plants—one of the first forms of biotechnology. Cultures such as those in Mesopotamia, Egypt, and India developed the process of brewing beer. It is still done by the same basic method of using malted grains (containing enzymes) to convert starch from grains into sugar and then adding specific yeasts to produce beer. In this process the carbohydrates in the grains were broken down into alcohols such as ethanol. Ancient Indians also used the juices of the plant Ephedra vulgaris and used to call it Soma. Later other cultures produced the process of Lactic acid fermentation which allowed the fermentation and preservation of other forms of food. Fermentation was also used in this time period to produce leavened bread. Although the process of fermentation was not fully understood until Pasteur's work in 1857, it is still the first use of biotechnology to convert a food source into another form.

For thousands of years, humans have used selective breeding to improve production of crops and livestock to use them for food. In selective breeding, organisms with desirable characteristics are mated to produce offspring with the same characteristics. For example, this technique was used with corn to produce the largest and sweetest crops.

In the early twentieth century scientists gained a greater understanding of microbiology and explored ways of manufacturing specific products. In 1917, Chaim Weizmann first used a pure microbiological culture in an industrial process, that of manufacturing corn starch using *Clostridium acetobutylicum,* to produce acetone, which the United Kingdom desperately needed to manufacture explosives during World War I.

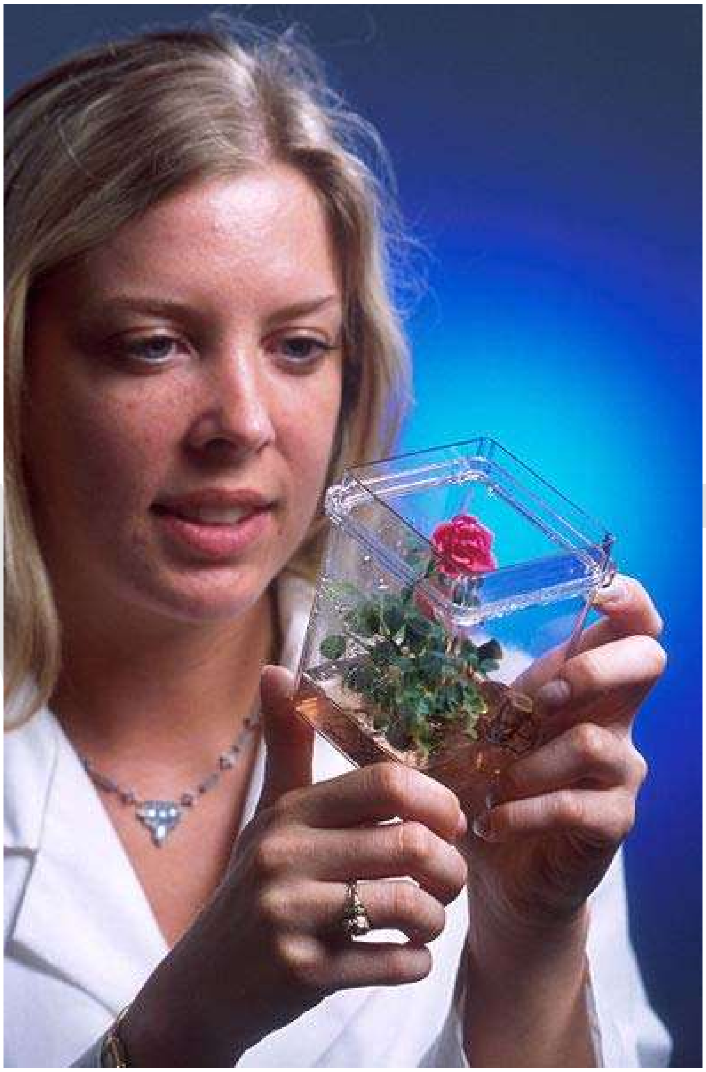
Biotechnology has led to the development of antibiotics. In 1928, Alexander Fleming discovered the mold Penicillium. His work led to the purification of the antibiotic by Howard Florey, Ernst Boris Chain and Norman Heatley penicillin. In 1940, penicillin became available for medicinal use to treat bacterial infections in humans.

The field of modern biotechnology is thought to have largely begun on June 16, 1980, when the United States Supreme Court ruled that a genetically modified microorganism could be patented in the case of *Diamond v. Chakrabarty*. Indian-born Ananda Chakrabarty, working for General Electric, had developed a bacterium (derived from the *Pseudomonas* genus) capable of breaking down crude oil, which he proposed to use in treating oil spills.

Revenue in the industry is expected to grow by 12.9% in 2008. Another factor influencing the biotechnology sector's success is improved intellectual property rights legislation—and enforcement—worldwide, as well as strengthened demand for medical and pharmaceutical products to cope with an ageing, and ailing, U.S. population.

Rising demand for biofuels is expected to be good news for the biotechnology sector, with the Department of Energy estimating ethanol usage could reduce U.S. petroleum-derived fuel consumption by up to 30% by 2030. The biotechnology sector has allowed the U.S. farming industry to rapidly increase its supply of corn and soybeans—the main inputs into biofuels—by developing genetically modified seeds which are resistant to pests and drought. By boosting farm productivity, biotechnology plays a crucial role in ensuring that biofuel production targets are met.

Applications



A rose plant that began as cells grown in a tissue culture

Biotechnology has applications in four major industrial areas, including health care (medical), crop production and agriculture, non food (industrial) uses of crops and other products (e.g. biodegradable plastics, vegetable oil, biofuels), and environmental uses.

For example, one application of biotechnology is the directed use of organisms for the manufacture of organic products (examples include beer and milk products). Another example is using naturally present bacteria by the mining industry in bioleaching. Biotechnology is also used to recycle, treat waste, clean up sites contaminated by industrial activities (bioremediation), and also to produce biological weapons.

A series of derived terms have been coined to identify several branches of biotechnology, for example:

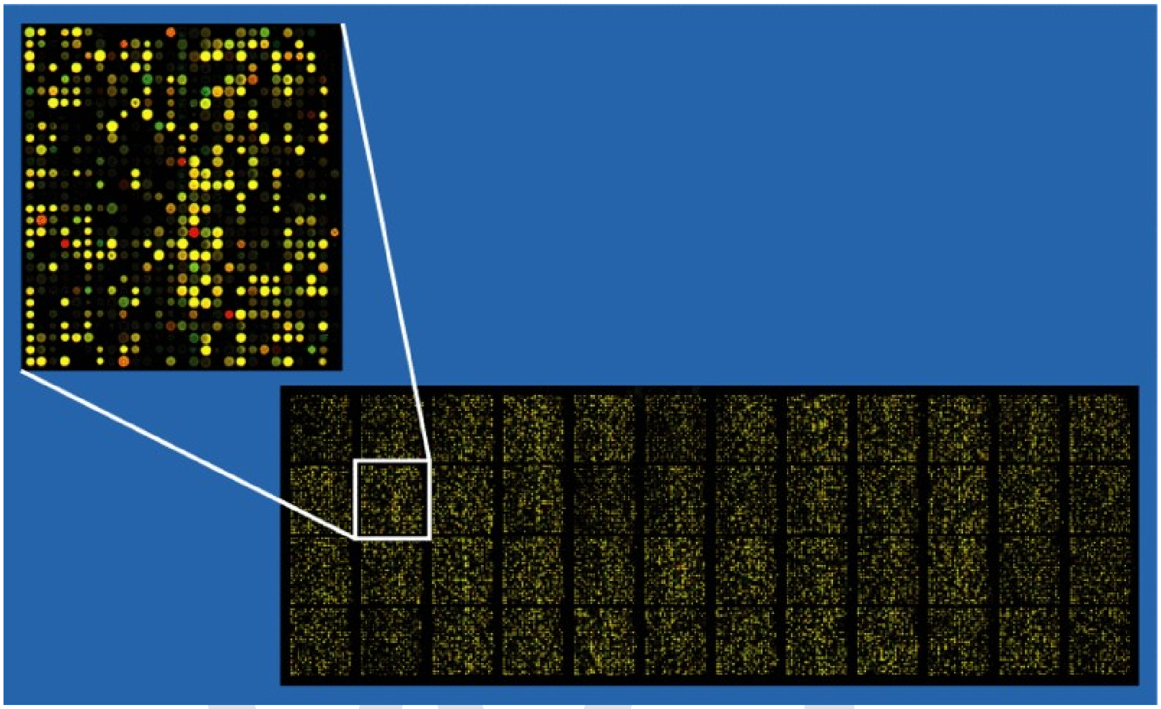
- **Bioinformatics** is an interdisciplinary field which addresses biological problems using computational techniques, and makes the rapid organization and analysis of biological data possible. The field may also be referred to as *computational biology*, and can be defined as, "conceptualizing biology in terms of molecules and then applying informatics techniques to understand and organize the information associated with these molecules, on a large scale." Bioinformatics plays a key role in various areas, such as functional genomics, structural genomics, and proteomics, and forms a key component in the biotechnology and pharmaceutical sector.
- **Blue biotechnology** is a term that has been used to describe the marine and aquatic applications of biotechnology, but its use is relatively rare.
- **Green biotechnology** is biotechnology applied to agricultural processes. An example would be the selection and domestication of plants via micropropagation. Another example is the designing of transgenic plants to grow under specific environments in the presence (or absence) of chemicals. One hope is that green biotechnology might produce more environmentally friendly solutions than traditional industrial agriculture. An example of this is the engineering of a plant to express a pesticide, thereby ending the need of external application of pesticides. An example of this would be Bt corn. Whether or not green biotechnology products such as this are ultimately more environmentally friendly is a topic of considerable debate.
- **Red biotechnology** is applied to medical processes. Some examples are the designing of organisms to produce antibiotics, and the engineering of genetic cures through genetic manipulation.
- **White biotechnology**, also known as industrial biotechnology, is biotechnology applied to industrial processes. An example is the designing of an organism to produce a useful chemical. Another example is the using of enzymes as industrial catalysts to either produce valuable chemicals or destroy hazardous/polluting chemicals. White biotechnology tends to consume less in resources than traditional processes used to produce industrial goods. The investment and economic output of all of these types of applied biotechnologies is termed as **bioeconomy**.

Medicine

In medicine, modern biotechnology finds promising applications in such areas as

- drug production
- pharmacogenomics
- gene therapy
- genetic testing: techniques in molecular biology detect genetic diseases. To test the developing fetus for Down syndrome, Amniocentesis and chorionic villus sampling can be used.

Pharmacogenomics



DNA Microarray chip – Some can do as many as a million blood tests at once

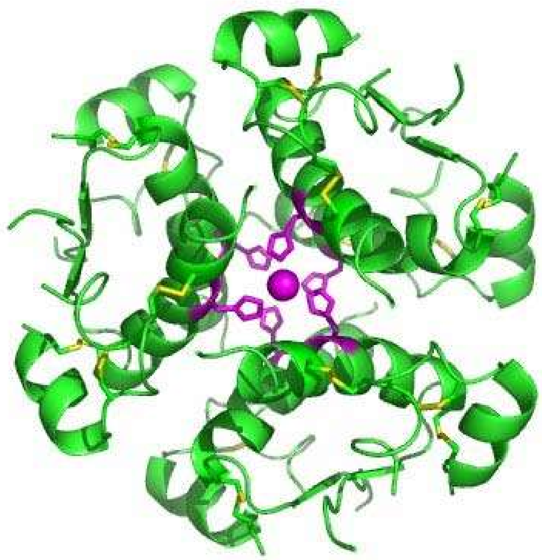
Pharmacogenomics is the study of how the genetic inheritance of an individual affects his/her body's response to drugs. It is a coined word derived from the words "pharmacology" and "genomics". It is hence the study of the relationship between pharmaceuticals and genetics. The vision of pharmacogenomics is to be able to design and produce drugs that are adapted to each person's genetic makeup.

Pharmacogenomics results in the following benefits:

1. Development of tailor-made medicines. Using pharmacogenomics, pharmaceutical companies can create drugs based on the proteins, enzymes and RNA molecules that are associated with specific genes and diseases. These tailor-made drugs promise not only to maximize therapeutic effects but also to decrease damage to nearby healthy cells.
2. More accurate methods of determining appropriate drug dosages. Knowing a patient's genetics will enable doctors to determine how well his/ her body can process and metabolize a medicine. This will maximize the value of the medicine and decrease the likelihood of overdose.
3. Improvements in the drug discovery and approval process. The discovery of potential therapies will be made easier using genome targets. Genes have been associated with numerous diseases and disorders. With modern biotechnology, these genes can be used as targets for the development of effective new therapies, which could significantly shorten the drug discovery process.

4. Better vaccines. Safer vaccines can be designed and produced by organisms transformed by means of genetic engineering. These vaccines will elicit the immune response without the attendant risks of infection. They will be inexpensive, stable, easy to store, and capable of being engineered to carry several strains of pathogen at once.

Pharmaceutical products



Computer-generated image of insulin hexamers highlighting the threefold symmetry, the zinc ions holding it together, and the histidine residues involved in zinc binding.

Most traditional pharmaceutical drugs are relatively simple molecules that have been found primarily through trial and error to treat the symptoms of a disease or illness. Biopharmaceuticals are large biological molecules known as proteins and these usually target the underlying mechanisms and pathways of a malady (but not always, as is the case with using insulin to treat type 1 diabetes mellitus, as that treatment merely addresses the symptoms of the disease, not the underlying cause which is autoimmunity); it is a relatively young industry. They can deal with targets in humans that may not be accessible with traditional medicines. A patient typically is dosed with a small molecule *via* a tablet while a large molecule is typically injected.

Small molecules are manufactured by chemistry but larger molecules are created by living cells such as those found in the human body: for example, bacteria cells, yeast cells, animal or plant cells.

Modern biotechnology is often associated with the use of genetically altered microorganisms such as *E. coli* or yeast for the production of substances like synthetic insulin or antibiotics. It can also refer to transgenic animals or transgenic plants, such as

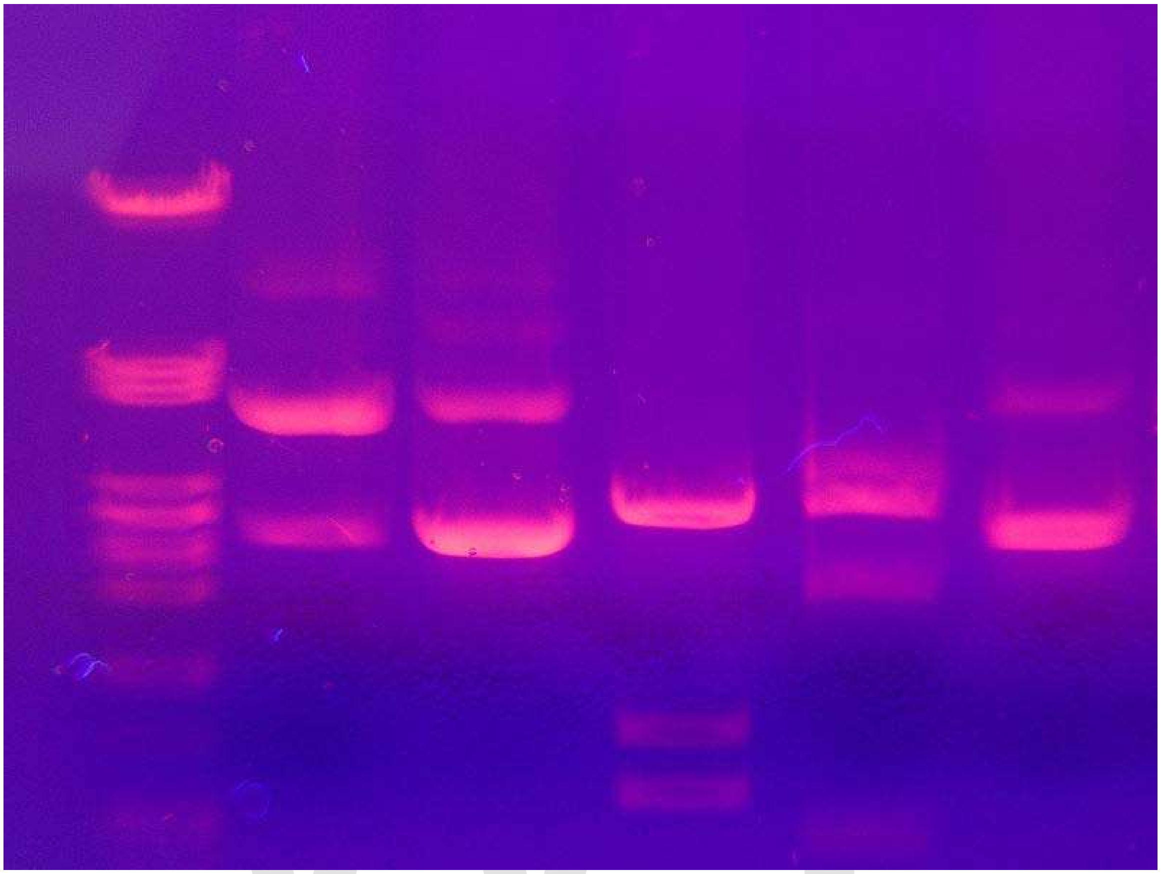
Bt corn. Genetically altered mammalian cells, such as Chinese Hamster Ovary (CHO) cells, are also used to manufacture certain pharmaceuticals. Another promising new biotechnology application is the development of plant-made pharmaceuticals.

Biotechnology is also commonly associated with landmark breakthroughs in new medical therapies to treat hepatitis B, hepatitis C, cancers, arthritis, haemophilia, bone fractures, multiple sclerosis, and cardiovascular disorders. The biotechnology industry has also been instrumental in developing molecular diagnostic devices that can be used to define the target patient population for a given biopharmaceutical. Herceptin, for example, was the first drug approved for use with a matching diagnostic test and is used to treat breast cancer in women whose cancer cells express the protein HER2.

Modern biotechnology can be used to manufacture existing medicines relatively easily and cheaply. The first genetically engineered products were medicines designed to treat human diseases. To cite one example, in 1978 Genentech developed synthetic humanized insulin by joining its gene with a plasmid vector inserted into the bacterium *Escherichia coli*. Insulin, widely used for the treatment of diabetes, was previously extracted from the pancreas of abattoir animals (cattle and/or pigs). The resulting genetically engineered bacterium enabled the production of vast quantities of synthetic human insulin at relatively low cost. According to a 2003 study undertaken by the International Diabetes Federation (IDF) on the access to and availability of insulin in its member countries, synthetic 'human' insulin is considerably more expensive in most countries where both synthetic 'human' and animal insulin are commercially available: e.g. within European countries the average price of synthetic 'human' insulin was twice as high as the price of pork insulin. Yet in its position statement, the IDF writes that "there is no overwhelming evidence to prefer one species of insulin over another" and "[modern, highly purified] animal insulins remain a perfectly acceptable alternative.

Modern biotechnology has evolved, making it possible to produce more easily and relatively cheaply human growth hormone, clotting factors for hemophiliacs, fertility drugs, erythropoietin and other drugs. Most drugs today are based on about 500 molecular targets. Genomic knowledge of the genes involved in diseases, disease pathways, and drug-response sites are expected to lead to the discovery of thousands more new targets.

Genetic testing



Gel electrophoresis

Genetic testing involves the direct examination of the DNA molecule itself. A scientist scans a patient's DNA sample for mutated sequences.

There are two major types of gene tests. In the first type, a researcher may design short pieces of DNA ("probes") whose sequences are complementary to the mutated sequences. These probes will seek their complement among the base pairs of an individual's genome. If the mutated sequence is present in the patient's genome, the probe will bind to it and flag the mutation. In the second type, a researcher may conduct the gene test by comparing the sequence of DNA bases in a patient's gene to disease in healthy individuals or their progeny.

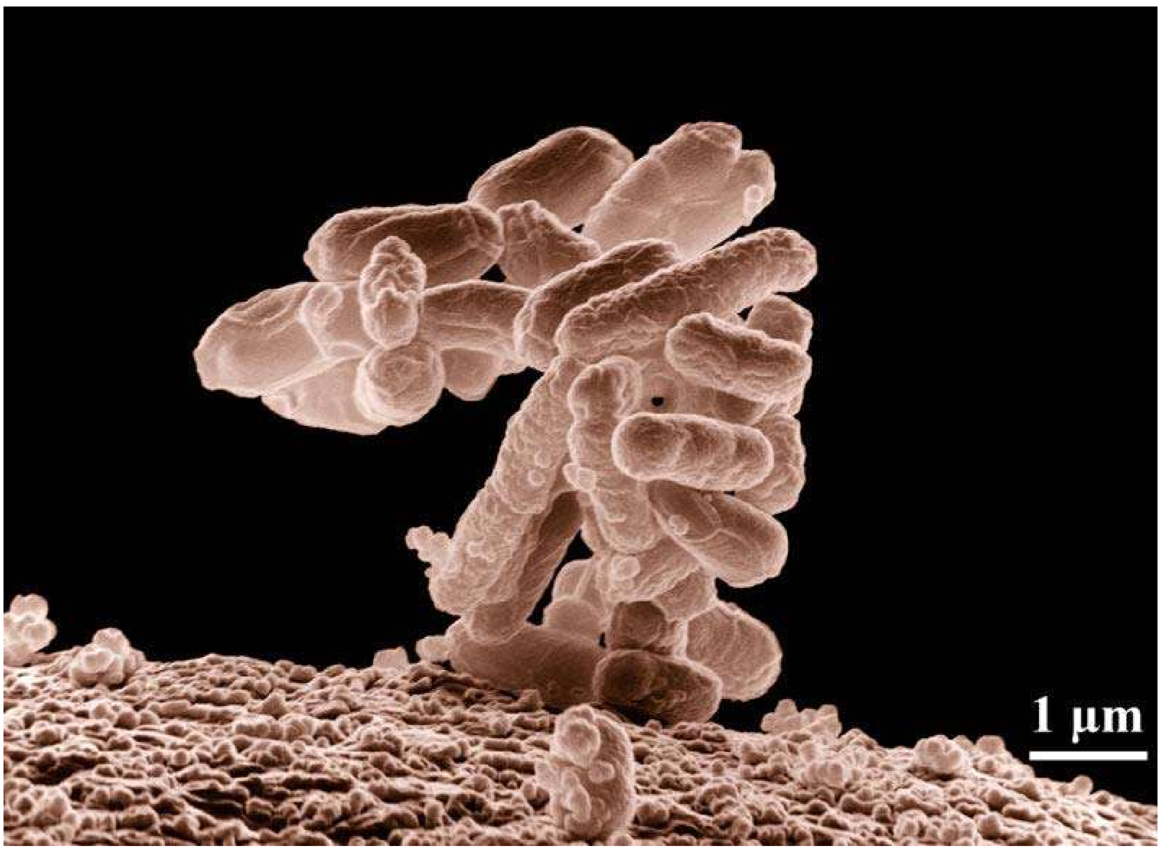
Genetic testing is now used for:

- Carrier screening, or the identification of unaffected individuals who carry one copy of a gene for a disease that requires two copies for the disease to manifest;
- Confirmational diagnosis of symptomatic individuals;
- Determining sex;
- Forensic/identity testing;
- Newborn screening;

- Prenatal diagnostic screening;
- Presymptomatic testing for estimating the risk of developing adult-onset cancers;
- Presymptomatic testing for predicting adult-onset disorders.

Some genetic tests are already available, although most of them are used in developed countries. The tests currently available can detect mutations associated with rare genetic disorders like cystic fibrosis, sickle cell anemia, and Huntington's disease. Recently, tests have been developed to detect mutation for a handful of more complex conditions such as breast, ovarian, and colon cancers. However, gene tests may not detect every mutation associated with a particular condition because many are as yet undiscovered, and the ones they do detect may present different risks to different people and populations.

Controversial questions



The bacterium *Escherichia coli* is routinely genetically engineered

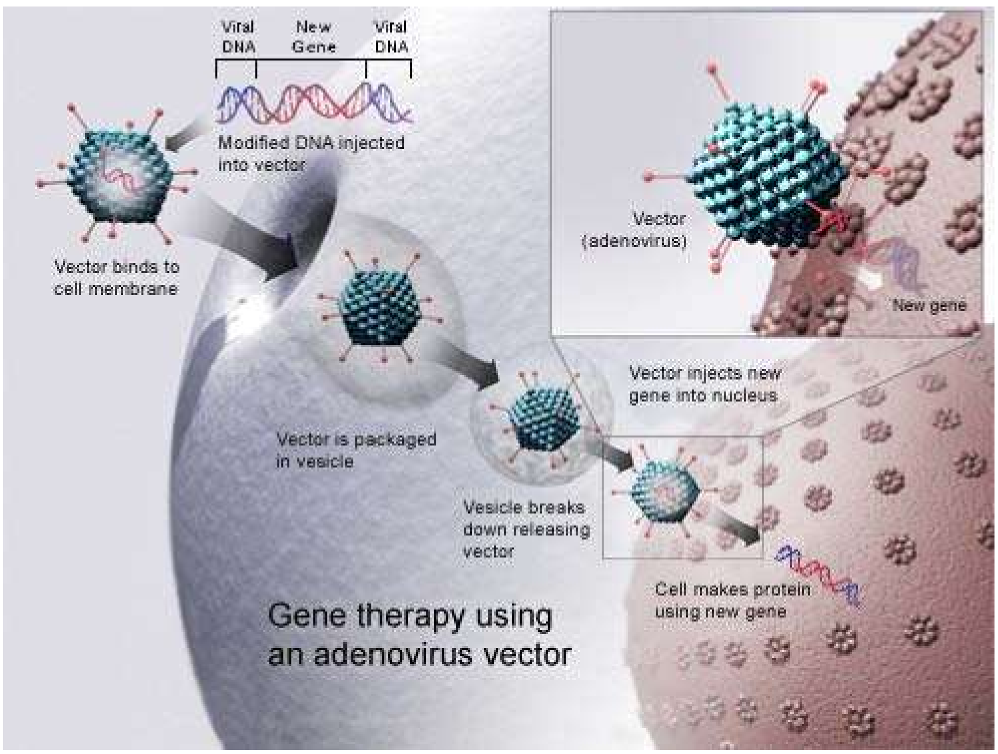
The absence of privacy and anti-discrimination legal protections in most countries can lead to discrimination in employment or insurance or other use of personal genetic information. This raises questions such as whether genetic privacy is different from medical privacy.

1. Reproductive issues. These include the use of genetic information in reproductive decision-making and the possibility of genetically altering reproductive cells that

may be passed on to future generations. For example, germline therapy changes the genetic make-up of an individual's descendants. Thus, any error in technology or judgment may have far-reaching consequences (though the same can also happen through natural reproduction). Ethical issues like designed babies and human cloning have also given rise to controversies between and among scientists and bioethicists, especially in the light of past abuses with eugenics.

2. Clinical issues. These center on the capabilities and limitations of doctors and other health-service providers, people identified with genetic conditions, and the general public in dealing with genetic information.
3. Effects on social institutions. Genetic tests reveal information about individuals and their families. Thus, test results can affect the dynamics within social institutions, particularly the family.
4. Conceptual and philosophical implications regarding human responsibility, free will vis-à-vis genetic determinism, and the concepts of health and disease.

Gene therapy



Gene therapy using an Adenovirus vector. A new gene is inserted into an adenovirus vector, which is used to introduce the modified DNA into a human cell. If the treatment is successful, the new gene will make a functional protein.

Gene therapy may be used for treating, or even curing, genetic and acquired diseases like cancer and AIDS by using normal genes to supplement or replace defective genes or to bolster a normal function such as immunity. It can be used to target somatic (i.e., body) or gametes (i.e., egg and sperm) cells. In somatic gene therapy, the genome of the recipient is changed, but this change is not passed along to the next generation. In contrast, in germline gene therapy, the egg and sperm cells of the parents are changed for the purpose of passing on the changes to their offspring.

There are basically two ways of implementing a gene therapy treatment:

1. *Ex vivo*, which means "outside the body" – Cells from the patient's blood or bone marrow are removed and grown in the laboratory. They are then exposed to a virus carrying the desired gene. The virus enters the cells, and the desired gene becomes part of the DNA of the cells. The cells are allowed to grow in the laboratory before being returned to the patient by injection into a vein.
2. *In vivo*, which means "inside the body" – No cells are removed from the patient's body. Instead, vectors are used to deliver the desired gene to cells in the patient's body.

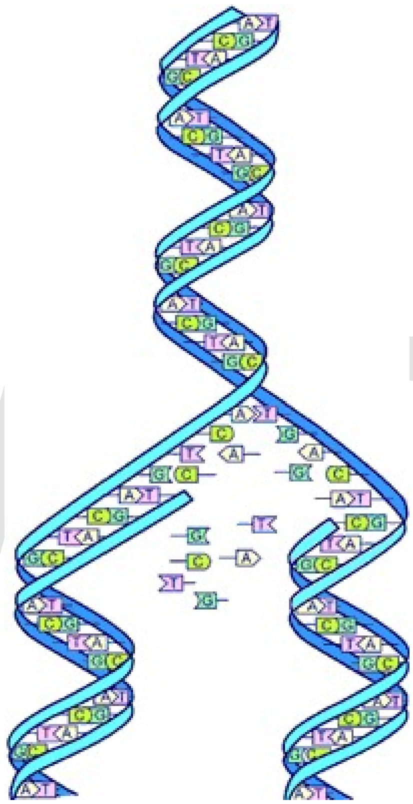
As of June 2001, more than 500 clinical gene-therapy trials involving about 3,500 patients have been identified worldwide. Around 78% of these are in the United States, with Europe having 18%. These trials focus on various types of cancer, although other multigenic diseases are being studied as well. Recently, two children born with severe combined immunodeficiency disorder ("SCID") were reported to have been cured after being given genetically engineered cells.

Gene therapy faces many obstacles before it can become a practical approach for treating disease. At least four of these obstacles are as follows:

1. *Gene delivery tools*. Genes are inserted into the body using gene carriers called vectors. The most common vectors now are viruses, which have evolved a way of encapsulating and delivering their genes to human cells in a pathogenic manner. Scientists manipulate the genome of the virus by removing the disease-causing genes and inserting the therapeutic genes. However, while viruses are effective, they can introduce problems like toxicity, immune and inflammatory responses, and gene control and targeting issues. In addition, in order for gene therapy to provide permanent therapeutic effects, the introduced gene needs to be integrated within the host cell's genome. Some viral vectors effect this in a random fashion, which can introduce other problems such as disruption of an endogenous host gene.
2. *High costs*. Since gene therapy is relatively new and at an experimental stage, it is an expensive treatment to undertake. This explains why current studies are focused on illnesses commonly found in developed countries, where more people can afford to pay for treatment. It may take decades before developing countries can take advantage of this technology.
3. *Limited knowledge of the functions of genes*. Scientists currently know the functions of only a few genes. Hence, gene therapy can address only some genes that cause a particular disease. Worse, it is not known exactly whether genes have more than one function, which creates uncertainty as to whether replacing such genes is indeed desirable.

4. *Multigene disorders and effect of environment*. Most genetic disorders involve more than one gene. Moreover, most diseases involve the interaction of several genes and the environment. For example, many people with cancer not only inherit the disease gene for the disorder, but may have also failed to inherit specific tumor suppressor genes. Diet, exercise, smoking and other environmental factors may have also contributed to their disease.

Human Genome Project



DNA Replication image from the Human Genome Project (HGP)

The Human Genome Project is an initiative of the U.S. Department of Energy ("DOE") that aims to generate a high-quality reference sequence for the entire human genome and identify all the human genes.

The DOE and its predecessor agencies were assigned by the U.S. Congress to develop new energy resources and technologies and to pursue a deeper understanding of potential health and environmental risks posed by their production and use. In 1986, the DOE announced its Human Genome Initiative. Shortly thereafter, the DOE and National Institutes of Health developed a plan for a joint Human Genome Project ("HGP"), which officially began in 1990.

The HGP was originally planned to last 15 years. However, rapid technological advances and worldwide participation accelerated the completion date to 2003 (making it a 13 year project). Already it has enabled gene hunters to pinpoint genes associated with more than 30 disorders.

Cloning

Cloning involves the removal of the nucleus from one cell and its placement in an unfertilized egg cell whose nucleus has either been deactivated or removed.

There are two types of cloning:

1. Reproductive cloning. After a few divisions, the egg cell is placed into a uterus where it is allowed to develop into a fetus that is genetically identical to the donor of the original nucleus.
2. Therapeutic cloning. The egg is placed into a Petri dish where it develops into embryonic stem cells, which have shown potentials for treating several ailments.

In February 1997, cloning became the focus of media attention when Ian Wilmut and his colleagues at the Roslin Institute announced the successful cloning of a sheep, named Dolly, from the mammary glands of an adult female. The cloning of Dolly made it apparent to many that the techniques used to produce her could someday be used to clone human beings. This stirred a lot of controversy because of its ethical implications.

Agriculture

Crop yield

Using the techniques of modern biotechnology, one or two genes (Smartstax from Monsanto in collaboration with Dow AgroSciences will use 8, starting in 2010) may be transferred to a highly developed crop variety to impart a new character that would increase its yield. However, while increases in crop yield are the most obvious applications of modern biotechnology in agriculture, it is also the most difficult one. Current genetic engineering techniques work best for effects that are controlled by a single gene. Many of the genetic characteristics associated with yield (e.g., enhanced growth) are controlled by a large number of genes, each of which has a minimal effect on the overall yield. There is, therefore, much scientific work to be done in this area.

Reduced vulnerability of crops to environmental stresses

Crops containing genes that will enable them to withstand biotic and abiotic stresses may be developed. For example, drought and excessively salty soil are two important limiting factors in crop productivity. Biotechnologists are studying plants that can cope with these extreme conditions in the hope of finding the genes that enable them to do so and eventually transferring these genes to the more desirable crops. One of the latest developments is the identification of a plant gene, At-DBF2, from Arabidopsis thaliana, a tiny weed that is often used for plant research because it is very easy to grow and its genetic code is well mapped out. When this gene was inserted into tomato and tobacco cells, the cells were able to withstand environmental stresses like salt, drought, cold and heat, far more than ordinary cells. If these preliminary results prove successful in larger trials, then At-DBF2 genes can help in engineering crops that can better withstand harsh environments. Researchers have also created transgenic rice plants that are resistant to rice yellow mottle virus (RYMV). In Africa, this virus destroys majority of the rice crops and makes the surviving plants more susceptible to fungal infections.

Increased nutritional qualities

Proteins in foods may be modified to increase their nutritional qualities. Proteins in legumes and cereals may be transformed to provide the amino acids needed by human beings for a balanced diet. A good example is the work of Professors Ingo Potrykus and Peter Beyer in creating Golden rice (discussed below).

Improved taste, texture or appearance of food

Modern biotechnology can be used to slow down the process of spoilage so that fruit can ripen longer on the plant and then be transported to the consumer with a still reasonable shelf life. This alters the taste, texture and appearance of the fruit. More importantly, it could expand the market for farmers in developing countries due to the reduction in spoilage. However, there is sometimes a lack of understanding by researchers in developed countries about the actual needs of prospective beneficiaries in developing countries. For example, engineering soybeans to resist spoilage makes them less suitable for producing tempeh which is a significant source of protein that depends on fermentation. The use of modified soybeans results in a lumpy texture that is less palatable and less convenient when cooking.

The first genetically modified food product was a tomato which was transformed to delay its ripening. Researchers in Indonesia, Malaysia, Thailand, Philippines and Vietnam are currently working on delayed-ripening papaya in collaboration with the University of Nottingham and Zeneca.

Biotechnology in cheese production: enzymes produced by micro-organisms provide an alternative to animal rennet – a cheese coagulant – and an alternative supply for cheese makers. This also eliminates possible public concerns with animal-derived material, although there are currently no plans to develop synthetic milk, thus making this argument less compelling. Enzymes offer an animal-friendly alternative to animal rennet. While providing comparable quality, they are theoretically also less expensive.

About 85 million tons of wheat flour is used every year to bake bread. By adding an enzyme called maltogenic amylase to the flour, bread stays fresher longer. Assuming that 10–15% of bread is thrown away as stale, if it could be made to stay fresh another 5–7 days then perhaps 2 million tons of flour per year would be saved. Other enzymes can cause bread to expand to make a lighter loaf, or alter the loaf in a range of ways.

Reduced dependence on fertilizers, pesticides and other agrochemicals

Most of the current commercial applications of modern biotechnology in agriculture are on reducing the dependence of farmers on agrochemicals. For example, *Bacillus thuringiensis* (Bt) is a soil bacterium that produces a protein with insecticidal qualities. Traditionally, a fermentation process has been used to produce an insecticidal spray from these bacteria. In this form, the Bt toxin occurs as an inactive protoxin, which requires digestion by an insect to be effective. There are several Bt toxins and each one is specific to certain target insects. Crop plants have now been engineered to contain and express the genes for Bt toxin, which they produce in its active form. When a susceptible insect ingests the transgenic crop cultivar expressing the Bt protein, it stops feeding and soon thereafter dies as a result of the Bt toxin binding to its gut wall. Bt corn is now commercially available in a number of countries to control corn borer (a lepidopteran insect), which is otherwise controlled by spraying (a more difficult process).

Crops have also been genetically engineered to acquire tolerance to broad-spectrum herbicide. The lack of herbicides with broad-spectrum activity and no crop injury was a consistent limitation in crop weed management. Multiple applications of numerous herbicides were routinely used to control a wide range of weed species detrimental to agronomic crops. Weed management tended to rely on preemergence—that is, herbicide applications were sprayed in response to expected weed infestations rather than in response to actual weeds present. Mechanical cultivation and hand weeding were often necessary to control weeds not controlled by herbicide applications. The introduction of herbicide-tolerant crops has the potential of reducing the number of herbicide active ingredients used for weed management, reducing the number of herbicide applications made during a season, and increasing yield due to improved weed management and less crop injury. Transgenic crops that express tolerance to glyphosate, glufosinate and bromoxynil have been developed. These herbicides can now be sprayed on transgenic crops without inflicting damage on the crops while killing nearby weeds.

From 1996 to 2001, herbicide tolerance was the most dominant trait introduced to commercially available transgenic crops, followed by insect resistance. In 2001, herbicide tolerance deployed in soybean, corn and cotton accounted for 77% of the 626,000 square kilometres planted to transgenic crops; Bt crops accounted for 15%; and "stacked genes" for herbicide tolerance and insect resistance used in both cotton and corn accounted for 8%.

Production of novel substances in crop plants

Biotechnology is being applied for novel uses other than food. For example, oilseed can be modified to produce fatty acids for detergents, substitute fuels and petrochemicals. Potatoes, tomatoes, rice tobacco, lettuce, safflowers, and other plants have been genetically engineered to produce insulin and certain vaccines. If future clinical trials prove successful, the advantages of edible vaccines would be enormous, especially for developing countries. The transgenic plants may be grown locally and cheaply. Homegrown vaccines would also avoid logistical and economic problems posed by having to transport traditional preparations over long distances and keeping them cold while in transit. And since they are edible, they will not need syringes, which are not only an additional expense in the traditional vaccine preparations but also a source of infections if contaminated. In the case of insulin grown in transgenic plants, it is well-established that the gastrointestinal system breaks the protein down therefore this could not currently be administered as an edible protein. However, it might be produced at significantly lower cost than insulin produced in costly bioreactors. For example, Calgary, Canada-based SemBioSys Genetics, Inc. reports that its safflower-produced insulin will reduce unit costs by over 25% or more and approximates a reduction in the capital costs associated with building a commercial-scale insulin manufacturing facility of over $100 million, compared to traditional biomanufacturing facilities.

Criticism

There is another side to the agricultural biotechnology issue. It includes increased herbicide usage and resultant herbicide resistance, "super weeds," residues on and in food crops, genetic contamination of non-GM crops which hurt organic and conventional farmers, etc.

Biological engineering

Biotechnological engineering or biological engineering is a branch of engineering that focuses on biotechnologies and biological science. It includes different disciplines such as biochemical engineering, biomedical engineering, bio-process engineering, biosystem engineering and so on. Because of the novelty of the field, the definition of a bioengineer is still undefined. However, in general it is an integrated approach of fundamental biological sciences and traditional engineering principles.

Biotechnologists are often employed to scale up bio processes from the laboratory scale to the manufacturing scale. Moreover, as with most engineers, they often deal with management, economic and legal issues. Since patents and regulation (e.g., U.S. Food and Drug Administration regulation in the U.S.) are very important issues for biotech enterprises, bioengineers are often required to have knowledge related to these issues.

The increasing number of biotech enterprises is likely to create a need for bioengineers in the years to come. Many universities throughout the world are now providing programs in bioengineering and biotechnology (as independent programs or specialty programs within more established engineering fields).

Bioremediation and biodegradation

Biotechnology is being used to engineer and adapt organisms especially microorganisms in an effort to find sustainable ways to clean up contaminated environments. The elimination of a wide range of pollutants and wastes from the environment is an absolute requirement to promote a sustainable development of our society with low environmental impact. Biological processes play a major role in the removal of contaminants and biotechnology is taking advantage of the astonishing catabolic versatility of microorganisms to degrade/convert such compounds. New methodological breakthroughs in sequencing, genomics, proteomics, bioinformatics and imaging are producing vast amounts of information. In the field of Environmental Microbiology, genome-based global studies open a new era providing unprecedented *in silico* views of metabolic and regulatory networks, as well as clues to the evolution of degradation pathways and to the molecular adaptation strategies to changing environmental conditions. Functional genomic and metagenomic approaches are increasing our understanding of the relative importance of different pathways and regulatory networks to carbon flux in particular environments and for particular compounds and they will certainly accelerate the development of bioremediation technologies and biotransformation processes.

Marine environments are especially vulnerable since oil spills of coastal regions and the open sea are poorly containable and mitigation is difficult. In addition to pollution through human activities, millions of tons of petroleum enter the marine environment every year from natural seepages. Despite its toxicity, a considerable fraction of petroleum oil entering marine systems is eliminated by the hydrocarbon-degrading activities of microbial communities, in particular by a remarkable recently discovered group of specialists, the so-called hydrocarbonoclastic bacteria (HCCB).

Biotechnology regulations

The National Institute of Health was the first federal agency to assume regulatory responsibility in the United States. The Recombinant DNA Advisory Committee of the NIH published guidelines for working with recombinant DNA and recombinant organisms in the laboratory. Nowadays, the agencies that are responsible for the biotechnology regulation are: US Department of Agriculture (USDA) that regulates plant pests and medical preparation from living organisms, Environmental Protection Agency (EPA) that regulates pesticides and herbicides, and the Food and Drug Administration (FDA) which ensures that the food and drug products are safe and effective

Education

In 1988, after prompting from the United States Congress, the National Institute of General Medical Sciences (National Institutes of Health) instituted a funding mechanism for biotechnology training. Universities nationwide compete for these funds to establish Biotechnology Training Programs (BTPs). Each successful application is generally funded for five years then must be competitively renewed. Graduate students in turn compete for acceptance into a BTP; if accepted then stipend, tuition and health insurance support is provided for two or three years during the course of their PhD thesis work. Nineteen institutions offer NIGMS supported BTPs. Biotechnology training is also offered at the undergraduate level and in community colleges.

Chapter- 4

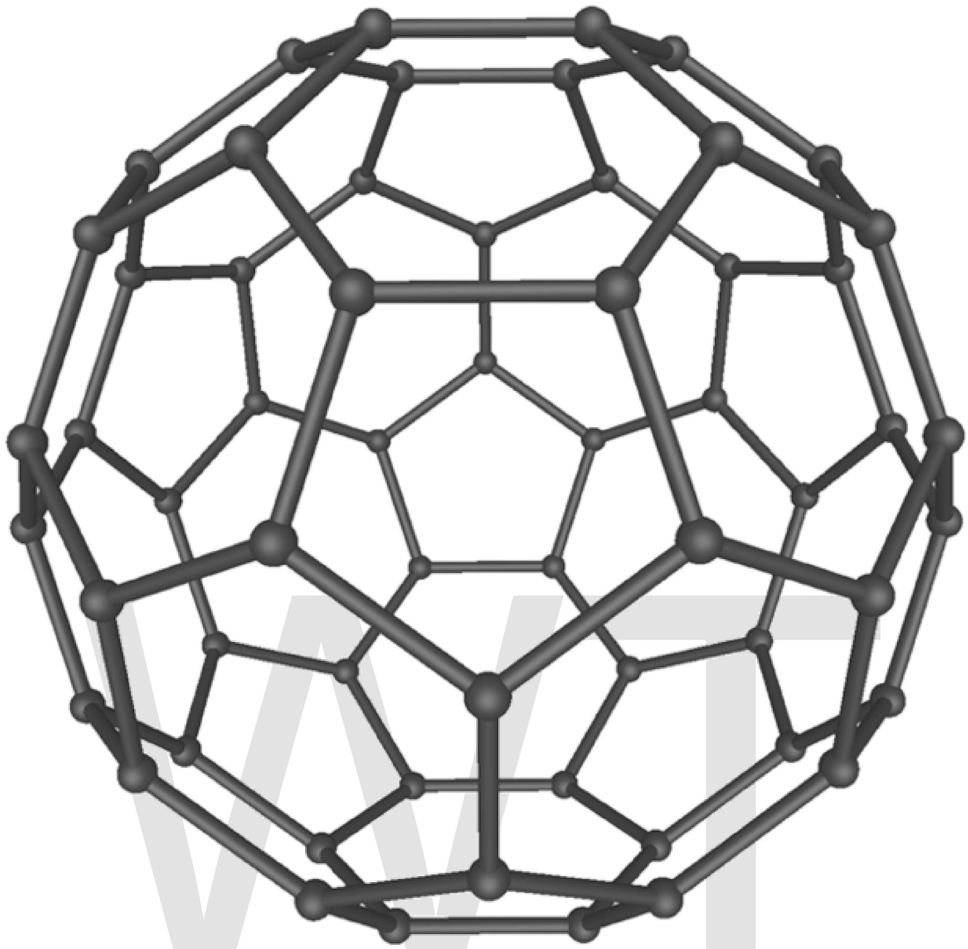
Nanotechnology

Nanotechnology (sometimes shortened to "**nanotech**") is the study of manipulating matter on an atomic and molecular scale. Generally, nanotechnology deals with structures sized between 1 to 100 nanometer in at least one dimension, and involves developing materials or devices within that size. Quantum mechanical effects are very important at this scale, which is in the quantum realm.

Nanotechnology is very diverse, ranging from extensions of conventional device physics to completely new approaches based upon molecular self-assembly, from developing new materials with dimensions on the nanoscale to investigating whether we can directly control matter on the atomic scale.

There is much debate on the future implications of nanotechnology. Nanotechnology may be able to create many new materials and devices with a vast range of applications, such as in medicine, electronics, biomaterials and energy production. On the other hand, nanotechnology raises many of the same issues as any new technology, including concerns about the toxicity and environmental impact of nanomaterials, and their potential effects on global economics, as well as speculation about various doomsday scenarios. These concerns have led to a debate among advocacy groups and governments on whether special regulation of nanotechnology is warranted.

Origins



Buckminsterfullerene C_{60}, also known as the buckyball, is a representative member of the carbon structures known as fullerenes. Members of the fullerene family are a major subject of research falling under the nanotechnology umbrella.

The first use of the concepts found in 'nano-technology' (but pre-dating use of that name) was in "There's Plenty of Room at the Bottom", a talk given by physicist Richard Feynman at an American Physical Society meeting at California Institute of Technology (Caltech) on December 29, 1959. Feynman described a process by which the ability to manipulate individual atoms and molecules might be developed, using one set of precise tools to build and operate another proportionally smaller set, and so on down to the needed scale. In the course of this, he noted, scaling issues would arise from the changing magnitude of various physical phenomena: gravity would become less important, surface tension and van der Waals attraction would become increasingly more significant, etc. This basic idea appeared plausible, and exponential assembly enhances it with parallelism to produce a useful quantity of end products. The term "nanotechnology" was defined by Tokyo University of Science Professor Norio Taniguchi in a 1974 paper as follows: "'Nano-technology' mainly consists of the processing of, separation, consolidation, and deformation of materials by one atom or by one molecule." In the 1980s the basic idea of this definition was explored in much more depth by Dr. K. Eric Drexler, who promoted the technological significance of nano-scale phenomena and devices through speeches and the books *Engines of Creation: The Coming Era of Nanotechnology* (1986) and *Nanosystems: Molecular Machinery, Manufacturing, and Computation*, and so the term acquired its current sense. *Engines of Creation* is considered the first book on the topic of nanotechnology. Nanotechnology and nanoscience got started in the early 1980s with two major developments; the birth of cluster science and the invention of the scanning tunneling microscope (STM). This development led to the discovery of fullerenes in 1985 and carbon nanotubes a few years later. In another development, the synthesis and properties of semiconductor nanocrystals was studied; this led to a fast increasing number of metal and metal oxide nanoparticles and quantum dots. The atomic force microscope (AFM or SFM) was invented six years after the STM was invented. In 2000, the United States National Nanotechnology Initiative was founded to coordinate Federal nanotechnology research and development and is evaluated by the President's Council of Advisors on Science and Technology.

Fundamental concepts

One nanometer (nm) is one billionth, or 10^{-9}, of a meter. By comparison, typical carbon-carbon bond lengths, or the spacing between these atoms in a molecule, are in the range 0.12–0.15 nm, and a DNA double-helix has a diameter around 2 nm. On the other hand, the smallest cellular life-forms, the bacteria of the genus Mycoplasma, are around 200 nm in length. By convention, nanotechnology is taken as the scale range 1 to 100 nm following the definition used by the National Nanotechnology Initiative in the US. The lower limit is set by the size of atoms (hydrogen has the smallest atoms, which are approximately a quarter of a nm diameter) since nanotechnology must build its devices from atoms and molecules. The upper limit is more or less arbitrary but is around the size that phenomena not observed in larger structures start to become apparent and can be made use of in the nano device. These new phenomena make nanotechnology distinct from devices which are merely miniaturised versions of an equivalent macroscopic device; such devices are on a larger scale and come under the description of microtechnology.

To put that scale in another context, the comparative size of a nanometer to a meter is the same as that of a marble to the size of the earth. Or another way of putting it: a nanometer is the amount an average man's beard grows in the time it takes him to raise the razor to his face.

Two main approaches are used in nanotechnology. In the "bottom-up" approach, materials and devices are built from molecular components which assemble themselves chemically by principles of molecular recognition. In the "top-down" approach, nano-objects are constructed from larger entities without atomic-level control.

Areas of physics such as nanoelectronics, nanomechanics, nanophotonics and nanoionics have evolved during the last few decades to provide a basic scientific foundation of nanotechnology.

Larger to smaller: a materials perspective

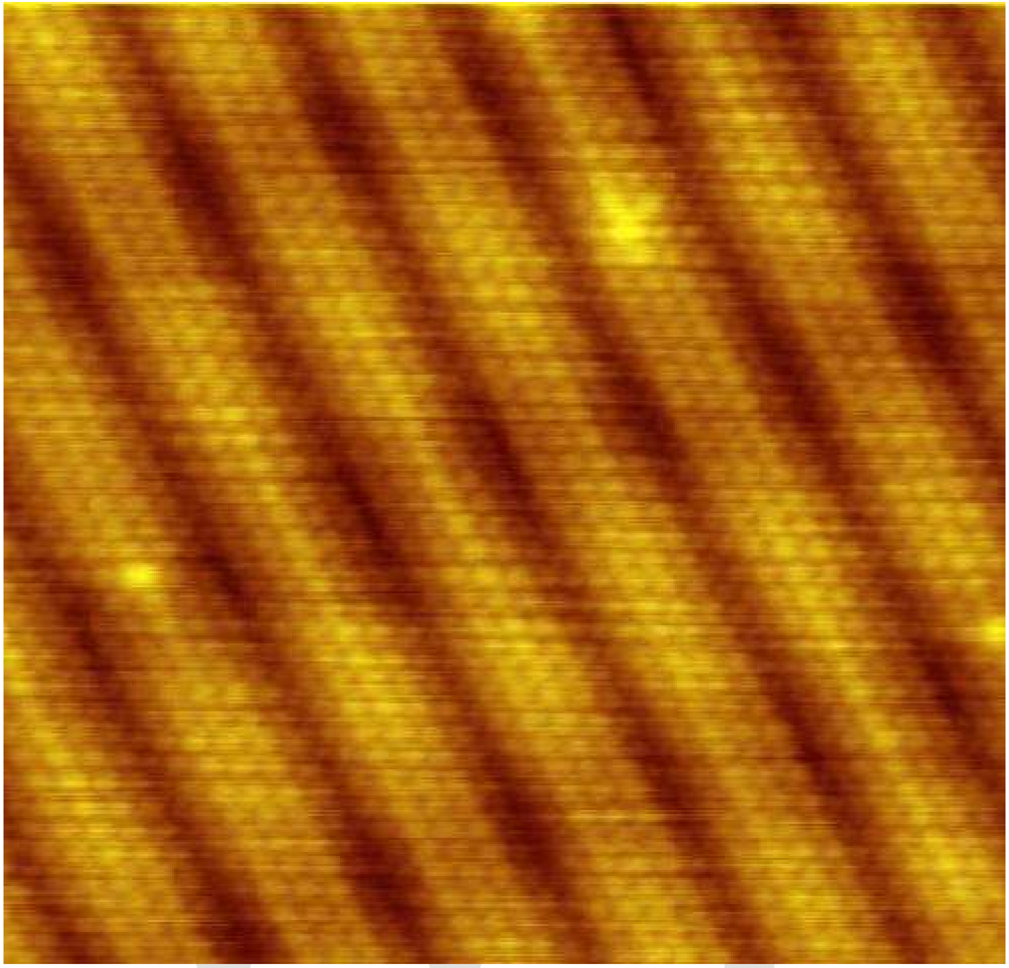


Image of reconstruction on a clean Gold(100) surface, as visualized using scanning tunneling microscopy. The positions of the individual atoms composing the surface are visible.

A number of physical phenomena become pronounced as the size of the system decreases. These include statistical mechanical effects, as well as quantum mechanical effects, for example the “quantum size effect” where the electronic properties of solids are altered with great reductions in particle size. This effect does not come into play by going from macro to micro dimensions. However, quantum effects become dominant when the nanometer size range is reached, typically at distances of 100 nanometers or less, the so called quantum realm. Additionally, a number of physical (mechanical, electrical, optical, etc.) properties change when compared to macroscopic systems. One example is the increase in surface area to volume ratio altering mechanical, thermal and catalytic properties of materials. Diffusion and reactions at nanoscale, nanostructures materials and nanodevices with fast ion transport are generally referred to nanoionics. *Mechanical* properties of nanosystems are of interest in the nanomechanics research. The catalytic activity of nanomaterials also opens potential risks in their interaction with biomaterials.

Materials reduced to the nanoscale can show different properties compared to what they exhibit on a macroscale, enabling unique applications. For instance, opaque substances become transparent (copper); stable materials turn combustible (aluminum); insoluble materials become soluble (gold). A material such as gold, which is chemically inert at normal scales, can serve as a potent chemical catalyst at nanoscales. Much of the fascination with nanotechnology stems from these quantum and surface phenomena that matter exhibits at the nanoscale.

Simple to complex: a molecular perspective

Modern synthetic chemistry has reached the point where it is possible to prepare small molecules to almost any structure. These methods are used today to manufacture a wide variety of useful chemicals such as pharmaceuticals or commercial polymers. This ability raises the question of extending this kind of control to the next-larger level, seeking methods to assemble these single molecules into supramolecular assemblies consisting of many molecules arranged in a well defined manner.

These approaches utilize the concepts of molecular self-assembly and/or supramolecular chemistry to automatically arrange themselves into some useful conformation through a bottom-up approach. The concept of molecular recognition is especially important: molecules can be designed so that a specific configuration or arrangement is favored due to non-covalent intermolecular forces. The Watson–Crick basepairing rules are a direct result of this, as is the specificity of an enzyme being targeted to a single substrate, or the specific folding of the protein itself. Thus, two or more components can be designed to be complementary and mutually attractive so that they make a more complex and useful whole.

Such bottom-up approaches should be capable of producing devices in parallel and be much cheaper than top-down methods, but could potentially be overwhelmed as the size and complexity of the desired assembly increases. Most useful structures require complex and thermodynamically unlikely arrangements of atoms. Nevertheless, there are many examples of self-assembly based on molecular recognition in biology, most notably Watson–Crick basepairing and enzyme-substrate interactions. The challenge for nanotechnology is whether these principles can be used to engineer new constructs in addition to natural ones.

Molecular nanotechnology: a long-term view

Molecular nanotechnology, sometimes called molecular manufacturing, describes engineered nanosystems (nanoscale machines) operating on the molecular scale. Molecular nanotechnology is especially associated with the molecular assembler, a machine that can produce a desired structure or device atom-by-atom using the principles of mechanosynthesis. Manufacturing in the context of productive nanosystems is not related to, and should be clearly distinguished from, the conventional technologies used to manufacture nanomaterials such as carbon nanotubes and nanoparticles.

When the term "nanotechnology" was independently coined and popularized by Eric Drexler (who at the time was unaware of an earlier usage by Norio Taniguchi) it referred to a future manufacturing technology based on molecular machine systems. The premise was that molecular scale biological analogies of traditional machine components demonstrated molecular machines were possible: by the countless examples found in biology, it is known that sophisticated, stochastically optimised biological machines can be produced.

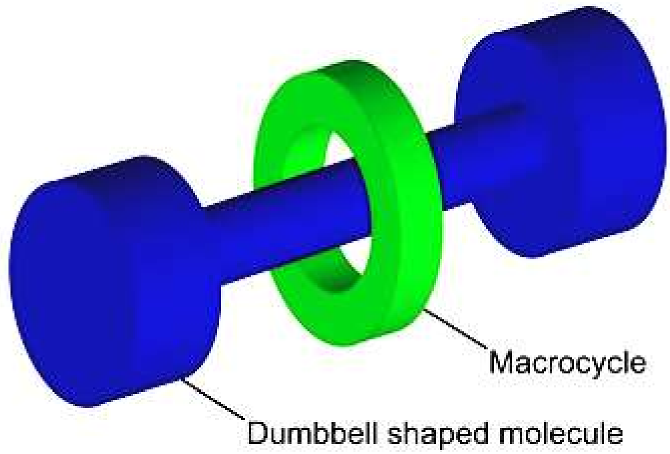
It is hoped that developments in nanotechnology will make possible their construction by some other means, perhaps using biomimetic principles. However, Drexler and other researchers have proposed that advanced nanotechnology, although perhaps initially implemented by biomimetic means, ultimately could be based on mechanical engineering principles, namely, a manufacturing technology based on the mechanical functionality of these components (such as gears, bearings, motors, and structural members) that would enable programmable, positional assembly to atomic specification. The physics and engineering performance of exemplar designs were analyzed in Drexler's book *Nanosystems*.

In general it is very difficult to assemble devices on the atomic scale, as all one has to position atoms on other atoms of comparable size and stickiness. Another view, put forth by Carlo Montemagno, is that future nanosystems will be hybrids of silicon technology and biological molecular machines. Yet another view, put forward by the late Richard Smalley, is that mechanosynthesis is impossible due to the difficulties in mechanically manipulating individual molecules.

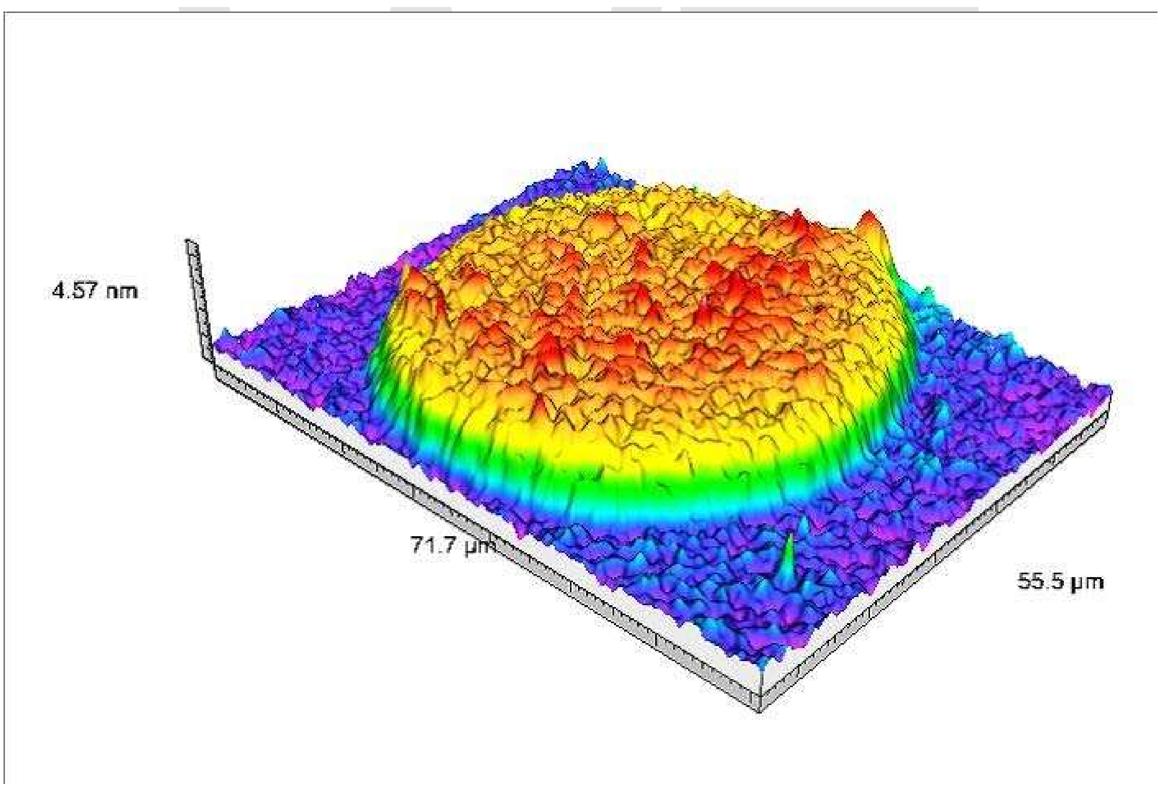
This led to an exchange of letters in the ACS publication Chemical & Engineering News in 2003. Though biology clearly demonstrates that molecular machine systems are possible, non-biological molecular machines are today only in their infancy. Leaders in research on non-biological molecular machines are Dr. Alex Zettl and his colleagues at Lawrence Berkeley Laboratories and UC Berkeley. They have constructed at least three distinct molecular devices whose motion is controlled from the desktop with changing voltage: a nanotube nanomotor, a molecular actuator, and a nanoelectromechanical relaxation oscillator.

An experiment indicating that positional molecular assembly is possible was performed by Ho and Lee at Cornell University in 1999. They used a scanning tunneling microscope to move an individual carbon monoxide molecule (CO) to an individual iron atom (Fe) sitting on a flat silver crystal, and chemically bound the CO to the Fe by applying a voltage.

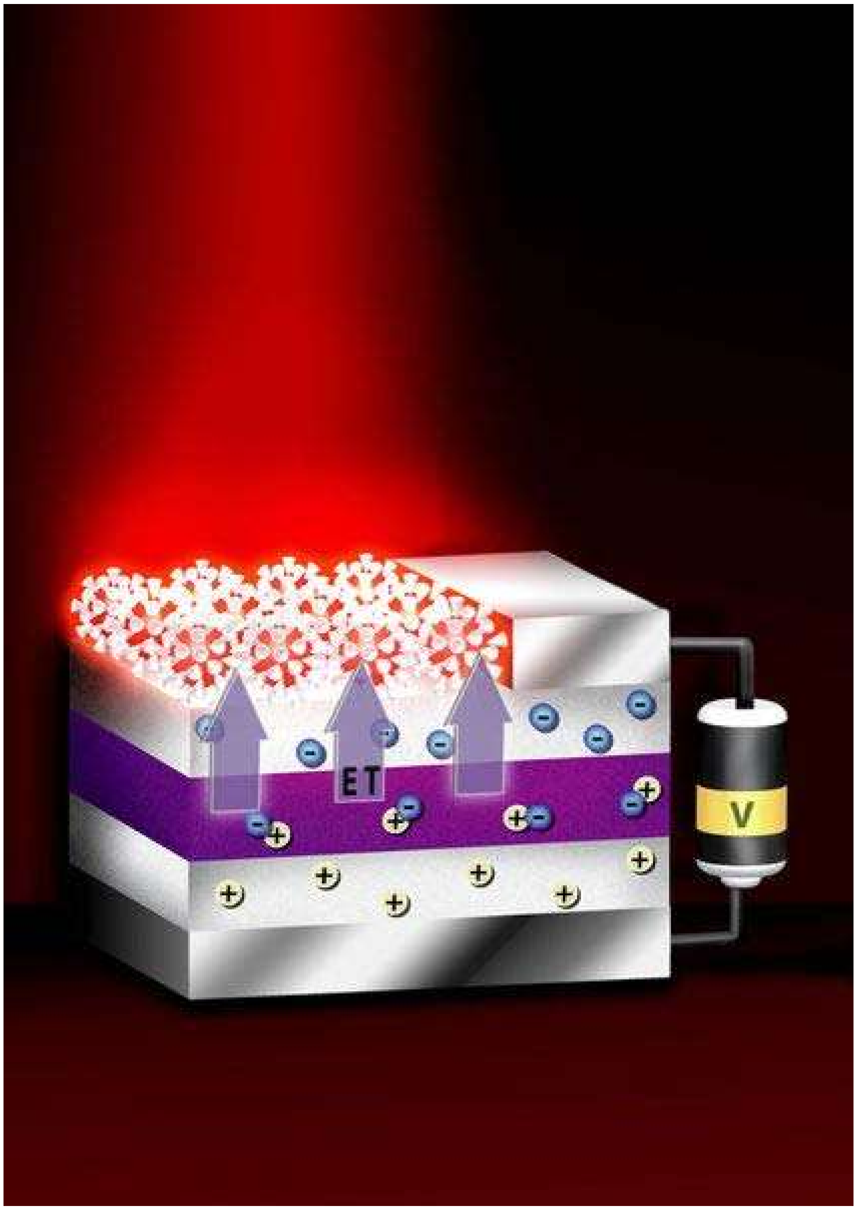
Current research



Graphical representation of a rotaxane, useful as a molecular switch



Sarfus image of a DNA biochip elaborated by bottom-up approach



This device transfers energy from nano-thin layers of quantum wells to nanocrystals above them, causing the nanocrystals to emit visible light.

Nanomaterials

The nanomaterials field includes subfields which develop or study materials having unique properties arising from their nanoscale dimensions.

- Interface and colloid science has given rise to many materials which may be useful in nanotechnology, such as carbon nanotubes and other fullerenes, and various nanoparticles and nanorods. Nanomaterials with fast ion transport are related also to nanoionics and nanoelectronics.

- Nanoscale materials can also be used for bulk applications; most present commercial applications of nanotechnology are of this flavor.
- Progress has been made in using these materials for medical applications.
- Nanoscale materials are sometimes used in solar cells which combats the cost of traditional Silicon solar cells
- Development of applications incorporating semiconductor nanoparticles to be used in the next generation of products, such as display technology, lighting, solar cells and biological imaging.

Bottom-up approaches

These seek to arrange smaller components into more complex assemblies.

- DNA nanotechnology utilizes the specificity of Watson–Crick basepairing to construct well-defined structures out of DNA and other nucleic acids.
- Approaches from the field of "classical" chemical synthesis also aim at designing molecules with well-defined shape (e.g. bis-peptides).
- More generally, molecular self-assembly seeks to use concepts of supramolecular chemistry, and molecular recognition in particular, to cause single-molecule components to automatically arrange themselves into some useful conformation.
- Atomic force microscope tips can be used as a nanoscale "write head" to deposit a chemical upon a surface in a desired pattern in a process called dip pen nanolithography. This technique fits into the larger subfield of nanolithography.

Top-down approaches

These seek to create smaller devices by using larger ones to direct their assembly.

- Many technologies that descended from conventional solid-state silicon methods for fabricating microprocessors are now capable of creating features smaller than 100 nm, falling under the definition of nanotechnology. Giant magnetoresistance-based hard drives already on the market fit this description, as do atomic layer deposition (ALD) techniques. Peter Grünberg and Albert Fert received the Nobel Prize in Physics in 2007 for their discovery of Giant magnetoresistance and contributions to the field of spintronics.
- Solid-state techniques can also be used to create devices known as nanoelectromechanical systems or NEMS, which are related to microelectromechanical systems or MEMS.
- Focused ion beams can directly remove material, or even deposit material when suitable pre-cursor gasses are applied at the same time. For example, this technique is used routinely to create sub-100 nm sections of material for analysis in Transmission electron microscopy.
- Atomic force microscope tips can be used as a nanoscale "write head" to deposit a resist, which is then followed by a etching process to remove material in a top-down method.

Functional approaches

These seek to develop components of a desired functionality without regard to how they might be assembled.

- Molecular electronics seeks to develop molecules with useful electronic properties. These could then be used as single-molecule components in a nanoelectronic device.
- Synthetic chemical methods can also be used to create synthetic molecular motors, such as in a so-called nanocar.

Biomimetic approaches

- Bionics or biomimicry seeks to apply biological methods and systems found in nature, to the study and design of engineering systems and modern technology. Biomineralization is one example of the systems studied.

- Bionanotechnology the use of biomolecules for applications in nanotechnology, including use of viruses.

Speculative

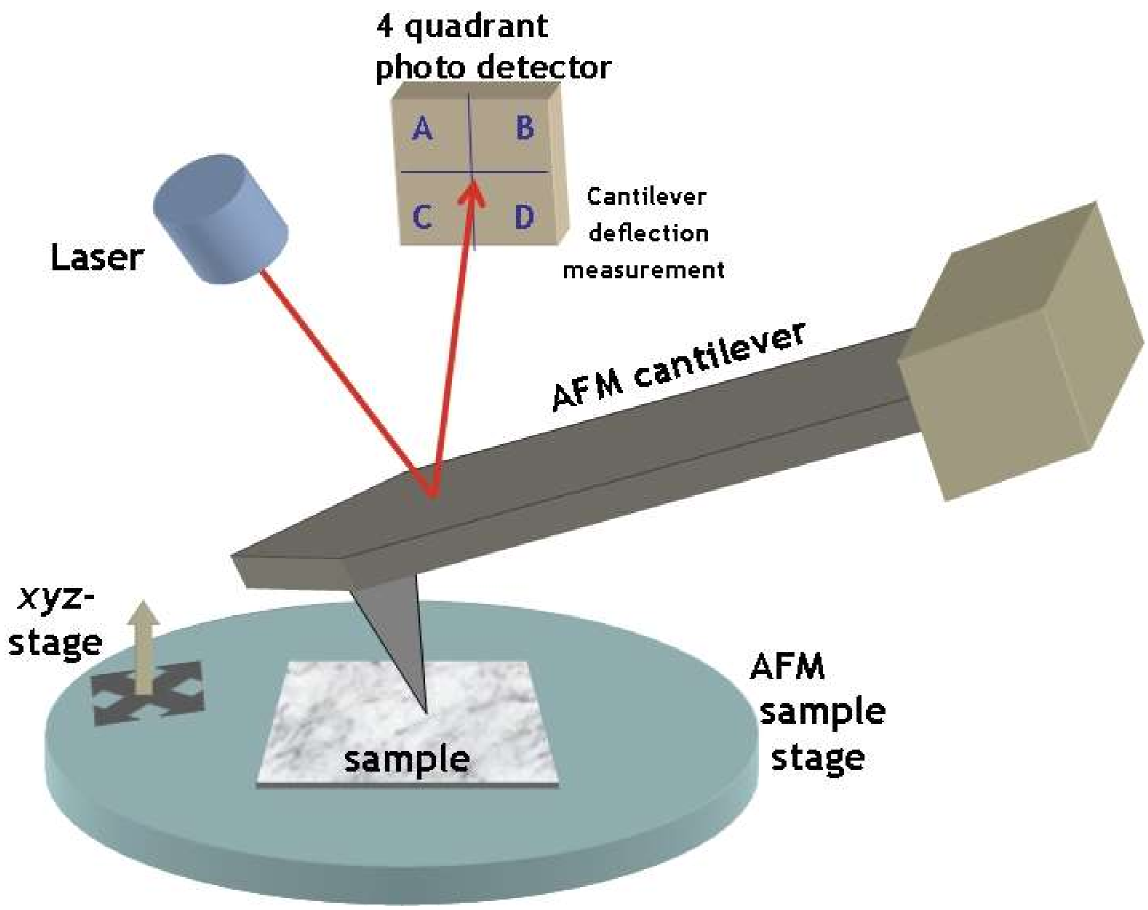
These subfields seek to anticipate what inventions nanotechnology might yield, or attempt to propose an agenda along which inquiry might progress. These often take a big-picture view of nanotechnology, with more emphasis on its societal implications than the details of how such inventions could actually be created.

- Molecular nanotechnology is a proposed approach which involves manipulating single molecules in finely controlled, deterministic ways. This is more theoretical than the other subfields and is beyond current capabilities.
- Nanorobotics centers on self-sufficient machines of some functionality operating at the nanoscale. There are hopes for applying nanorobots in medicine, but it may not be easy to do such a thing because of several drawbacks of such devices. Nevertheless, progress on innovative materials and methodologies has been demonstrated with some patents granted about new nanomanufacturing devices for future commercial applications, which also progressively helps in the development towards nanorobots with the use of embedded nanobioelectronics concepts.
- Productive nanosystems are "systems of nanosystems" which will be complex nanosystems that produce atomically precise parts for other nanosystems, not necessarily using novel nanoscale-emergent properties, but well-understood fundamentals of manufacturing. Because of the discrete (i.e. atomic) nature of matter and the possibility of exponential growth, this stage is seen as the basis of another industrial revolution. Mihail Roco, one of the architects of the USA's

National Nanotechnology Initiative, has proposed four states of nanotechnology that seem to parallel the technical progress of the Industrial Revolution, progressing from passive nanostructures to active nanodevices to complex nanomachines and ultimately to productive nanosystems.

- Programmable matter seeks to design materials whose properties can be easily, reversibly and externally controlled though a fusion of information science and materials science.
- Due to the popularity and media exposure of the term nanotechnology, the words picotechnology and femtotechnology have been coined in analogy to it, although these are only used rarely and informally.

Tools and techniques



Typical AFM setup. A microfabricated cantilever with a sharp tip is deflected by features on a sample surface, much like in a phonograph but on a much smaller scale. A laser beam reflects off the backside of the cantilever into a set of photodetectors, allowing the deflection to be measured and assembled into an image of the surface.

There are several important modern developments. The atomic force microscope (AFM) and the Scanning Tunneling Microscope (STM) are two early versions of scanning probes that launched nanotechnology. There are other types of scanning probe microscopy, all flowing from the ideas of the scanning confocal microscope developed by Marvin Minsky in 1961 and the scanning acoustic microscope (SAM) developed by Calvin Quate and coworkers in the 1970s, that made it possible to see structures at the nanoscale. The tip of a scanning probe can also be used to manipulate nanostructures (a process called positional assembly). Feature-oriented scanning-positioning methodology suggested by Rostislav Lapshin appears to be a promising way to implement these nanomanipulations in automatic mode. However, this is still a slow process because of low scanning velocity of the microscope. Various techniques of nanolithography such as optical lithography, X-ray lithography dip pen nanolithography, electron beam lithography or nanoimprint lithography were also developed. Lithography is a top-down fabrication technique where a bulk material is reduced in size to nanoscale pattern.

Another group of nanotechnological techniques include those used for fabrication of nanowires, those used in semiconductor fabrication such as deep ultraviolet lithography, electron beam lithography, focused ion beam machining, nanoimprint lithography, atomic layer deposition, and molecular vapor deposition, and further including molecular self-assembly techniques such as those employing di-block copolymers. However, all of these techniques preceded the nanotech era, and are extensions in the development of scientific advancements rather than techniques which were devised with the sole purpose of creating nanotechnology and which were results of nanotechnology research.

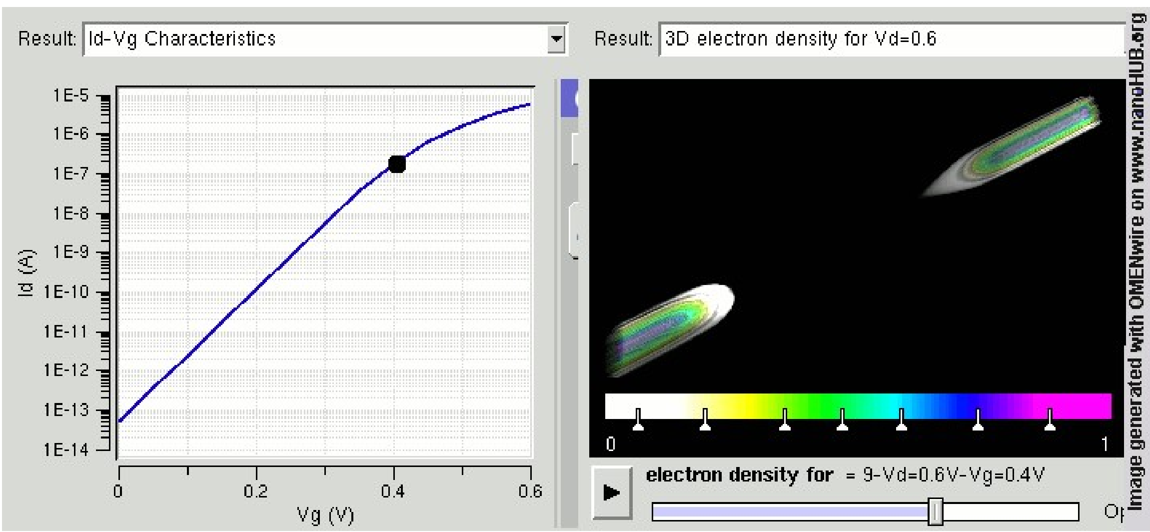
The top-down approach anticipates nanodevices that must be built piece by piece in stages, much as manufactured items are made. Scanning probe microscopy is an important technique both for characterization and synthesis of nanomaterials. Atomic force microscopes and scanning tunneling microscopes can be used to look at surfaces and to move atoms around. By designing different tips for these microscopes, they can be used for carving out structures on surfaces and to help guide self-assembling structures. By using, for example, feature-oriented scanning-positioning approach, atoms can be moved around on a surface with scanning probe microscopy techniques. At present, it is expensive and time-consuming for mass production but very suitable for laboratory experimentation.

In contrast, bottom-up techniques build or grow larger structures atom by atom or molecule by molecule. These techniques include chemical synthesis, self-assembly and positional assembly. Dual polarisation interferometry is one tool suitable for characterisation of self assembled thin films. Another variation of the bottom-up approach is molecular beam epitaxy or MBE. Researchers at Bell Telephone Laboratories like John R. Arthur. Alfred Y. Cho, and Art C. Gossard developed and implemented MBE as a research tool in the late 1960s and 1970s. Samples made by MBE were key to the discovery of the fractional quantum Hall effect for which the 1998 Nobel Prize in Physics was awarded. MBE allows scientists to lay down atomically precise layers of atoms and, in the process, build up complex structures. Important for research on semiconductors, MBE is also widely used to make samples and devices for the newly emerging field of spintronics.

However, new therapeutic products, based on responsive nanomaterials, such as the ultradeformable, stress-sensitive Transfersome vesicles, are under development and already approved for human use in some countries.

Applications

As of August 21, 2008, the Project on Emerging Nanotechnologies estimates that over 800 manufacturer-identified nanotech products are publicly available, with new ones hitting the market at a pace of 3–4 per week. The project lists all of the products in a publicly accessible online. Most applications are limited to the use of "first generation" passive nanomaterials which includes titanium dioxide in sunscreen, cosmetics and some food products; Carbon allotropes used to produce gecko tape; silver in food packaging, clothing, disinfectants and household appliances; zinc oxide in sunscreens and cosmetics, surface coatings, paints and outdoor furniture varnishes; and cerium oxide as a fuel catalyst.



One of the major applications of nanotechnology is in the area of nanoelectronics with MOSFET's being made of small nanowires ~10 nm in length. Here is a simulation of such a nanowire.

The National Science Foundation (a major distributor for nanotechnology research in the United States) funded researcher David Berube to study the field of nanotechnology. His findings are published in the monograph Nano-Hype: The Truth Behind the Nanotechnology Buzz. This study concludes that much of what is sold as “nanotechnology” is in fact a recasting of straightforward materials science, which is leading to a “nanotech industry built solely on selling nanotubes, nanowires, and the like” which will “end up with a few suppliers selling low margin products in huge volumes." Further applications which require actual manipulation or arrangement of nanoscale components await further research. Though technologies branded with the term 'nano' are sometimes little related to and fall far short of the most ambitious and transformative technological goals of the sort in molecular manufacturing proposals, the term still connotes such ideas. According to Berube, there may be a danger that a "nano bubble" will form, or is forming already, from the use of the term by scientists and entrepreneurs to garner funding, regardless of interest in the transformative possibilities of more ambitious and far-sighted work.

Implications

Because of the far-ranging claims that have been made about potential applications of nanotechnology, a number of serious concerns have been raised about what effects these will have on our society if realized, and what action if any is appropriate to mitigate these risks.

There are possible dangers that arise with the development of nanotechnology. The Center for Responsible Nanotechnology suggests that new developments could result, among other things, in untraceable weapons of mass destruction, networked cameras for use by the government, and weapons developments fast enough to destabilize arms races ("Nanotechnology Basics").

One area of concern is the effect that industrial-scale manufacturing and use of nanomaterials would have on human health and the environment, as suggested by nanotoxicology research. Groups such as the Center for Responsible Nanotechnology have advocated that nanotechnology should be specially regulated by governments for these reasons. Others counter that overregulation would stifle scientific research and the development of innovations which could greatly benefit mankind.

Other experts, including director of the Woodrow Wilson Center's Project on Emerging Nanotechnologies David Rejeski, have testified that successful commercialization depends on adequate oversight, risk research strategy, and public engagement. Berkeley, California is currently the only city in the United States to regulate nanotechnology; Cambridge, Massachusetts in 2008 considered enacting a similar law, but ultimately rejected this.

Health and environmental concerns

Some of the recently developed nanoparticle products may have unintended consequences. Researchers have discovered that silver nanoparticles used in socks only to reduce foot odor are being released in the wash with possible negative consequences. Silver nanoparticles, which are bacteriostatic, may then destroy beneficial bacteria which are important for breaking down organic matter in waste treatment plants or farms.

A study at the University of Rochester found that when rats breathed in nanoparticles, the particles settled in the brain and lungs, which led to significant increases in biomarkers for inflammation and stress response. A study in China indicated that nanoparticles induce skin aging through oxidative stress in hairless mice.

A two-year study at UCLA's School of Public Health found lab mice consuming nano-titanium dioxide showed DNA and chromosome damage to a degree "linked to all the big killers of man, namely cancer, heart disease, neurological disease and aging".

A major study published more recently in Nature Nanotechnology suggests some forms of carbon nanotubes – a poster child for the "nanotechnology revolution" – could be as harmful as asbestos if inhaled in sufficient quantities. Anthony Seaton of the Institute of Occupational Medicine in Edinburgh, Scotland, who contributed to the article on carbon nanotubes said "We know that some of them probably have the potential to cause mesothelioma. So those sorts of materials need to be handled very carefully." In the absence of specific nano-regulation forthcoming from governments, Paull and Lyons (2008) have called for an exclusion of engineered nanoparticles from organic food. A newspaper article reports that workers in a paint factory developed serious lung disease and nanoparticles were found in their lungs.

Regulation

Calls for tighter regulation of nanotechnology have occurred alongside a growing debate related to the human health and safety risks associated with nanotechnology. Furthermore, there is significant debate about who is responsible for the regulation of nanotechnology. While some non-nanotechnology specific regulatory agencies currently cover some products and processes (to varying degrees) – by "bolting on" nanotechnology to existing regulations – there are clear gaps in these regimes. In "Nanotechnology Oversight: An Agenda for the Next Administration," former EPA deputy administrator J. Clarence (Terry) Davies lays out a clear regulatory roadmap for the next presidential administration and describes the immediate and longer term steps necessary to deal with the current shortcomings of nanotechnology oversight.

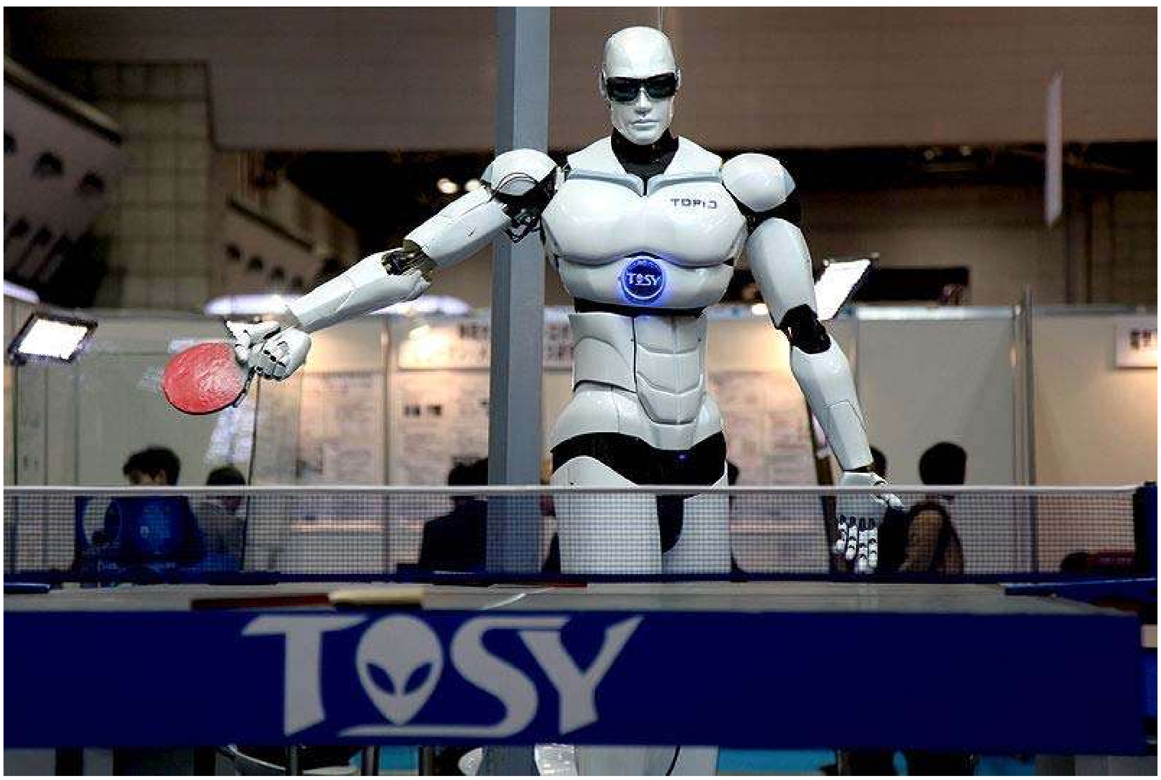
Stakeholders concerned by the lack of a regulatory framework to assess and control risks associated with the release of nanoparticles and nanotubes have drawn parallels with bovine spongiform encephalopathy ('mad cow's disease), thalidomide, genetically modified food, nuclear energy, reproductive technologies, biotechnology, and asbestosis. Dr. Andrew Maynard, chief science advisor to the Woodrow Wilson Center's Project on Emerging Nanotechnologies, concludes (among others) that there is insufficient funding for human health and safety research, and as a result there is currently limited understanding of the human health and safety risks associated with nanotechnology. As a result, some academics have called for stricter application of the precautionary principle, with delayed marketing approval, enhanced labelling and additional safety data development requirements in relation to certain forms of nanotechnology.

The Royal Society report identified a risk of nanoparticles or nanotubes being released during disposal, destruction and recycling, and recommended that "manufacturers of products that fall under extended producer responsibility regimes such as end-of-life regulations publish procedures outlining how these materials will be managed to minimize possible human and environmental exposure" (p.xiii). Reflecting the challenges for ensuring responsible life cycle regulation, the Institute for Food and Agricultural

Standards has proposed standards for nanotechnology research and development should be integrated across consumer, worker and environmental standards. They also propose that NGOs and other citizen groups play a meaningful role in the development of these standards.

Chapter- 5

Robotics



TOPIO, a humanoid robot, played ping pong at Tokyo International Robot Exhibition (IREX) 2009.

The Shadow robot hand system

A Pick and Place robot in a factory

Robotics is a branch of science and engineering dealing with the study of robots. It is involved with a robot's design, manufacture, application, and structural disposition. Robotics is related to electronics, mechanics, and software. The word "robot" was introduced to the public by Czech writer Karel Čapek in his play R.U.R. (Rossum's Universal Robots), published in 1920. The term "robotics" was coined by Isaac Asimov in his 1941 science fiction short-story "Liar!"

History

Stories of artificial helpers and companions and attempts to create them have a long history.

In 1921, Czech writer Karel Čapek introduced the word "robot" in his play *R.U.R. (Rossum's Universal Robots)*. The word "robot" comes from the word "robota", meaning, in Czech, "forced labour, drudgery".

In 1927, the Maschinenmensch ("machine-human"), a gynoid humanoid robot, also called "Parody", "Futura", "Robotrix", or the "Maria impersonator" (played by German actress Brigitte Helm), the first and perhaps the most memorable depiction of a robot ever to appear on film, was depicted in Fritz Lang's film Metropolis.

In 1942, the science fiction writer Isaac Asimov formulated his Three Laws of Robotics, and in the process of doing so, coined the word "robotics".

In 1948, Norbert Wiener formulated the principles of cybernetics, the basis of practical robotics.

Fully autonomous robots only appeared in the second half of the 20th century. The first digitally operated and programmable robot, the Unimate, was installed in 1961 to lift hot pieces of metal from a die casting machine and stack them. Today, commercial and industrial robots are in widespread use performing jobs more cheaply or more accurately and reliably than humans. They are also employed in jobs which are too dirty, dangerous, or dull to be suitable for humans. Robots are widely used in manufacturing, assembly, and packing; transport; earth and space exploration; surgery; weaponry; laboratory research; safety; and mass production of consumer and industrial goods.

Date	Significance	Robot Name	Inventor
First century A.D. and earlier	Descriptions of more than 100 machines and automata, including a fire engine, a wind organ, a coin-operated machine, and a steam-powered engine, in *Pneumatica* and *Automata* by Heron of Alexandria		Ctesibius, Philo of Byzantium, Heron of Alexandria, and others
1206	Created early humanoid automata, programmable automaton band	Robot band, hand-washing automaton, automated moving peacocks	Al-Jazari
1495	Designs for a humanoid robot	Mechanical knight	Leonardo da Vinci
1738	Mechanical duck that was able to eat, flap its wings, and excrete	Digesting Duck	Jacques de Vaucanson
1837	The novel *Spinoza* introduced a humanoid automaton activated by inscribing Hebrew letters on its forehead based on Jewish folklore	The Golem of Prague	Berthold Auerbach
1898	Nikola Tesla demonstrates first radio-controlled vessel.	Teleautomaton	Nikola Tesla
1921	First fictional automatons called "robots" appear in the play *R.U.R.*	Rossum's Universal Robots	Karel Čapek
1930s	Humanoid robot exhibited at the 1939 and 1940 World's Fairs	Elektro	Westinghouse Electric Corporation
1948	Simple robots exhibiting biological behaviors	Elsie and Elmer	William Grey Walter
1956	First commercial robot, from the Unimation company founded by George Devol and Joseph Engelberger, based on Devol's patents	Unimate	George Devol
1961	First installed industrial robot.	Unimate	George Devol

1963	First palletizing robot	Palletizer	Fuji Yusoki Kogyo
1973	First industrial robot with six electromechanically driven axes	Famulus	KUKA Robot Group
1975	Programmable universal manipulation arm, a Unimation product	PUMA	Victor Scheinman

Etymology

According to the *Oxford English Dictionary*, the word *robotics* was first used in print by Isaac Asimov, in his science fiction short story "Liar!", published in May 1941 in *Astounding Science Fiction*. Asimov was unaware that he was coining the term; since the science and technology of electrical devices is *electronics*, he assumed *robotics* already referred to the science and technology of robots. However, in some of Asimov's other works, he states that the first use of the word *robotics* was in his short story *Runaround* (Astounding Science Fiction, March 1942). The word *robotics* was derived from the word *robot*, which was introduced to the public by Czech writer Karel Čapek in his play *R.U.R. (Rossum's Universal Robots)*, which premiered in 1921.

Components

Structure

The structure of a robot is usually mostly mechanical and can be called a kinematic chain (its functionality being similar to the skeleton of the human body). The chain is formed of links (its bones), actuators (its muscles), and joints which can allow one or more degrees of freedom. Most contemporary robots use open serial chains in which each link connects the one before to the one after it. These robots are called serial robots and often resemble the human arm. Some robots, such as the Stewart platform, use a closed parallel kinematical chain. Other structures, such as those that mimic the mechanical structure of humans, various animals, and insects, are comparatively rare. However, the development and use of such structures in robots is an active area of research (e.g. biomechanics). Robots used as manipulators have an end effector mounted on the last link. This end effector can be anything from a welding device to a mechanical hand used to manipulate the environment.

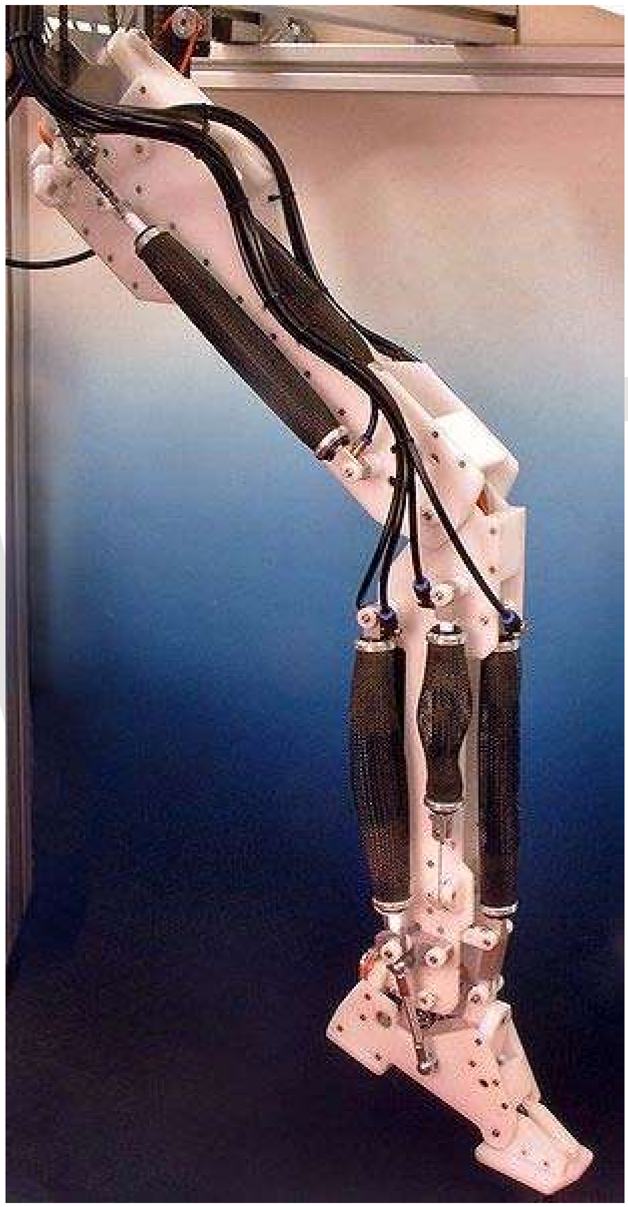
Power source

At present; mostly (lead-acid) batteries are used, but potential power sources could be:

- pneumatic (compressed gases)
- hydraulics (compressed liquids)
- flywheel energy storage
- organic garbage (through anaerobic digestion)

- faeces (human, animal); may be interesting in a military context as feces of small combat groups may be reused for the energy requirements of the robot assistant
- still untested energy sources (e.g. Nuclear Fusion reactors, ...)
- radioactive source (such as with the proposed Ford car of the '50s); to those proposed in movies such as *Red Planet*

Actuation



A robot leg powered by Air Muscles

Actuators are like the "muscles" of a robot, the parts which convert stored energy into movement. By far the most popular actuators are electric motors that spin a wheel or gear, and linear actuators that control industrial robots in factories. But there are some recent advances in alternative types of actuators, powered by electricity, chemicals, or compressed air:

- **Electric motors:** The vast majority of robots use electric motors, often brushed and brushless DC motors in portable robots or AC motors in industrial robots and CNC machines.
- **Linear Actuators:** Various types of linear actuators move in and out instead of by spinning, particularly when very large forces are needed such as with industrial robotics. They are typically powered by compressed air (pneumatic actuator) or an oil (hydraulic actuator).
- **Series Elastic Actuators:** A spring can be designed as part of the motor actuator, to allow improved force control. It has been used in various robots, particularly walking humanoid robots.
- **Air muscles:** (Also known as Pneumatic Artificial Muscles) are special tubes that contract (typically up to 40%) when air is forced inside it. They have been used for some robot applications.
- **Muscle wire:** (Also known as Shape Memory Alloy, Nitinol or Flexinol Wire) is a material that contracts slightly (typically under 5%) when electricity runs through it. They have been used for some small robot applications.
- **Electroactive Polymers:** (EAPs or EPAMs) are a new plastic material that can contract substantially (up to 400%) from electricity, and have been used in facial muscles and arms of humanoid robots, and to allow new robots to float, fly, swim or walk.
- **Piezo motor:** A recent alternative to DC motors are piezo motors or ultrasonic motors. These work on a fundamentally different principle, whereby tiny piezoceramic elements, vibrating many thousands of times per second, cause linear or rotary motion. There are different mechanisms of operation; one type uses the vibration of the piezo elements to walk the motor in a circle or a straight line. Another type uses the piezo elements to cause a nut to vibrate and drive a screw. The advantages of these motors are nanometer resolution, speed, and available force for their size. These motors are already available commercially, and being used on some robots.
- **Elastic nanotubes:** These are a promising, early-stage experimental technology. The absence of defects in nanotubes enables these filaments to deform elastically by several percent, with energy storage levels of perhaps 10 J/cm^3 for metal nanotubes. Human biceps could be replaced with an 8 mm diameter wire of this material. Such compact "muscle" might allow future robots to outrun and outjump humans.

Sensing

Touch

Current robotic and prosthetic hands receive far less tactile information than the human hand. Recent research has developed a tactile sensor array that mimics the mechanical properties and touch receptors of human fingertips. The sensor array is constructed as a rigid core surrounded by conductive fluid contained by an elastomeric skin. Electrodes are mounted on the surface of the rigid core and are connected to an impedance-measuring device within the core. When the artificial skin touches an object the fluid path around the electrodes is deformed, producing impedance changes that map the forces received from the object. The researchers expect that an important function of such artificial fingertips will be adjusting robotic grip on held objects.

In 2009, scientists from several European countries and Israel developed a prosthetic hand, called SmartHand, which functions like a real one, allowing patients to write with it, type on a keyboard, play piano and perform other fine movements. The prosthesis has sensors which enable the patient to sense real feeling in its fingertips.

Vision

Computer vision is the science and technology of machines that see. As a scientific discipline, computer vision is concerned with the theory behind artificial systems that extract information from images. The image data can take many forms, such as video sequences and views from cameras.

In most practical computer vision applications, the computers are pre-programmed to solve a particular task, but methods based on learning are now becoming increasingly common.

Computer vision systems rely on image sensors which detect electromagnetic radiation which is typically in the form of either visible light or infra-red light. The sensors are designed using solid-state physics. The process by which light propagates and reflects off surfaces is explained using optics. Sophisticated image sensors even require quantum mechanics to provide a complete understanding of the image formation process.

There is a subfield within computer vision where artificial systems are designed to mimic the processing and behavior of biological systems, at different levels of complexity. Also, some of the learning-based methods developed within computer vision have their background in biology.

Manipulation

Robots which must work in the real world require some way to manipulate objects; pick up, modify, destroy, or otherwise have an effect. Thus the 'hands' of a robot are often referred to as end effectors, while the arm is referred to as a manipulator. Most robot arms have replaceable effectors, each allowing them to perform some small range of tasks. Some have a fixed manipulator which cannot be replaced, while a few have one very general purpose manipulator, for example a humanoid hand.

- **Mechanical Grippers:** One of the most common effectors is the gripper. In its simplest manifestation it consists of just two fingers which can open and close to pick up and let go of a range of small objects. Fingers can for example be made of a chain with a metal wire run through it.

- **Vacuum Grippers:** Pick and place robots for electronic components and for large objects like car windscreens, will often use very simple vacuum grippers. These are very simple astrictive devices, but can hold very large loads provided the prehension surface is smooth enough to ensure suction.
- **General purpose effectors:** Some advanced robots are beginning to use fully humanoid hands, like the Shadow Hand, MANUS, and the Schunk hand. These highly dexterous manipulators, with as many as 20 degrees of freedom and hundreds of tactile sensors.

For the definitive guide to all forms of robot endeffectors, their design, and usage consult the book "Robot Grippers".

Locomotion

Rolling robots

Segway in the Robot museum in Nagoya

For simplicity, most mobile robots have four wheels. However, some researchers have tried to create more complex wheeled robots, with only one or two wheels. These can have certain advantages such as greater efficiency, reduced parts, and allow a robot to navigate in tight places that a four wheeled robot would not be able to.

- **Two-wheeled balancing:** Balancing robots generally use a gyroscope to detect how much a robot is falling and then drive the wheels proportionally in the opposite direction, to counter-balance the fall at hundreds of times per second, based on the dynamics of an inverted pendulum. Many different balancing robots have been designed. While the Segway is not commonly thought of as a robot, it can be thought of as a component of a robot, such as NASA's Robonaut that has been mounted on a Segway.
- **One-wheeled balancing:** A one-wheeled balancing robot is an extension of a two-wheeled balancing robot so that it can move in any 2D direction using a round ball as its only wheel. Several one-wheeled balancing robots have been designed recently, such as Carnegie Mellon University's "Ballbot" that is the approximate height and width of a person, and Tohoku Gakuin University's "BallIP". Because of the long, thin shape and ability to maneuver in tight spaces, they have the potential to function better than other robots in environments with people.
- **Spherical orb robots:** Several attempts have been made in robots that are completely inside a spherical ball, either by spinning a weight inside the ball, or by rotating the outer shells of the sphere. These have also been referred to as an orb bot or a ball bot
- **Six-wheeled robots:** Using six wheels instead of four wheels can give better traction or grip in outdoor terrain such as on rocky dirt or grass.
- **Tracked robots:** Tank tracks provide even more traction than a six-wheeled robot. Tracked wheels behave as if they were made of hundreds of wheels, therefore are very common for outdoor and military robots, where the robot must drive on very rough terrain. However, they are difficult to use indoors such as on carpets and smooth floors. Examples include NASA's Urban Robot "Urbie".

Walking robots

iCub robot, designed by the RobotCub Consortium

Walking is a difficult and dynamic problem to solve. Several robots have been made which can walk reliably on two legs, however none have yet been made which are as robust as a human. Many other robots have been built that walk on more than two legs, due to these robots being significantly easier to construct. Hybrids too have been proposed in movies such as I, Robot, where they walk on 2 legs and switch to 4 (arms+legs) when going to a sprint. Typically, robots on 2 legs can walk well on flat floors, and can occasionally walk up stairs. None can walk over rocky, uneven terrain. Some of the methods which have been tried are:

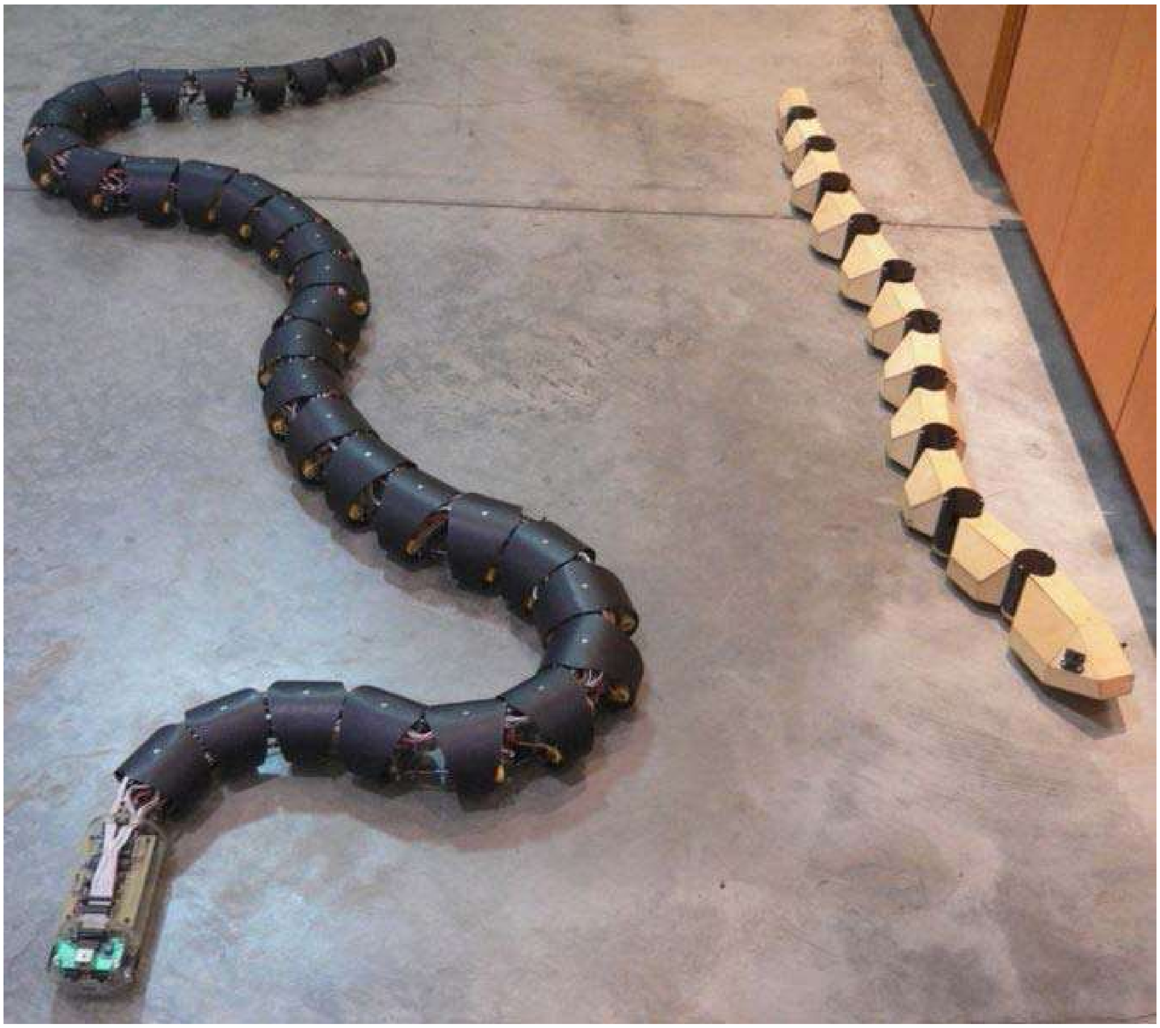
- **ZMP Technique:** The Zero Moment Point (ZMP) is the algorithm used by robots such as Honda's ASIMO. The robot's onboard computer tries to keep the total inertial forces (the combination of earth's gravity and the acceleration and deceleration of walking), exactly opposed by the floor reaction force (the force of the floor pushing back on the robot's foot). In this way, the two forces cancel out, leaving no moment (force causing the robot to rotate and fall over). However, this is not exactly how a human walks, and the difference is obvious to human observers, some of whom have pointed out that ASIMO walks as if it needs the lavatory. ASIMO's walking algorithm is not static, and some dynamic balancing is used (See below). However, it still requires a smooth surface to walk on.
- **Hopping:** Several robots, built in the 1980s by Marc Raibert at the MIT Leg Laboratory, successfully demonstrated very dynamic walking. Initially, a robot with only one leg, and a very small foot, could stay upright simply by hopping. The movement is the same as that of a person on a pogo stick. As the robot falls to one side, it would jump slightly in that direction, in order to catch itself. Soon, the algorithm was generalised to two and four legs. A bipedal robot was demonstrated running and even performing somersaults. A quadruped was also demonstrated which could trot, run, pace, and bound.

- **Dynamic Balancing** or controlled falling: A more advanced way for a robot to walk is by using a dynamic balancing algorithm, which is potentially more robust than the Zero Moment Point technique, as it constantly monitors the robot's motion, and places the feet in order to maintain stability. This technique was recently demonstrated by Anybots' Dexter Robot, which is so stable, it can even jump. Another example is the TU Delft Flame.
- **Passive Dynamics:** Perhaps the most promising approach utilizes passive dynamics where the momentum of swinging limbs is used for greater efficiency. It has been shown that totally unpowered humanoid mechanisms can walk down a gentle slope, using only gravity to propel themselves. Using this technique, a robot need only supply a small amount of motor power to walk along a flat surface or a little more to walk up a hill. This technique promises to make walking robots at least ten times more efficient than ZMP walkers, like ASIMO.

Other methods of locomotion

RQ-4 Global Hawk unmanned aerial vehicle

- **Flying:** A modern passenger airliner is essentially a flying robot, with two humans to manage it. The autopilot can control the plane for each stage of the journey, including takeoff, normal flight, and even landing. Other flying robots are uninhabited, and are known as unmanned aerial vehicles (UAVs). They can be smaller and lighter without a human pilot onboard, and fly into dangerous territory for military surveillance missions. Some can even fire on targets under command. UAVs are also being developed which can fire on targets automatically, without the need for a command from a human. Other flying robots include cruise missiles, the Entomopter, and the Epson micro helicopter robot. Robots such as the Air Penguin, Air Ray, and Air Jelly have lighter-than-air bodies, propelled by paddles, and guided by sonar.



Two robot snakes. Left one has 64 motors (with 2 degrees of freedom per segment), the right one 10.

- **Snaking:** Several snake robots have been successfully developed. Mimicking the way real snakes move, these robots can navigate very confined spaces, meaning they may one day be used to search for people trapped in collapsed buildings. The Japanese ACM-R5 snake robot can even navigate both on land and in water.
- **Skating:** A small number of skating robots have been developed, one of which is a multi-mode walking and skating device, Titan VIII. It has four legs, with unpowered wheels, which can either step or roll. Another robot, Plen, can use a miniature skateboard or rollerskates, and skate across a desktop.

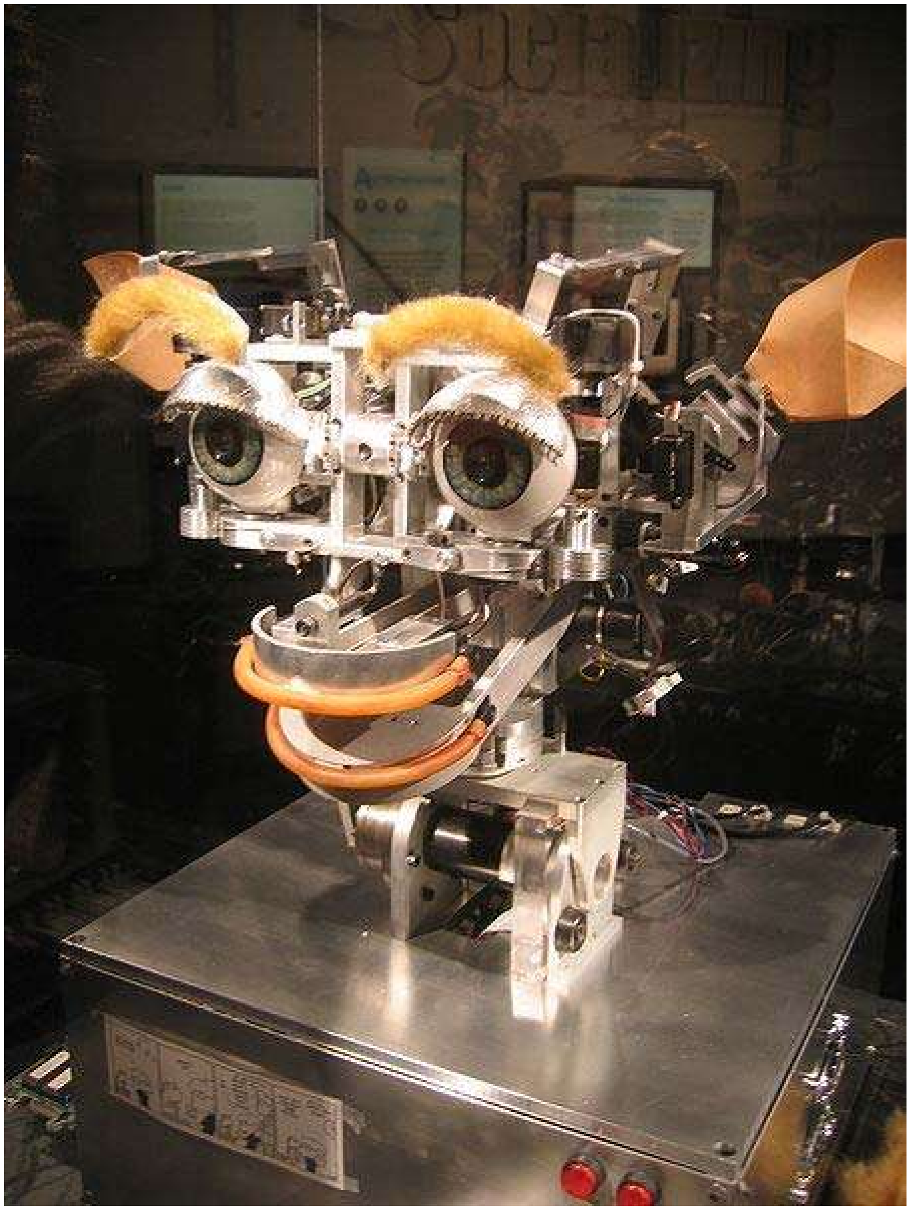
- **Climbing:** Several different approaches have been used to develop robots that have the ability to climb vertical surfaces. One approach mimicks the movements of a human climber on a wall with protrusions; adjusting the center of mass and moving each limb in turn to gain leverage. An example of this is Capuchin, built by Stanford University, California. Another approach uses the specialised toe pad method of wall-climbing geckoes, which can run on smooth surfaces such as vertical glass. Examples of this approach include Wallbot and Stickybot. China's "Technology Daily" November 15, 2008 reported New Concept Aircraft (ZHUHAI) Co., Ltd. Dr. Li Hiu Yeung and his research group have recently successfully developed the bionic gecko robot "Speedy Freelander".According to Dr. Li introduction, this gecko robot can rapidly climbing up and down in a variety of building walls, ground and vertical wall fissure or walking upside down on the ceiling, it is able to adapt on smooth glass, rough or sticky dust walls as well as the various surface of metallic materials and also can automatically identify obstacles, circumvent the bypass and flexible and realistic movements. Its flexibility and speed are comparable to the natural gecko. A third approach is to mimick the motion of a snake climbing a pole.
- **Swimming:** It is calculated that when swimming some fish can achieve a propulsive efficiency greater than 90%. Furthermore, they can accelerate and maneuver far better than any man-made boat or submarine, and produce less noise and water disturbance. Therefore, many researchers studying underwater robots would like to copy this type of locomotion. Notable examples are the Essex University Computer Science Robotic Fish, and the Robot Tuna built by the Institute of Field Robotics, to analyze and mathematically model thunniform motion. The Aqua Penguin, designed and built by Festo of Germany, copies the streamlined shape and propulsion by front "flippers" of penguins. Festo have also built the Aqua Ray and Aqua Jelly, which emulate the locomotion of manta ray, and jellyfish, respectively.

Environmental interaction and navigation

RADAR, GPS, LIDAR, ... are all combined to provide proper navigation and obstacle avoidance

Though a significant percentage of robots in commission today are either human controlled, or operate in a static environment, there is an increasing interest in robots that can operate autonomously in a dynamic environment. These robots require some combination of navigation hardware and software in order to traverse their environment. In particular unforeseen events (e.g. people and other obstacles that are not stationary) can cause problems or collisions. Some highly advanced robots as ASIMO, EveR-1, Meinü robot have particularly good robot navigation hardware and software. Also, self-controlled cars, Ernst Dickmanns' driverless car, and the entries in the DARPA Grand Challenge, are capable of sensing the environment well and subsequently making navigational decisions based on this information. Most of these robots employ a GPS navigation device with waypoints, along with radar, sometimes combined with other sensory data such as LIDAR, video cameras, and inertial guidance systems for better navigation between waypoints.

Human-robot interaction

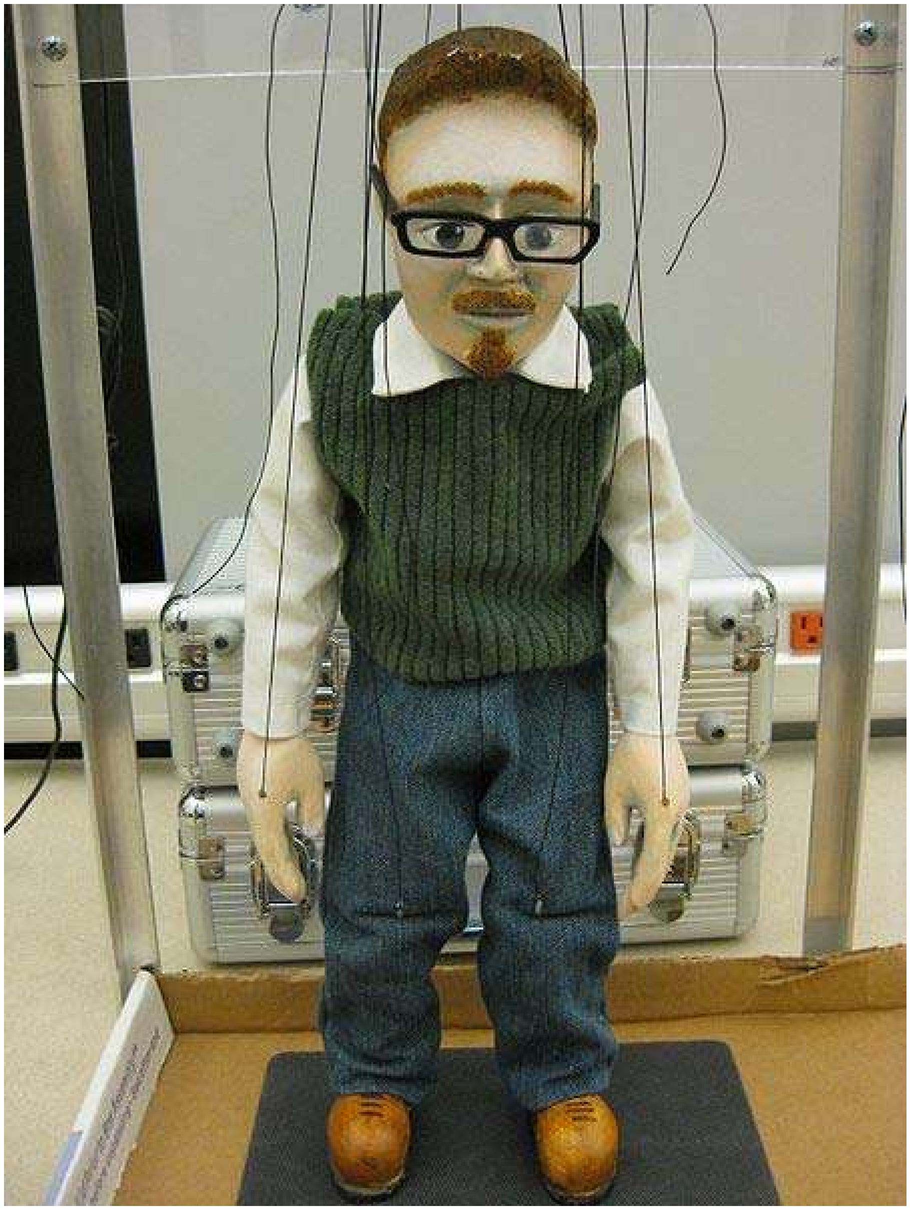


Kismet can produce a range of facial expressions

If robots are to work effectively in homes and other non-industrial environments, the way they are instructed to perform their jobs and especially how they will be told to stop will be of critical importance. The people who interact with them may have little or no training in robotics, and so any interface will need to be extremely intuitive. Science fiction authors also typically assume that robots will eventually be capable of communicating with humans through speech, gestures, and facial expressions, rather than a command-line interface. Although speech would be the most natural way for the human to communicate, it is unnatural for the robot. It will be a long time before robots interact as naturally as the fictional C-3PO.

- **Speech recognition:** Interpreting the continuous flow of sounds coming from a human (speech recognition), in real time, is a difficult task for a computer, mostly because of the great variability of speech. The same word, spoken by the same person may sound different depending on local acoustics, volume, the previous word, whether or not the speaker has a cold, etc.. It becomes even harder when the speaker has a different accent. Nevertheless, great strides have been made in the field since Davis, Biddulph, and Balashek designed the first "voice input system" which recognized "ten digits spoken by a single user with 100% accuracy" in 1952. Currently, the best systems can recognize continuous, natural speech, up to 160 words per minute, with an accuracy of 95%.
- **Gestures:** One can imagine, in the future, explaining to a robot chef how to make a pastry, or asking directions from a robot police officer. In both of these cases, making hand gestures would aid the verbal descriptions. In the first case, the robot would be recognizing gestures made by the human, and perhaps repeating them for confirmation. In the second case, the robot police officer would gesture to indicate "down the road, then turn right". It is likely that gestures will make up a part of the interaction between humans and robots. A great many systems have been developed to recognize human hand gestures.
- **Facial expression:** Facial expressions can provide rapid feedback on the progress of a dialog between two humans, and soon it may be able to do the same for humans and robots. Robotic faces have been constructed by Hanson Robotics using their elastic polymer called Frubber, allowing a great amount of facial expressions due to the elasticity of the rubber facial coating and imbedded subsurface motors (servos) to produce the facial expressions. The coating and servos are built on a metal skull. A robot should know how to approach a human, judging by their facial expression and body language. Whether the person is happy, frightened, or crazy-looking affects the type of interaction expected of the robot. Likewise, robots like Kismet and the more recent addition, Nexi can produce a range of facial expressions, allowing it to have meaningful social exchanges with humans.
- **Artificial emotions** Artificial emotions can also be imbedded and are composed of a sequence of facial expressions and/or gestures. As can be seen from the movie Final Fantasy: The Spirits Within, the programming of these artificial emotions is complex and requires a great amount of human observation. To simplify this programming in the movie, presets were created together with a special software program. This decreased the amount of time needed to make the film. These presets could possibly be transferred for use in real-life robots.
- **Personality:** Many of the robots of science fiction have a personality, something which may or may not be desirable in the commercial robots of the future. Nevertheless, researchers are trying to create robots which appear to have a personality: i.e. they use sounds, facial expressions, and body language to try to convey an internal state, which may be joy, sadness, or fear. One commercial example is Pleo, a toy robot dinosaur, which can exhibit several apparent emotions.

Control



A robot-manipulated marionette, with complex control systems

The mechanical structure of a robot must be controlled to perform tasks. The control of a robot involves three distinct phases - perception, processing, and action (robotic paradigms). Sensors give information about the environment or the robot itself (e.g. the position of its joints or its end effector). This information is then processed to calculate the appropriate signals to the actuators (motors) which move the mechanical.

The processing phase can range in complexity. At a reactive level, it may translate raw sensor information directly into actuator commands. Sensor fusion may first be used to estimate parameters of interest (e.g. the position of the robot's gripper) from noisy sensor data. An immediate task (such as moving the gripper in a certain direction) is inferred from these estimates. Techniques from control theory convert the task into commands that drive the actuators.

At longer time scales or with more sophisticated tasks, the robot may need to build and reason with a "cognitive" model. Cognitive models try to represent the robot, the world, and how they interact. Pattern recognition and computer vision can be used to track objects. Mapping techniques can be used to build maps of the world. Finally, motion planning and other artificial intelligence techniques may be used to figure out how to act. For example, a planner may figure out how to achieve a task without hitting obstacles, falling over, etc.

Autonomy levels

Control systems may also have varying levels of autonomy.

1. Direct interaction is used for haptic or tele-operated devices, and the human has nearly complete control over the robot's motion.
2. Operator-assist modes have the operator commanding medium-to-high-level tasks, with the robot automatically figuring out how to achieve them.
3. An autonomous robot may go for extended periods of time without human interaction. Higher levels of autonomy do not necessarily require more complex cognitive capabilities. For example, robots in assembly plants are completely autonomous, but operate in a fixed pattern.

Another classification takes into account the interaction between human control and the machine motions.

1. Teleoperation. A human controls each movement, each machine actuator change is specified by the operator.
2. Supervisory. A human specifies general moves or position changes and the machine decides specific movements of its actuators.
3. Task-level autonomy. The operator specifies only the task and the robot manages itself to complete it.
4. Full autonomy. The machine will create and complete all its tasks without human interaction.

Dynamics and kinematics

The study of motion can be divided into kinematics and dynamics. Direct kinematics refers to the calculation of end effector position, orientation, velocity, and acceleration when the corresponding joint values are known. Inverse kinematics refers to the opposite case in which required joint values are calculated for given end effector values, as done in path planning. Some special aspects of kinematics include handling of redundancy (different possibilities of performing the same movement), collision avoidance, and singularity avoidance. Once all relevant positions, velocities, and accelerations have been calculated using kinematics, methods from the field of dynamics are used to study the effect of forces upon these movements. Direct dynamics refers to the calculation of accelerations in the robot once the applied forces are known. Direct dynamics is used in computer simulations of the robot. Inverse dynamics refers to the calculation of the actuator forces necessary to create a prescribed end effector acceleration. This information can be used to improve the control algorithms of a robot.

In each area mentioned above, researchers strive to develop new concepts and strategies, improve existing ones, and improve the interaction between these areas. To do this, criteria for "optimal" performance and ways to optimize design, structure, and control of robots must be developed and implemented.

Robot research

Much of the research in robotics focuses not on specific industrial tasks, but on investigations into new types of robots, alternative ways to think about or design robots, and new ways to manufacture them but other investigations, such as MIT's cyberflora project, are almost wholly academic.

A first particular new innovation in robot design is the opensourcing of robot-projects. To describe the level of advancement of a robot, the term "Generation Robots" can be used. This term is coined by Professor Hans Moravec, Principal Research Scientist at the Carnegie Mellon University Robotics Institute in describing the near future evolution of robot technology. *First generation* robots, Moravec predicted in 1997, should have an intellectual capacity comparable to perhaps a lizard and should become available by 2010. Because the *first generation* robot would be incapable of learning, however, Moravec predicts that the *second generation* robot would be an improvement over the *first* and become available by 2020, with an intelligence maybe comparable to that of a mouse. The *third generation* robot should have an intelligence comparable to that of a monkey. Though *fourth generation* robots, robots with human intelligence, professor Moravec predicts, would become possible, he does not predict this happening before around 2040 or 2050.

The second is Evolutionary Robots. This is a methodology that uses evolutionary computation to help design robots, especially the body form, or motion and behavior controllers. In a similar way to natural evolution, a large population of robots is allowed to compete in some way, or their ability to perform a task is measured using a fitness function. Those that perform worst are removed from the population, and replaced by a new set, which have new behaviors based on those of the winners. Over time the population improves, and eventually a satisfactory robot may appear. This happens without any direct programming of the robots by the researchers. Researchers use this method both to create better robots, and to explore the nature of evolution. Because the process often requires many generations of robots to be simulated, this technique may be run entirely or mostly in simulation, then tested on real robots once the evolved algorithms are good enough. Currently, there are about 1 million industrial robots toiling around the world, and Japan is the top country having high density of utilizing robots in its manufacturing industry.

Education and training

The SCORBOT-ER 4u - educational robot

Robots recently became a popular tool in raising interests in computing for middle and high school students. First year computer science courses at several universities were developed which involves the programming of a robot instead of the traditional software engineering based coursework.

Career training

Universities offer Bachelors, Masters and Doctoral degrees in the field of robotics. Select Private Career Colleges and vocational schools offer robotics training to train individuals towards being job ready and employable in the emerging robotics industry.

Certification

The Robotics Certification Standards Alliance (RCSA) is an international robotics certification authority who confers various industry and educational related robotics certifications.

Employment in robotics

A robot technician builds small all-terrain robots.

Robotics is an essential component in any modern manufacturing environment. As factories increase their use of robots, the number of robotics related jobs grow and have been observed to be on a steady rise.

Relationship to unemployment

Some analysts, such as Martin Ford, argue that robots and other forms of automation will ultimately result in significant unemployment as machines begin to match and exceed the capability of workers to perform most jobs. At present the negative impact is only on average and repetitive jobs, and there is actually a positive impact on the number of jobs for highly skilled technicians, engineers, and knowledge workers. However, these highly skilled jobs are not sufficient in number to offset the greater decrease in employment among the general population, causing structural unemployment in which overall (net) unemployment rises.

As robotics and artificial intelligence develop further, some worry even many skilled jobs may be threatened. In conventional economic theory, this should cause merely an increase in the productivity of the involved industries, resulting in higher demand for other goods, and hence higher labour demand in these sectors, offsetting whatever negatives are caused. However, some authors believe that the conventional theory describes the past well but may not describe the future because of shifts in the parameter values that shape the context.

Healthcare

Script Pro manufactures a robot designed to help pharmacies fill prescriptions that consist of oral solids or medications in pill form. The pharmacist or pharmacy technician enters the prescription information into its information system. The system, upon determining whether or not the drug is in the robot, will send the information to the robot for filling. The robot has 3 different size vials to fill determined by the size of the pill. The robot technician, user, or pharmacist determines the needed size of the vial based on the tablet when the robot is stocked. Once the vial is filled it is brought up to a conveyor belt that delivers it to a holder that spins the vial and attaches the patient label. Afterwards it is set on another conveyor that delivers the patient's medication vial to a slot labeled with the patient's name on an LED read out. The pharmacist or technician then checks the contents of the vial to ensure it's the correct drug for the correct patient and then seals the vials and sends it out front to be picked up. The robot is a very time efficient device that the pharmacy depends on to fill prescriptions.

McKesson's Robot RX is another healthcare robotics product that helps pharmacies dispense thousands of medications daily with little or no errors. The robot can be ten feet wide and thirty feet long and can hold hundreds of different kinds of medications and thousands of doses. The pharmacy saves many resources like staff members that are otherwise unavailable in a resource scarce industry. It uses an electromechanical head coupled with a pneumatic system to capture each dose and deliver it to its either stocked or dispensed location. The head moves along a single axis while it rotates 180 degrees to pull the medications. During this process it uses barcode technology to verify its pulling the correct drug. It then delivers the drug to a patient specific bin on a conveyor belt. Once the bin is filled with all of the drugs that a particular patient needs and that the robot stocks, the bin is then released and returned out on the conveyor belt to a technician waiting to load it into a cart for delivery to the floor.

Chapter- 6

High-tech Architecture

The HSBC Hong Kong headquarters is one example of high-tech architecture

High-tech architecture, also known as **Late Modernism** or **Structural Expressionism**, is an architectural style that emerged in the 1970s, incorporating elements of high-tech industry and technology into building design. High-tech architecture appeared as a revamped modernism, an extension of those previous ideas aided by even more advances in technological achievements. This category serves as a bridge between modernism and post-modernism, however there remain gray areas as to where one category ends and the other begins. In the 1980s, high-tech architecture became more difficult to distinguish from post-modern architecture. Many of its themes and ideas were absorbed into the language of the post-modern architectural schools.

Like Brutalism, Structural Expressionist buildings reveal their structure on the outside as well as the inside, but with visual emphasis placed on the internal steel and/or concrete skeletal structure as opposed to exterior concrete walls. In buildings such as the Pompidou Centre, this idea of revealed structure is taken to the extreme, with apparently structural components serving little or no structural role. In this case, the use of "structural" steel is a stylistic or aesthetic matter.

The style's premier practitioners include the British architects Sir Norman Foster, Sir Richard Rogers, Sir Michael Hopkins, Italian Architect Renzo Piano and Spanish architect Santiago Calatrava, known for his organic, skeleton-like designs. Early High Tech buildings were referred to by historian Reyner Banham as "serviced sheds" due to their additional exposure of mechanical services in addition to the structure. Most of these early examples used exposed structural steel as their material of choice. As hollow structural sections had only become widely available in the early 1970s, we see much experimentation with this material.

Origins

Background

860-880 Lake Shore Drive Apartments

John Hancock Center

Lloyd's Building

Buildings in this architectural style were constructed mainly in North America and Europe. It is deeply connected with what is called the Second School of Chicago which emerged after World War II. The main content is that the technological kind of construction, mostly with steel and glass, is expressed in a formal independent way to gain own aesthetic qualities out of it. The first proper example are the 860-880 Lake Shore Drive Apartments by Ludwig Mies van der Rohe.

The scientific and technological advances had a big impact on societies in the 1970s. The Space Race climaxed in 1969 with Neil Armstrong's landing on the moon, and came along with excessive military developments. These advances set people's minds thinking that much more can be achieved with advancing technology. Technological instruments became a common sight for people at the time because of the use of ramps, video screens, headphones, and bare scaffolds. These high-tech constructions became more visible everyday to the average person.

Name

The style got its name from the book *High Tech: The Industrial Style and Source Book for The Home*, written by design journalists Joan Kron and Suzanne Slesin and published in November 1978 by Clarkson N. Potter, New York. The book, illustrated with hundreds of photos, showed how designers, architects, and home owners were appropriating classic industrial objects—library shelving, chemical glass, metal deck plate, restaurant supply, factory and airport runway light fixtures, movers' quilts, industrial carpeting etc.—found in industrial catalogues and putting these to use in residential settings. The foreword to the book by architect Emilio Ambasz, former curator of design at the Museum of Modern Art, put the trend in historical context.

As a result of the publicity and popularity of the book, the decorating style became known as "High-Tech", and accelerated the entry of the still-obscure term "high-tech" into everyday language. In 1979, the term high-tech appeared for the first time in a *New Yorker* magazine cartoon showing a woman berating her husband for not being high-tech enough: "You're middle-, middle-, middle-tech." After *Esquire* excerpted Kron and Slesin's book in six installments, mainstream retailers across the United States, beginning with Macy's New York, started featuring high-tech decor in windows and in furniture departments. But credit should go to a shop on 64th Street and Lexington Avenue in New York, Ad Hoc Housewares, which opened in 1977, for marketing these objects to a residential audience before anyone else. The book went on to be reprinted in England, France, and Japan, and like the original, each edition included a directory of local sources for the objects.

Aims

High-tech architecture was, in some ways, a response to growing disillusionment with modern architecture. The realization of Le Corbusier's urban development plans led to cities with monotonous and standardized buildings. Enthusiasm for economic building led to extremely low-quality finishes, with subsequent degradation countering a now-waning aesthetic novelty. High-tech architecture created a new aesthetic in contrast with standard modern architecture. In *High Tech: The Industrial Style and Source Book for The Home*, when discussing the high-tech aesthetic, the authors emphasized using elements "your parents might find insulting". This humour so aptly demonstrates the rebellious attitude.

Kron and Slesin further explain the term "high-tech" as one being used in architectural circles to describe an increasing number of residences and public buildings with a "nuts-and-bolts, exposed-pipes, technological look". There is no need to look further than Rogers's Pompidou Centre for an example of this. This highlights the one of the aims of high-tech architecture, to boast the technical elements of the building by externalizing them. Thus, the technical aspects create the building's aesthetic.

For interior design there was a trend of using formerly industrial appliances as household objects, e.g. chemical beakers as vases for flowers. This was because of an aim to use an industrial aesthetic. This was assisted by the conversion of former industrial spaces into residential spaces. High-tech architecture aimed to give everything an industrial appearance.

Another aspect to the aims of high-tech architecture was that of a renewed belief in the power of technology to improve the world. This is especially evident in Kenzo Tange's plans for technically sophisticated buildings in Japan's post-war boom in the 1960s, but few of these plans actually became buildings. High-tech architecture aimed to achieve a new industrial aesthetic, spurred on by the renewed faith in the progression of technology.

But however prominent the industrial look appeared, the functional element of modern architecture was very much retained. The pieces still served a purpose in the building's function. The function of the building was also aimed as not being set. This dynamic property means that a building should be a "catalyst", the "technical services are provided but do not become set."

Characteristics

Characteristics of high-tech architecture have varied somewhat, yet all have accentuated technical elements. They included the prominent display of the building's technical and functional components, and an orderly arrangement and use of pre-fabricated elements. Glass walls and steel frames were also immensely popular.

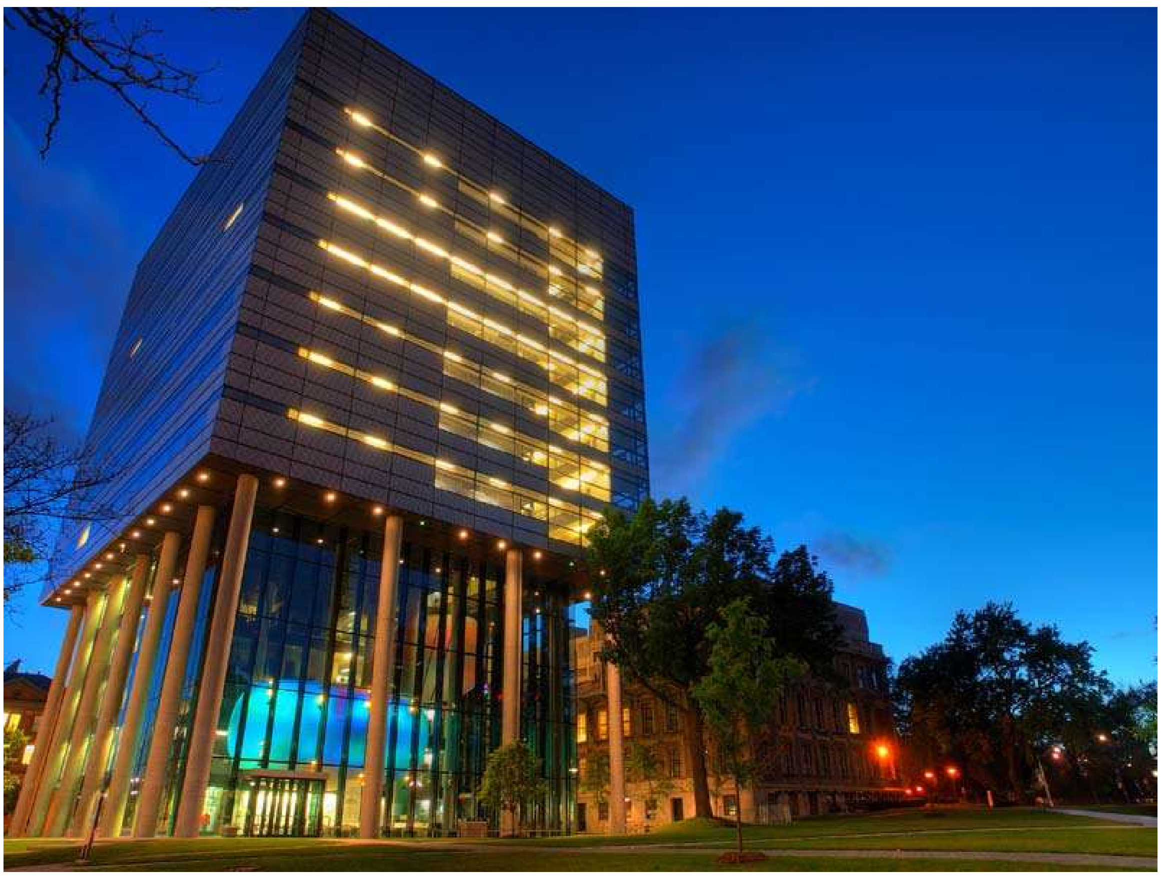
To boast technical features, they were externalized, often along with load-bearing structures. There can be no more illustrious example than Pompidou Centre. The ventilation ducts are all prominently shown on the outside. This was a radical design, as previous ventilation ducts would have been a component hidden on the inside of the building. The means of access to the building is also on the outside, with the large tube allowing visitors to enter the building.

The orderly and logical fashion in which buildings in the high-tech architectural style are designed to keep to their functional essence is demonstrated in Norman Foster's Hong Kong and Shanghai Bank HQ. Besides the technology being the overriding feature of the building, its design is very much functionally orientated. The large interior open space and the easy access to all floors enhance the function of being a bank. Also, the elements of the buildings are very neatly composed to achieve optimal orderliness in order to logically solve the problem of the needs of a bank. This can be seen in the levels' structure and in the escalators.

The high-tech buildings make persistent use of glass curtain walls and steel structure. It is greatly indebted to modern architecture for this, and influenced by Mies van der Rohe's highrise buildings. The SOM Sears Tower demonstrates that with glass walls and skeleton pipe structure of steel, a very tall building can be built. Many high-tech buildings meant their purposes to be dynamic. This could best be explained by Günther Behnisch and Frei Otto's Munich Olympic Stadium. This structure made sport in the open possible and is meant to be used for many purposes. Originally an abandoned airfield, it is now a sport stadium, used for various disciplines.

Buildings designed in this style usually consist of a clear glass facade, with the building's network of support beams exposed behind it. Perhaps the most famous and easily recognized building built in this style is I.M. Pei's Bank of China Tower in Hong Kong. The World Trade Center in New York City, although generally considered to be an International Style building, was technically a Structural Expressionist design due to its load-bearing steel exoskeleton.

Examples



The Leslie L. Dan Pharmacy Building at University of Toronto is one example of high-tech architecture

- Žižkov TV Tower - Prague
- Lord's Media Centre - London

- Irvine Company headquarters, Newport Beach, California, United States (William Pereira, 1968)
- John Hancock Center, Chicago, Illinois, United States (Fazlur Khan, 1969)
- World Trade Center, New York City, United States (Minoru Yamasaki, 1971) (destroyed 2001)
- One US Bank Plaza, St. Louis, Missouri, United States (Thompson, Ventulett, Stainback & Associates), 1976
- Centre Georges Pompidou, Paris, France (Renzo Piano and Richard Rogers, 1977)
- BNZ Centre, Wellington, New Zealand (Stephenson & Turner, 1983)
- HSBC Hong Kong headquarters building, Hong Kong (Norman Foster, 1985)
- Lloyd's Building, London, United Kingdom (Richard Rogers, 1986)
- Bank of China Tower, Hong Kong (I.M. Pei, 1989)
- Hotel Arts, Barcelona, Spain (Skidmore, Owings and Merrill, 1992)
- 30 St. Mary Axe, London, United Kingdom (Norman Foster, 2003)
- Torre Agbar, Barcelona, Spain (Jean Nouvel, 2005)
- Hearst Tower, New York City, United States (Norman Foster, 2004)
- Marquette Plaza, Minneapolis, Minnesota, United States (Gunnar Birkerts, 1973)
- Beetham Tower
- Leslie L. Dan Pharmacy Building, University of Toronto, Toronto, Ontario, Canada (Norman Foster, 2006)

HSBC Main Building

HSBC Main Building
香港上海滙豐銀行總行大廈

HSBC Main Building in June 2008

General information	
Location	Hong Kong
Coordinates	22°16′48″N 114°9′34″E / 22.28°N 114.15944°ECoordinates: 22°16′48″N 114°9′34″E / 22.28°N 114.15944°E
Status	Complete
Constructed	1983–1985
Use	Office
Height	
Roof	178.8 m (586.6 ft)
Technical details	
Floor count	44
Floor area	99,000 m^2 (1,065,627 sq ft)
Cost	5.2 billion HKD
Companies involved	
Architect(s)	Lord Norman Foster and Partners

The **HSBC Main Building** (traditional Chinese: 香港滙豐總行大廈) is a headquarters building of The Hongkong and Shanghai Banking Corporation Limited in Central, Hong

Kong. It is located along the southern side of Statue Square near the location of the old City Hall, Hong Kong (built in 1869, demolished in 1933). The previous HSBC building was built in 1935 and pulled down to make way for the current building. The address remains as *1 Queen's Road Central, Central*. The building can be reached from Exit K of Central MTR Station and facing Statue Square.

Design

The new building was designed by the British architect Lord Norman Foster and engineers Arup and was constructed by Wimpey Construction. From the concept to completion, it took 6 years (1979–1985). The building is 180-metres high with 47 storeys and four basement levels. The building has a module design consisting of five steel modules prefabricated in the UK by Scott Lithgow Shipbuilders near Glasgow, and shipped to Hong Kong. 30,000 tons of steel and 4,500 tons of aluminium were used. It is rumoured that the building's modular design enables it to be dismantled and moved, if there was any possibility of a disrupted handover to the People's Republic of China.

The new Lobby and its 2-part Asian Story Wall were designed by Greg Pearce, of One Space Limited. Pearce was also the Principal Architect of the Hong Kong Airport Express (MTR) station. Conceived as a minimalist glass envelope, the new lobby is designed to be deferential to Foster's structure and appears almost to be part of the original.

The building is also one of the few to not have elevators as the primary carrier of building traffic. Instead, elevators only stop every few floors, and floors are interconnected by escalators.

Characteristics

The main characteristic of HSBC Hong Kong headquarters is its absence of internal supporting structure.

Another notable feature is that natural sunlight is the major source of lighting inside the building. There is a bank of giant mirrors at the top of the atrium, which can reflect natural sunlight into the atrium and hence down into the plaza. Through the use of natural sunlight, this design helps to conserve energy. Additionally, sun shades are provided on the external facades to block direct sunlight going into the building and to reduce heat gain. Instead of fresh water, sea water is used as coolant for the air-conditioning system.

All flooring is made from lightweight movable panels, under which lies a comprehensive network of power, telecommunication, and air-conditioning systems. This design was to allow equipment such as computer terminals to be installed quickly and easily.

Because of the urgency to finish the project, the construction of the building relied heavily on off-site prefabrication; components were manufactured all over the world. For example, the structural steel came from Britain; the glass, aluminium cladding and flooring came from the United States while the service modules came from Japan.

The inverted ‘va’ segments of the suspension trusses spanning the construction at double-height levels is the most obvious characteristic of the building. It consists of eight groups of four aluminium-clad steel columns which ascend from the foundations up through the core structure, and five levels of triangular suspension trusses which are locked into these masts.

Feng Shui

The early British settlers in Hong Kong had an interest in Feng Shui; thus, most of the earliest buildings in Hong Kong, and many buildings constructed thereafter, were built with the philosophies of Feng Shui in mind. The Chinese and even the British believe that those who have a direct view of a body of water—whether it is a river, a sea, or an ocean—are more likely to prosper than those who do not (water is strongly associated with wealth in Feng Shui). The HSBC building has a wide open area (the Statue Square) in front of it, with no other buildings blocking its view of Victoria Harbour; thus, it is considered to have "good feng shui."

Even though the Hong Kong Government is proposing extending the existing coastline further out into the harbour in its latest land reclamation project, it will still set aside space so that no new developments will block the HSBC Building's view of the harbour. (It has been said that the HSBC is guaranteed its view of the harbour by the government.)

Lion statues

The left lion statue (Stephen) of HSBC Main Building

When HSBC decided to build its third Headquarters at 1 Queen's Road Central, opened in 1935, it commissioned two bronze lions from Shanghai-based British sculptor W W Wagstaffe (d 1977, aged 82). This commission was inspired by two earlier lions that had been ordered for the new Shanghai office opened in 1923. Cast by J W Singer & Sons in the English town of Frome, to a design by Henry Poole RA, these lions had quickly become part of the Shanghai scene, and passers-by would affectionately stroke the lions in the belief that power and money would rub off on them. They became known as Stephen and Stitt: an in-joke. Stephen was named for A G Stephen, formerly Manager Shanghai, and in 1923 the Chief Manager of HSBC, and G H Stitt, the then Manager Shanghai. Stephen is depicted roaring, Stitt quiescent, and again insiders said that this represented the characters of these two famous bankers.

The Hong Kong lions were to be considerably larger, as befitted the Head Office of the Bank.

Wagstaffe worked with "Shanghai Arts and Crafts" foreman Chou Yin Hsiang who in an interview with John Loch of HSBC's house magazine "Group News" in June 1977 recalled that when he first joined Arts and Crafts he worked with Wagstaffe for two years to make the lions, without having to learn a word of English: Wagstaffe spoke perfect Shanghai dialect. Hunch-backed, Wagstaffe was nicknamed "Lao Doo Pei", meaning "Old Hunchback". His son, inevitably, was called "Sau Doo Pei" - "Young Hunchback." Wagstaffe had two sons - Tom, killed in Naval service in the war, and Harry, killed while interned in Shanghai by the Japanese. Chou Yin Hsiang himself came to Hong Kong in 1935, and by 1977 was the proprietor of Jeh Hsing Metal Works - and still casting bronze for HSBC.

Like the Shanghai lions, the Hong Kong lions became objects of veneration, and focii of the Bank's perceived excellent feng shui. Young couples still bring their toddlers to stroke the paws and noses of the statues hoping for luck and prosperity.

When the 1935 building was to be demolished in 1984 the lions were temporarily moved to Statue Square, opposite. As a mark of the respect the lions were held in, the move to Statue Square, and the move back in 1985, were accompanied by the Chairman and senior management of the Bank and the placement of the lions both temporarily and in their current locations was made only after extensive consultations with feng shui practitioners.

Their 2-year sojourn in Statue Square aside, the lions have only left their positions as guardians of the Des Voeux Road entrance of the Bank once: they were confiscated by the Japanese and sent to Japan to be melted down. Luckily the war ended before this could happen, and the lions were recognised by an American sailor in a dockyard in Osaka in 1945. They were returned a few months later and restored to their original positions in October 1946.

The Hong Kong lions are also called Stephen and Stitt, and the Hong Kong Stephen has bullet or shrapnel scars in its left hind-quarters dating from the fighting in the Battle of Hong Kong. When this pair of lions was used as the model for the pair commissioned for the new UK Headquarters of HSBC in 2002, Zambian-born New Zealand sculptor Mark Kennedy was asked not to reproduce these 'war wounds" in the copies. They had to earn their own battle-scars.

There are also a few HSBC branches sporting copies of these lions:

- Canada
    - 3640 Victoria Park Avenue, Toronto - 2 lions flank the entrance to the branch
    - 230 Spadina Avenue, Toronto - 2 small lions at entrance to branch
    - HSBC building, Hastings and Keefer, Vancouver, BC - 2 lions
    - HSBC Branch No. 3 Road at Saba Road, Richmond, BC - standing lions and since stolen

- Britain
    - HSBC World Head Office, Canary Wharf, London - clones of originals in Shanghai

- China
    - Pudong Development Bank Building (former HSBC Shanghai office) - replicas of origins now stored at Shanghai Museum

Lighting scheme

The HSBC Main Building at night

In 2003, the Hong Kong Tourism Board developed a harbour lighting plan called "A Symphony of Lights", a large-scale multimedia show featuring lighting, laser, music, and occasionally special pyrotechnics effects during festivals, in order to promote tourism in Hong Kong. The show is based on the illumination of key buildings on the Hong Kong Island side, and is best viewed from the Kowloon side across the Victoria Harbour. The HSBC Hong Kong headquarters building is one of the participating buildings in the show. The building has been installed with 716 intelligent lighting units, including 450 Martin Professional Cyclo 03 colour changing fluorescent fixtures in the glass stairwells, Martin Professional Exterior 600's and Exterior 200 fixtures on five levels, 8 search lights, and over one kilometre of LED lighting around the top. Completed by mid-December 2003, the cost of installation is estimated to be HK$5.5 million.

Intelligent lighting is distributed across six sections of the building:

1. Vertical Ladder Trusses
2. Exoskeleton: Inner + Outer
3. Refuge Floors
4. Northwest Stairwell
5. Eastern Stairwells
6. Roof Building Maintenance Units

HSBC has always aimed to adopt a new lighting scheme because Foster did not pay much attention to the illumination of the building at nighttime.

Chapter- 7

Aerospace Engineering

Aerospace engineer

NASA engineers, like the ones depicted in Apollo 13, worked diligently to protect the lives of the astronauts on the mission.

	Occupation
Names	engineer aerospace engineer
Type	profession
Activity sectors	aeronautics, astronautics, science
	Description
Competencies	technical knowledge, management skills
Fields of employment	technology, science, military

Aerospace engineering is the branch of engineering behind the design, construction and science of aircraft and spacecraft. It is broken into two major and overlapping branches: aeronautical engineering and astronautical engineering. The former deals with craft that stay within Earth's atmosphere, and the latter deals with craft that operate outside of Earth's atmosphere.

While **aeronautical engineering** was the original term, the broader "aerospace" has superseded it in usage, as flight technology advanced to include craft operating in outer space. Aerospace engineering, particularly the astronautics branch, is often informally called rocket science.

Overview

Flight vehicles undergo severe conditions such as differences in atmospheric pressure, and temperature, with structural loads applied upon vehicle components. Consequently, they are usually the products of various technological and engineering disciplines including aerodynamics, propulsion, avionics, materials science, structural analysis and manufacturing. These technologies are collectively known as aerospace engineering. Because of the complexity of the field, aerospace engineering is conducted by a team of engineers, each specializing in their own branches of science.

The development and manufacturing of a modern flight vehicle is an extremely complex process and demands careful balance and compromise between abilities, design, available technology and costs. Aerospace engineers design, test, and supervise the manufacture of aircraft, spacecraft, and missiles. Aerospace engineers develop new technologies for use in aviation, defense systems, and space exploration.

History

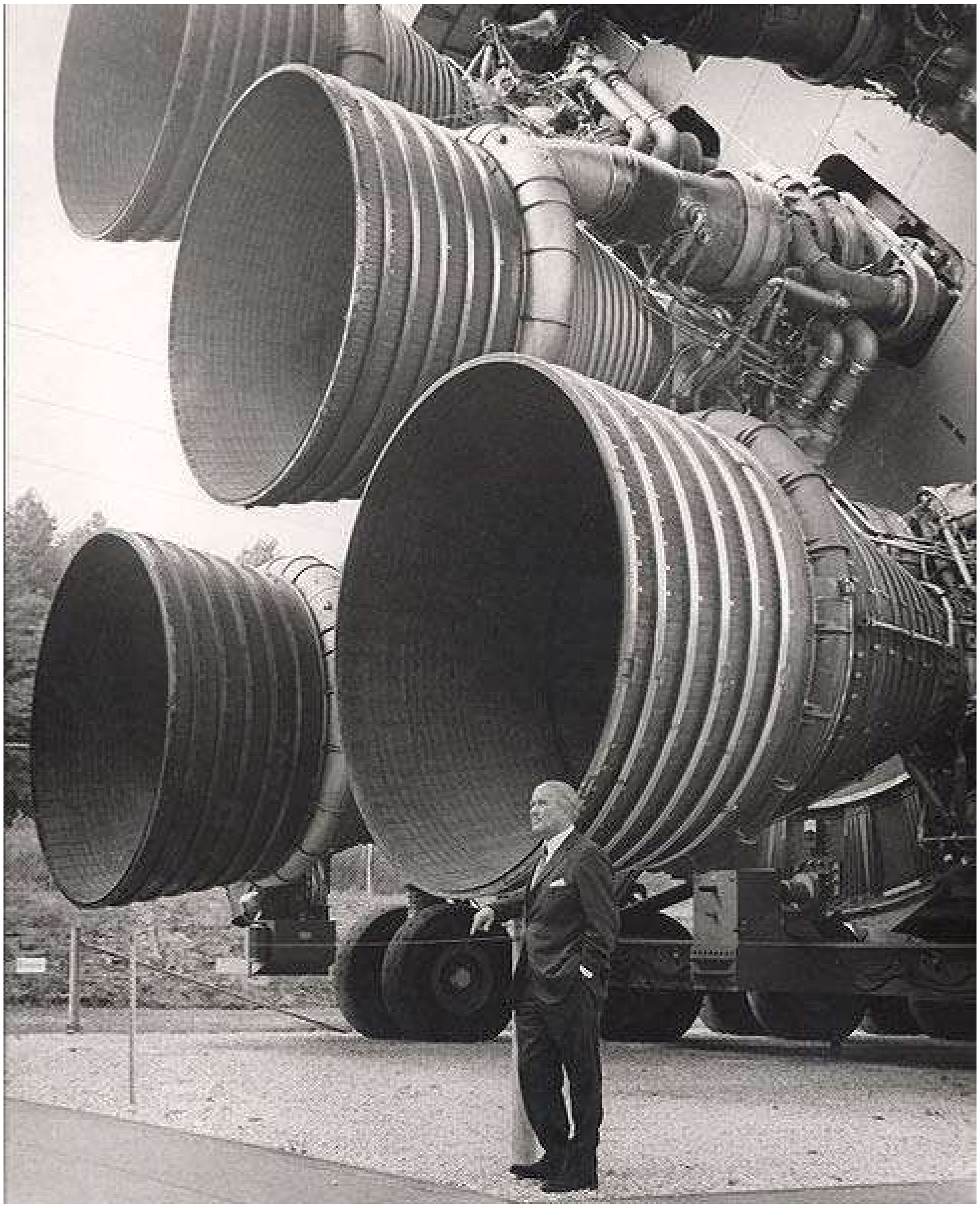
Alberto Santos-Dumont, a pioneer who built the first machines able to fly, played an important role in the development of aviation. Some of the first ideas for powered flight may have come from Leonardo da Vinci, who, although he did not build any successful models, did develop many sketches and ideas for "flying machines".

Orville and Wilbur Wright flew the Wright Flyer I, the first airplane, on December 17, 1903 at Kitty Hawk, North Carolina.

The origin of aerospace engineering can be traced back to the aviation pioneers around the late 19th century to early 20th centuries, although the work of Sir George Cayley has recently been dated as being from the last decade of the 18th to mid 19th century. One of the most important people in the history of aeronautics, Cayley was a pioneer in aeronautical engineering and is credited as the first person to separate the forces of lift and drag, which are in effect on any flight vehicle. Early knowledge of aeronautical engineering was largely empirical with some concepts and skills imported from other branches of engineering. Scientists understood some key elements of aerospace engineering, like fluid dynamics, in the 18th century. Several years later after the successful flights by the Wright brothers, the 1910s saw the development of aeronautical engineering through the design of World War I military aircraft.

The first definition of aerospace engineering appeared in February 1958. The definition considered the Earth's atmosphere and the outer space as a single realm, thereby encompassing both aircraft (*aero*) and spacecraft (*space*) under a newly coined word *aerospace*. The National Aeronautics and Space Administration was founded in 1958 as a response to the Cold War. United States aerospace engineers launched the first American satellite on January 31, 1958 in response to the USSR launching Sputnik on October 4, 1957.

Elements



Wernher von Braun, with the F-1 engines of the Saturn V first stage at the US Space and Rocket Center

Some of the elements of aerospace engineering are:

A fighter jet engine undergoing testing. The tunnel behind the engine muffles noise and allows exhaust to escape.

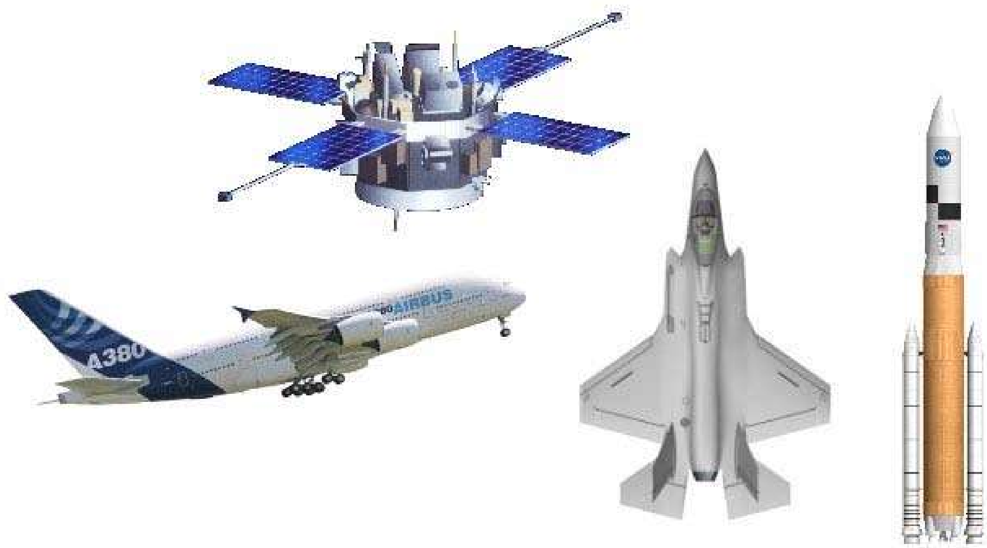
- Fluid mechanics – the study of fluid flow around objects. Specifically aerodynamics concerning the flow of air over bodies such as wings or through objects such as wind tunnels.
- Astrodynamics – the study of orbital mechanics including prediction of orbital elements when given a select few variables. While few schools in the United States teach this at the undergraduate level, several have graduate programs covering this topic (usually in conjunction with the Physics department of said college or university).
- Statics and Dynamics (engineering mechanics) – the study of movement, forces, moments in mechanical systems.
- Mathematics – in particular, calculus, differential equations, and linear algebra.
- Electrotechnology – the study of electronics within engineering.
- Propulsion – the energy to move a vehicle through the air (or in outer space) is provided by internal combustion engines, jet engines and turbomachinery, or rockets. A more recent addition to this module is electric propulsion and ion propulsion.
- Control engineering – the study of mathematical modeling of the dynamic behavior of systems and designing them, usually using feedback signals, so that their dynamic behavior is desirable (stable, without large excursions, with minimum error). This applies to the dynamic behavior of aircraft, spacecraft, propulsion systems, and subsystems that exist on aerospace vehicles.

- Aircraft structures – design of the physical configuration of the craft to withstand the forces encountered during flight. Aerospace engineering aims to keep structures lightweight.
- Materials science – related to structures, aerospace engineering also studies the materials of which the aerospace structures are to be built. New materials with very specific properties are invented, or existing ones are modified to improve their performance.
- Solid mechanics – Closely related to material science is solid mechanics which deals with stress and strain analysis of the components of the vehicle. Nowadays there are several Finite Element programs such as MSC Patran/Nastran which aid engineers in the analytical process.
- Aeroelasticity – the interaction of aerodynamic forces and structural flexibility, potentially causing flutter, divergence, etc.
- Avionics – the design and programming of computer systems on board an aircraft or spacecraft and the simulation of systems.
- Software – the specification, design, development, test, and implementation of computer software for aerospace applications, including flight software, ground control software, test & evaluation software, etc.
- Risk and reliability – the study of risk and reliability assessment techniques and the mathematics involved in the quantitative methods.
- Noise control – the study of the mechanics of sound transfer.
- Flight test – designing and executing flight test programs in order to gather and analyze performance and handling qualities data in order to determine if an aircraft meets its design and performance goals and certification requirements.

The basis of most of these elements lies in theoretical mathematics, such as fluid dynamics for aerodynamics or the equations of motion for flight dynamics. There is also a large empirical component. Historically, this empirical component was derived from testing of scale models and prototypes, either in wind tunnels or in the free atmosphere. More recently, advances in computing have enabled the use of computational fluid dynamics to simulate the behavior of fluid, reducing time and expense spent on wind-tunnel testing.

Additionally, aerospace engineering addresses the integration of all components that constitute an aerospace vehicle (subsystems including power, aerospace bearings, communications, thermal control, life support, etc.) and its life cycle (design, temperature, pressure, radiation, velocity, life time).

Aerospace engineering degrees



Aerospace engineering

Aerospace engineering may be studied at the advanced diploma, bachelor's, master's, and Ph.D. levels in aerospace engineering departments at many universities, and in mechanical engineering departments at others. A few departments offer degrees in space-focused astronautical engineering. The Delft University of Technology (TU Delft) in the Netherlands offers one of the top European aerospace educational and research platforms, while the programs of the Massachusetts Institute of Technology and Rutgers University are two such examples. In 2009, U.S. News & World Report ranked the undergraduate aerospace engineering programs at the Massachusetts Institute of Technology, Georgia Institute of Technology, and the University of Michigan as the top three best programs for doctorate granting universities in the United States. The other programs in the top ten were Purdue University, California Institute of Technology, University of Maryland, University of Illinois, Stanford University, University of Texas at Austin, and Virginia Tech in that order. The magazine also rates Embry-Riddle Aeronautical University, the United States Air Force Academy, and the United States Naval Academy as the premier aerospace engineering programs at universities that do not grant doctorate degrees. Wichita State University is renowned for its Aerospace Engineering program and also has the third highest research budget for Aerospace Engineering in the United States.

In Canada, the University of Toronto has a quality aerospace engineering program. The aerospace program requires the students to go through a competitive program called engineering science. The academic program in aerospace science and engineering at U of T includes undergraduate and graduate studies. At the graduate level U of T offers research-intensive programs leading to MASc and PhD degrees, and a professionally-oriented program leading to the MEng degree. The scope of U of T's research includes aeronautical engineering (aircraft flight systems, propulsion, aerodynamics, computational fluid dynamics, and structural mechanics) and space systems engineering (spacecraft dynamics and control, space robotics and mechatronics, and microsatellite technology). Carleton University and Ryerson University are other top aerospace and mechanical engineering universities in Canada which offer accredited graduate and under-graduate degrees.

In the UK, Aerospace (or aeronautical) engineering can be studied for the B.Eng., M.Eng., MSc. and Ph.D. levels at a number of universities. The top 10 universities are University of Cambridge, University of Surrey, University of Bristol, University of Southampton, Queens University Belfast, University of Sheffield, Newcastle University, University of Bath, Imperial College London, Loughborough University and University of Nottingham for 2010. The Department of Aeronautics at Imperial College London is noted for providing engineers for the Formula One industry, an industry that uses aerospace technology.

Aerospace can be studied at University of Limerick in Ireland. In Australia, the RMIT University offers Aerospace (or aeronautical) engineering and has more than 60 years teaching experience in this profession. Monash University, University of New South Wales, University of Sydney, University of Queensland, University of Adelaide and Queensland University of Technology also offers Aerospace Engineering.

European universities that are renowned for their teaching and expertise in aerospace engineering include TU Delft in the Netherlands, ISAE, ENAC and ESTACA in France, RWTH Aachen, TU München, the University of Stuttgart, TU Berlin and TU Braunschweig in Germany. In Austria the FH Joanneum. In Portugal the Instituto Superior Técnico. In Spain the Universidad Politecnica de Madrid, the Universidad Carlos III de Madrid, and Universitat Politècnica de Catalunya offer the degree, while in Italy there also several universities where aerospace engineering can be studied including the Politecnico di Torino, the Politecnico di Milano, the University of Pisa and the University of Padua. In Eastern Europe they are the University of Belgrade, the Warsaw University of Technology and Rzeszów University of Technology in Poland and Brno University of Technology in Brno, Czech Republic.

In India IIT Kanpur possesses its own flight test aircraft and airfield for students in the discipline, while the other IITs also offer degrees in this discipline. From academic year 2010 onwards Bengal Engineering and Science University, Shibpur has started offering an undergraduate course Bachelor of Engineering in Aerospace Engineering. While in China Nanjing Aeronautics and Astronautics University is a regional leader in the field of aerospace engineering education. In Pakistan Aerospace Engineering can be studied at National University of Sciences and Technology at (CAE), at PAF Academy in Risalpur & at Air University which is Pakistan's only university that grants a Doctorate degree in Aerospace Engineering & Avionics Engineering. In 2002, SUPARCO established IST which is a federally chartered public sector institute of Pakistan offering under graduate and graduate degree in Aerospace Engineering. The MS degree at IST is being offered in collaboration with Beihang University (BUAA), China and Seoul National University, South Korea

Chapter- 8

Nuclear Technology

A residential smoke detector is the most familiar piece of nuclear technology for some people

Nuclear technology is technology that involves the reactions of atomic nuclei. It has found applications from smoke detectors to nuclear reactors, and from gun sights to nuclear weapons.

History and scientific background

Discovery

The vast majority of common, natural phenomena on Earth only involve gravity and electromagnetism, and not nuclear reactions. This is because atomic nuclei are generally kept apart because they contain positive electrical charges and therefore repel each other.

In 1896, Henri Becquerel was investigating phosphorescence in uranium salts when he discovered a new phenomenon which came to be called radioactivity. He, Pierre Curie and Marie Curie began investigating the phenomenon. In the process, they isolated the element radium, which is highly radioactive. They discovered that radioactive materials produce intense, penetrating rays of three distinct sorts, which they labeled alpha, beta, and gamma after the Greek letters. Some of these kinds of radiation could pass through ordinary matter, and all of them could be harmful in large amounts. All the early researchers received various radiation burns, much like sunburn, and thought little of it.

The new phenomenon of radioactivity was seized upon by the manufacturers of quack medicine (as had the discoveries of electricity and magnetism, earlier), and a number of patent medicines and treatments involving radioactivity were put forward. Gradually it was realized that the radiation produced by radioactive decay was ionizing radiation, and that even quantities too small to burn posed a severe long-term hazard. Many of the scientists working on radioactivity died of cancer as a result of their exposure. Radioactive patent medicines mostly disappeared, but other applications of radioactive materials persisted, such as the use of radium salts to produce glowing dials on meters.

As the atom came to be better understood, the nature of radioactivity became clearer. Some larger atomic nuclei are unstable, and so decay (release matter or energy) after a random interval. The three forms of radiation that Becquerel and the Curies discovered are also more fully understood. Alpha decay is when a nucleus releases an alpha particle, which is two protons and two neutrons, equivalent to a helium nucleus. Beta decay is the release of a beta particle, a high-energy electron. Gamma decay releases gamma rays, which unlike alpha and beta radiation are not matter but electromagnetic radiation of very high frequency, and therefore energy. This type of radiation is the most dangerous, and most difficult to block. All three types of radiation occur naturally in certain elements.

It has also become clear that the ultimate source of most terrestrial energy is nuclear, either through radiation from the Sun caused by stellar thermonuclear reactions or by radioactive decay of uranium within the Earth, the principal source of geothermal energy.

Fission

In natural nuclear radiation, the byproducts are very small compared to the nuclei from which they originate. Nuclear fission is the process of splitting a nucleus into roughly equal parts, and releasing energy and neutrons in the process. If these neutrons are captured by another unstable nucleus, they can fission as well, leading to a chain reaction. The average number of neutrons released per nucleus that go on to fission another nucleus is referred to as k. Values of k larger than 1 mean that the fission reaction is releasing more neutrons than it absorbs, and therefore is referred to as a self-sustaining chain reaction. A mass of fissile material large enough (and in a suitable configuration) to induce a self-sustaining chain reaction is called a critical mass.....

When a neutron is captured by a suitable nucleus, fission may occur immediately, or the nucleus may persist in an unstable state for a short time. If there are enough immediate decays to carry on the chain reaction, the mass is said to be prompt critical, and the energy release will grow rapidly and uncontrollably, usually leading to an explosion.

When discovered on the eve of World War II, this insight led multiple countries to begin programs investigating the possibility of constructing an atomic bomb — a weapon which utilized fission reactions to generate far more energy than could be created with chemical explosives. The Manhattan Project, run by the United States with the help of the United Kingdom and Canada, developed multiple fission weapons which were used against Japan in 1945. During the project, the first fission reactors were developed as well, though they were primarily for weapons manufacture and did not generate electricity.

However, if the mass is critical only when the delayed neutrons are included, then the reaction can be controlled, for example by the introduction or removal of neutron absorbers. This is what allows nuclear reactors to be built. Fast neutrons are not easily captured by nuclei; they must be slowed (slow neutrons), generally by collision with the nuclei of a neutron moderator, before they can be easily captured. Today, this type of fission is commonly used to generate electricity.

Fusion

If nuclei are forced to collide, they can undergo nuclear fusion. This process may release or absorb energy. When the resulting nucleus is lighter than that of iron, energy is normally released; when the nucleus is heavier than that of iron, energy is generally absorbed. This process of fusion occurs in stars, which derive their energy from hydrogen and helium. They form, through stellar nucleosynthesis, the light elements (lithium to calcium) as well as some of the heavy elements (beyond iron and nickel, via the S-process). The remaining abundance of heavy elements, from nickel to uranium and beyond, is due to supernova nucleosynthesis, the R-process.

Of course, these natural processes of astrophysics are not examples of nuclear "technology". Because of the very strong repulsion of nuclei, fusion is difficult to achieve in a controlled fashion. Hydrogen bombs obtain their enormous destructive power from fusion, but their energy cannot be controlled. Controlled fusion is achieved in particle accelerators; this is how many synthetic elements are produced. A fusor can also produce controlled fusion and is a useful neutron source. However, both of these devices operate at a net energy loss. Controlled, viable fusion power has proven elusive, despite the occasional hoax. Technical and theoretical difficulties have hindered the development of working civilian fusion technology, though research continues to this day around the world.

Nuclear fusion was initially pursued only in theoretical stages during World War II, when scientists on the Manhattan Project (led by Edward Teller) investigated it as a method to build a bomb. The project abandoned fusion after concluding that it would require a fission reaction to detonate. It took until 1952 for the first full hydrogen bomb to be detonated, so-called because it used reactions between deuterium and tritium. Fusion reactions are much more energetic per unit mass of fuel than fission reactions, but starting the fusion chain reaction is much more difficult.

Nuclear Weapons

A nuclear weapon is an explosive device that derives its destructive force from nuclear reactions, either fission or a combination of fission and fusion. Both reactions release vast quantities of energy from relatively small amounts of matter. Even small nuclear devices can devastate a city by blast, fire and radiation. Nuclear weapons are considered weapons of mass destruction, and their use and control has been a major aspect of international policy since their debut.

The design of a nuclear weapon is more complicated than it might seem. Such a weapon must hold one or more subcritical fissile masses stable for deployment, then induce criticality (create a critical mass) for detonation. It also is quite difficult to ensure that such a chain reaction consumes a significant fraction of the fuel before the device flies apart. The procurement of a nuclear fuel is also more difficult than it might seem, as no naturally occurring substance is sufficiently unstable for this process to occur.

One isotope of uranium, namely uranium-235, is naturally occurring and sufficiently unstable, but it is always found mixed with the more stable isotope uranium-238. The latter accounts for more than 99% of the weight of natural uranium. Therefore some method of isotope separation based on the weight of three neutrons must be performed to enrich (isolate) uranium-235.

Alternatively, the element plutonium possesses an isotope that is sufficiently unstable for this process to be usable. Plutonium does not occur naturally, so it must be manufactured in a nuclear reactor.

Ultimately, the Manhattan Project manufactured nuclear weapons based on each of these elements. They detonated the first nuclear weapon in a test code-named "Trinity", near Alamogordo, New Mexico, on July 16, 1945. The test was conducted to ensure that the implosion method of detonation would work, which it did. A uranium bomb, Little Boy, was dropped on the Japanese city Hiroshima on August 6, 1945, followed three days later by the plutonium-based Fat Man on Nagasaki. In the wake of unprecedented devastation and casualties from a single weapon, the Japanese government soon surrendered, ending World war II.

Since these bombings, no nuclear weapons have been deployed offensively. Nevertheless, they prompted an arms race to develop increasingly destructive bombs to provide a nuclear deterrent. Just over four years later, on August 29, 1949, the Soviet Union detonated its first fission weapon. The United Kingdom followed on October 2, 1952; France, on February 13, 1960; and China on October 16, 1964. These five powers are permitted to possess nuclear weapons under the Nuclear Non-Proliferation Treaty. Only four recognized sovereign states are not parties to the treaty: India, Israel, Pakistan and North Korea. India, Pakistan and North Korea have openly tested and declared that they possess nuclear weapons. Israel has had a policy of opacity regarding its own nuclear weapons program. North Korea acceded to the treaty, violated it, and withdrew it in 2003.

Unlike convention weapons, the intense light, heat, and explosive force is not the only deadly component to a nuclear weapon. Approximately half of the deaths from Hiroshima and Nagasaki died two to five years afterward from radiation exposure. A radiological weapons is a type of nuclear weapon designed to distribute hazardous nuclear material in enemy areas. Such a weapon would not have the explosive capability of a fission or fusion bomb, but would kill many people and contaminate a large area. A radiological weapon has never been deployed. While considered useless by a conventional military, such a weapon raises concerns over nuclear terrorism.

There have been over 2,000 nuclear tests conducted since 1945. In 1963, all nuclear and many non-nuclear states signed the Limited Test Ban Treaty, pledging to refrain from testing nuclear weapons in the atmosphere, underwater, or in outer space. The treaty permitted underground nuclear testing. France continued atmospheric testing until 1974, while China continued up until 1980. The last underground test by the United States was in 1992, the Soviet Union in 1990, the United Kingdom in 1991, and both France and China continued testing until 1996. After adopting the Comprehensive Test Ban Treaty in 1996, all of these states have pledged to discontinue all nuclear testing. Non-signatories India and Pakistan last tested nuclear weapons in 1998.

Nuclear weapons are the most destructive weapons known - the archetypal weapons of mass destruction. Throughout the Cold War, the opposing powers had huge nuclear arsenals, sufficient to kill hundreds of millions of people. Generations of people grew up under the shadow of nuclear devastation, portrayed in films such as *Dr. Strangelove* and *The Atomic Cafe*.

However, the tremendous energy release in the detonation of a nuclear weapon also suggested the possibility of a new energy source.

Civilian uses

Nuclear power

Nuclear power is a type of nuclear technology involving the controlled use of nuclear fission to release energy for work including propulsion, heat, and the generation of electricity. Nuclear energy is produced by a controlled nuclear chain reaction which creates heat—and which is used to boil water, produce steam, and drive a steam turbine. The turbine is used to generate electricity and/or to do mechanical work.

Currently nuclear power provides approximately 15.7% of the world's electricity (in 2004) and is used to propel aircraft carriers, icebreakers and submarines (so far economics and fears in some ports have prevented the use of nuclear power in transport ships). All nuclear power plants use fission. Despite years of effort and the occasional hoax (i.e. cold fusion), no man-made fusion reaction has produced more energy than it consumed and been a viable source of electricity.

Medical applications

The medical applications of nuclear technology are divided into diagnostics and radiation treatment.

Imaging - medical and dental x-ray imagers use of Cobalt-60 or other x-ray sources. Technetium-99m is used, attached to organic molecules, as radioactive tracer in the human body, before being excreted by the kidneys. Positron emitting nucleotides are used for high resolution, short time span imaging in applications known as Positron emission tomography.

Radiation therapy is an effective treatment for cancer.

Industrial applications

Oil and Gas Exploration- Nuclear well logging is used to help predict the commercial viability of new or existing wells. The technology involves the use of a neutron or gamma-ray source and a radiation detector which are lowered into boreholes to determine the properties of the surrounding rock such as porosity and lithography.

Road Construction - Nuclear moisture/density gauges are used to determine the density of soils, asphalt, and concrete. Typically a Cesium-137 source is used.

Commercial applications

An ionization smoke detector includes a tiny mass of radioactive americium-241, which is a source of alpha radiation. Tritium is used with phosphor in rifle sights to increase nighttime firing accuracy. Luminescent exit signs use the same technology.

Food processing and agriculture

The Radura logo, used to show a food has been treated with ionizing radiation

Food irradiation is the process of exposing food to ionizing radiation in order to destroy microorganisms, bacteria, viruses, or insects that might be present in the food. The radiation sources used include radioisotope gamma ray sources, X-ray generators and electron accelerators. Further applications include sprout inhibition, delay of ripening, increase of juice yield, and improvement of re-hydration. Irradiation is a more general term of deliberate exposure of materials to radiation to achieve a technical goal (in this context 'ionizing radiation' is implied). As such it is also used on non-food items, such as medical hardware, plastics, tubes for gas-pipelines, hoses for floor-heating, shrink-foils for food packaging, automobile parts, wires and cables (isolation), tires, and even gemstones. Compared to the amount of food irradiated, the volume of those every-day applications is huge but not noticed by the consumer.

The genuine effect of processing food by ionizing radiation relates to damages to the DNA, the basic genetic information for life. Microorganisms can no longer proliferate and continue their malignant or pathogen activities. Spoilage causing micro-organisms cannot continue their activities. Insects do not survive or become incapable of procreation. Plants cannot continue the natural ripening or aging process. All these effects are beneficial to the consumer and the food industry, likewise.

The amount of energy imparted for effective food irradiation is low compared to cooking the same; even at a typical dose of 10 kGy most food, which is (with regard to warming) physically equivalent to water, would warm by only about 2.5 °C (4.5 °F).

The specialty of processing food by ionizing radiation is the fact, that the energy density per atomic transition is very high, it can cleave molecules and induce ionization (hence the name) which cannot be achieved by mere heating. This is the reason for new beneficial effects, however at the same time, for new concerns. The treatment of solid food by ionizing radiation can provide an effect similar to heat pasteurization of liquids, such as milk. However, the use of the term, cold pasteurization, to describe irradiated foods is controversial, because pasteurization and irradiation are fundamentally different processes, although the intended end results can in some cases be similar.

Food irradiation is currently permitted by over 40 countries and volumes are estimated to exceed 500,000 metric tons (490,000 LT; 550,000 ST) annually world wide.

Food irradiation is essentially a non-nuclear technology; it relies on the use of ionizing radiation which may be generated by accelerators for electrons and conversion into bremsstrahlung, but which may use also gamma-rays from nuclear decay. There is a worldwide industry for processing by ionizing radiation, the majority by number and by processing power using accelerators. Food irradiation is only a niche application compared to medical supplies, plastic materials, raw materials, gemstones, cables and wires, etc.

Accidents

Nuclear accidents, because of the powerful forces involved, are often very dangerous. Historically, the first incidents involved fatal radiation exposure. Marie Curie died from aplastic anemia which resulted from her high levels of exposure. Two scientists, an American and Canadian respectively, Harry Daghlian and Louis Slotin, died after mishandling the same plutonium mass. Unlike convention weapons, the intense light, heat, and explosive force is not the only deadly component to a nuclear weapon. Approximately half of the deaths from Hiroshima and Nagasaki died two to five years afterward from radiation exposure.

Civilian nuclear and radiological accidents primarily involve nuclear power plants. Most common are nuclear leaks that expose workers to hazardous material. A nuclear meltdown refers to the more serious hazard of releasing nuclear material into the surrounding environment. The most significant meltdowns occurred at Three Mile Island in Pennsylvania and Chernobyl in the Soviet Ukraine. Military reactors that experienced similar accidents were Windscale in the United Kingdom and SL-1 in the United States.

Military accidents usually involve the loss or unexpected detonation of nuclear weapons. The Castle Bravo test in 1954 produced a larger yield than expected, which contaminated nearby islands, a Japanese fishing boat (with one fatality), and raised concerns about contaminated fish in Japan. In the 1950s through 1970s, several nuclear bombs were lost from submarines and aircraft, some of which have never been recovered. The last twenty years have seen a marked decline in such accidents.