Technology and Society

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Chapter- 1

Technology and Society

Technology in society or **technology and culture** refers to cyclical co-dependence, co-influence, co-production of technology and society upon the other (technology upon culture, and vice-versa). This synergistic relationship occurred from the dawn of humankind, with the invention of simple tools and continues into modern technologies such as the printing press and computers. The academic discipline studying the impacts of science, technology, and society and vice versa is called (and can be found at) Science and technology studies.

Pre-historical examples

The importance of stone tools, circa 2.5 million years ago, is considered fundamental in human development in the hunting hypothesis.

It has been suggested, in *Catching Fire: How Cooking Made Us Human,* that the control of fire by early humans and the associated development of cooking was the spark that radically changed human evolution.

All these little changes in mobile phones, like Internet access, are further examples of the cycle of co-production. Society's need for being able to call on people and be available everywhere resulted in the research and development of mobile phones. They in turn influenced the way we live our lives. As the populace relies more and more on mobile phones, additional features were requested. This is also true with today's modern media player.

Society also influenced changes to previous generation media players. In the first personal music players, cassettes stored music. However, that method seemed fragile and relatively low fidelity when compact disks came along. Later, availability of MP3 and other compact file formats made compact disks seem too large and limited, so manufactures created MP3 players which are small and hold large amount of data. Societal preferences helped determined the course of events through predictable preferences.

Economics and technological development

Nuclear reactor, Doel, Belgium

In ancient history, economics began when occasional, spontaneous exchange of goods and services was replaced over time by deliberate trade structures. Makers of arrowheads, for example, might have realized they could do better by concentrating on making arrowheads and barter for other needs. Clearly, regardless of goods and services bartered, some amount of technology was involved—if no more than in the making of shell and bead jewelry. Even the shaman's potions and sacred objects can be said to have involved some technology. So, from the very beginnings, technology can be said to have spurred the development of more elaborate economies.

In the modern world, superior technologies, resources, geography, and history give rise to robust economies; and in a well-functioning, robust economy, economic excess naturally flows into greater use of technology. Moreover, because technology is such an inseparable part of human society, especially in its economic aspects, funding sources for (new) technological endeavors are virtually illimitable. However, while in the beginning, technological investment involved little more than the time, efforts, and skills of one or a few men, today, such investment may involve the collective labor and skills of many millions.

Funding

Consequently, the sources of funding for large technological efforts have dramatically narrowed, since few have ready access to the collective labor of a whole society, or even a large part. It is conventional to divide up funding sources into governmental (involving whole, or nearly whole, social enterprises) and private (involving more limited, but generally more sharply focused) business or individual enterprises.

Government funding for new technology

The government is a major contributor to the development of new technology in many ways. In the United States alone, many government agencies specifically invest billions of dollars in new technology.

[In 1980, the UK government invested just over 6-million pounds in a four-year program, later extended to six years, called the Microelectronics Education Programme (MEP), which was intended to give every school in Britain at least one computer, software, training materials, and extensive teacher training. Similar programs have been instituted by governments around the world.]

Technology has frequently been driven by the military, with many modern applications developed for the military before they were adapted for civilian use. However, this has always been a two-way flow, with industry often developing and adopting a technology only later adopted by the military.

Entire government agencies are specifically dedicated to research, such as America's National Science Foundation, the United Kingdom's scientific research institutes, America's Small Business Innovative Research effort. Many other government agencies dedicate a major portion of their budget to research and development.

Private funding

Research and development is one of the smallest areas of investments made by corporations toward new and innovative technology.

Many foundations and other nonprofit organizations contribute to the development of technology. In the OECD, about two-thirds of research and development in scientific and technical fields is carried out by industry, and 98 percent and 10 percent respectively by universities and government. But in poorer countries such as Portugal and Mexico the industry contribution is significantly less. The U.S. government spends more than other countries on military research and development, although the proportion has fallen from about 30 percent in the 1980s to less than 10 percent.

Other economic considerations

- Appropriate technology, sometimes called "intermediate" technology, more of an economics concern, refers to compromises between central and expensive technologies of developed nations and those that developing nations find most effective to deploy given an excess of labour and scarcity of cash.
- Persuasion technology: In economics, definitions or assumptions of progress or growth are often related to one or more assumptions about technology's economic influence. Challenging prevailing assumptions about technology and its usefulness has led to alternative ideas like uneconomic growth or measuring well-being. These, and economics itself, can often be described as technologies, specifically, as persuasion technology.
- Technocapitalism
- Technological diffusion
- Technology acceptance model
- Technology lifecycle
- Technology transfer

Sociological factors and effects

Downtown Tokyo (2005)

The use of technology has a great many effects; these may be separated into intended effects and unintended effects. Unintended effects are usually also unanticipated, and often unknown before the arrival of a new technology. Nevertheless, they are often as important as the intended effect.

Values

The implementation of technology influences the values of a society by changing expectations and realities. The implementation of technology is also influenced by values. There are (at least) three major, interrelated values that inform, and are informed by, technological innovations:

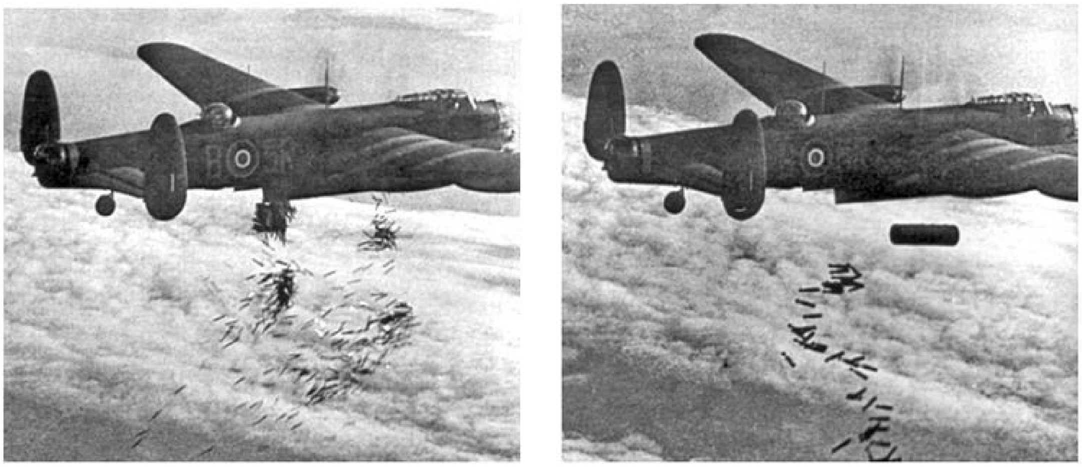
- Mechanistic world view: Viewing the universe as a collection of parts, (like a machine), that can be individually analyzed and understood (McGinn 1991). This is a form of reductionism that is rare nowadays. However, the "neo-mechanistic world view" holds that nothing in the universe cannot be understood by the human intellect. Also, while all things are greater than the sum of their parts (e.g., even if we consider nothing more than the information involved in their combination), in principle, even this excess must eventually be understood by human intelligence. That is, no divine or vital principle or essence is involved.

- Efficiency: A value, originally applied only to machines, but now applied to all aspects of society, so that each element is expected to attain a higher and higher percentage of its maximal possible performance, output, or ability. (McGinn 1991)
- Social progress: The belief that there is such a thing as social progress, and that, in the main, it is beneficent. Before the Industrial Revolution, and the subsequent explosion of technology, almost all societies believed in a cyclical theory of social movement and, indeed, of all history and the universe. This was, obviously, based on the cyclicity of the seasons, and an agricultural economy's and society's strong ties to that cyclicity. Since much of the world is closer to their agricultural roots, they are still much more amenable to cyclicity than progress in history. This may be seen, for example, in Prabhat rainjan sarkar's modern social cycles theory. For a more westernized version of social cyclicity, *Generations: The History of America's Future, 1584 to 2069* (Paperback) by Neil Howe and William Strauss; Harper Perennial; Reprint edition (September 30, 1992); ISBN 0-688-11912-3, and subsequent books by these authors.

Ethics

Winston (Winston 2003) provides an excellent summary of the ethical implications of technological development and deployment. He states there are four major ethical implications:

- Challenges traditional ethical norms. Because technology impacts relationships among individuals, it challenges how individuals deal with each other, even in ethical ways. One example of this is challenging the definition of "human life" as embodied by debates in the areas of abortion, euthanasia, capital punishment, etc., which all involve modern technological developments.
- Creates an aggregation of effects. One of the greatest problems with technology is that its detrimental effects are often small, but cumulative. Such is the case with the pollution from the burning of fossil fuels in automobiles. Each individual automobile creates a very small, almost negligible, amount of pollution, however the cumulative effect could possibly contribute to the global warming effect. Other examples include accumulations of chemical pollutants in the human body, urbanization effects on the environment, etc.



A Lancaster dropping bundles of 4lb stick incendiaries (left), 30lb incendiaries and a "cookie" (right)

- Changes the distribution of justice. In essence, those with technology tend to have higher access to justice systems. Or, justice is not distributed equally to those with technology versus those without.
- Provides great power. Not only does technology amplify the ability, and hence the strength, of humans, it also provides a great strategic advantage to the human(s) who hold the greatest amount of technology. Consider the strategic advantage gained by having greater technological innovations in the military, pharmaceuticals, computers, etc. For example, Bill Gates has considerable influence even outside of the computer industry) in the course of human affairs due to his successful implementation of computer technology

Lifestyle

In many ways, technology simplifies life.

- The rise of a leisure class
- A more informed society
- Sets the stage for more complex learning tasks
- Increases multi-tasking (although this may not be simplifying)
- Global networking
- Creates denser social circles
- Cheaper prices
- Greater specialization in jobs

In other ways, technology complicates life.

- Pollution is a serious problem in a technologically advanced society (from acid rain to Chernobyl and Bhopal)

- The increase in transportation technology has brought congestion in some areas
- Technicism (although this may not be complicating)
- New forms of danger existing as a consequence of new forms of technology, such as the first generation of nuclear reactors
- New forms of entertainment, such as video games and internet access could have possible social effects on areas such as academic performance
- Increased probability of some diseases and disorders, such as obesity
- Social separation of singular human interaction. Technology has increased the need to talk to more people faster.
- Structural unemployment
- Anthropogenic climate change

Institutions and groups

Technology often enables organizational and bureaucratic group structures that otherwise and heretofore were simply not possible. Examples of this might include:

- The rise of very large organizations: e.g., governments, the military, health and social welfare institutions, supranational corporations.
- The commercialization of leisure: sports events, products, etc. (McGinn)
- The almost instantaneous dispersal of information (especially news) and entertainment around the world.

International

Technology enables greater knowledge of international issues, values, and cultures. Due mostly to mass transportation and mass media, the world seems to be a much smaller place, due to the following, among others:

- Globalization of ideas
- Embeddedness of values
- Population growth and control
- Others

Environment

Technology provides an understanding, and an appreciation for the world around us.

Most modern technological processes produce unwanted byproducts in addition to the desired products, which is known as industrial waste and pollution. While most material waste is re-used in the industrial process, many forms are released into the environment, with negative environmental side effects, such as pollution and lack of sustainability. Different social and political systems establish different balances between the value they place on additional goods versus the disvalues of waste products and pollution. Some technologies are designed specifically with the environment in mind, but most are designed first for economic or ergonomic effects. Historically, the value of a clean environment and more efficient productive processes has been the result of an increase in the wealth of society, because once people are able to provide for their basic needs, they are able to focus on less-tangible goods such as clean air and water.

The effects of technology on the environment are both obvious and subtle. The more obvious effects include the depletion of nonrenewable natural resources (such as petroleum, coal, ores), and the added pollution of air, water, and land. The more subtle effects include debates over long-term effects (e.g., global warming, deforestation, natural habitat destruction, coastal wetland loss.)

Each wave of technology creates a set of waste previously unknown by humans: toxic waste, radioactive waste, electronic waste.

One of the main problems is the lack of an effective way to remove these pollutants on a large scale expediently. In nature, organisms "recycle" the wastes of other organisms, for example, plants produce oxygen as a by-product of photosynthesis, oxygen-breathing organisms use oxygen to metabolize food, producing carbon dioxide as a by-product, which plants use in a process to make sugar, with oxygen as a waste in the first place. No such mechanism exists for the removal of technological wastes.

Humanity at the moment may be compared to a colony of bacteria in a Petri dish with a constant food supply: with no way to remove the wastes of their metabolism, the bacteria eventually poison themselves.

Construction and shaping

Choice

Society also controls technology through the choices it makes. These choices not only include consumer demands; they also include:

- the channels of distribution, how do products go from raw materials to consumption to disposal;
- the cultural beliefs regarding style, freedom of choice, consumerism, materialism, etc.;
- the economic values we place on the environment, individual wealth, government control, capitalism, etc.

According to Williams and Edge (Williams & Edge 1996), the construction and shaping of technology includes the concept of choice (and not necessarily conscious choice). Choice is inherent in both the design of individual artifacts and systems, and in the making of those artifacts and systems.

The idea here is that a single technology may not emerge from the unfolding of a predetermined logic or a single determinant, technology could be a garden of forking paths, with different paths potentially leading to different technological outcomes. This is a position that has been developed in detail by Judy Wajcman Therefore, choices could have differing implications for society and for particular social groups.hh

Autonomous technology

In one line of thought, technology develops autonomously, in other words, technology seems to feed on itself, moving forward with a force irresistible by humans. To these individuals, technology is "inherently dynamic and self-augmenting." (McGinn 1991, p. 73) Jacques Ellul is one proponent of the irresistibleness of technology to humans. He espouses the idea that humanity cannot resist the temptation of expanding our knowledge and our technological abilities. However, he does not believe that this seeming autonomy of technology is inherent. But the perceived autonomy is because humans do not adequately consider the responsibility that is inherent in technological processes.

Another proponent of these ideas is Langdon Winner who believes that technological evolution is essentially beyond the control of individuals or society.

Government

Individuals rely on governmental assistance to control the side effects and negative consequences of technology.

- Supposed independence of government. An assumption commonly made about the government is that their governance role is neutral or independent. However some argue that governing is a political process, so government will be influenced by political winds of influence. In addition, because government provides much of the funding for technological research and development, it has a vested interest in certain outcomes. Other point out that the world's biggest ecological disasters, such as the Aral Sea, Chernobyl, and Lake Karachay have been caused by government projects, which are not accountable to consumers.

- Liability. One means for controlling technology is to place responsibility for the harm with the agent causing the harm. Government can allow more or less legal liability to fall to the organizations or individuals responsible for damages.
- Legislation. A source of controversy is the role of industry versus that of government in maintaining a clean environment. While it is generally agreed that industry needs to be held responsible when pollution harms other people, there is disagreement over whether this should be prevented by legislation or civil courts, and whether ecological systems as such should be protected from harm by governments.

Recently, the social shaping of technology has had new influence in the fields of e-science and e-social science in the United Kingdom, which has made centers focusing on the social shaping of science and technology a central part of their funding programs.

Chapter- 2

Theories of Technology

There are a number of theories attempting to address technology, which tend to be associated with the disciplines of science and technology studies (STS) and communication studies. Most generally, the theories attempt to address the relationship between technology and society and prompt questions about agency, determinism/autonomy, and teleonomy.

If forced, one might categorize them into social and group theories. Additionally, one might distinguish between descriptive and critical theories. *Descriptive* theories attempt to address the definition and substance of technology, how does it emerge, change, and, of course, what is its relation to the human/social sphere? More substantively, to what extent is technology autonomous and how much force does it have in determining social structure or human practice? *Critical* **theories of technology** often take a descriptive theory as their basis and articulate concerns and ask in what ways can that relationship be changed?

Social theories

Descriptive approaches

- Actor-network theory (ANT) **-** posits a heterogeneous network of humans and non-humans as equal interrelated actors. It strives for impartiality in the description of human and nonhuman actors and the reintegration of the natural and social worlds. For example, Latour (1992) argues that instead of worrying whether we are anthropomorphizing technology, we should embrace it as inherently anthropomorphic: technology is made by humans, substitutes for the actions of humans, and shapes human action. What is important is the chain and gradients of actors' actions and competences, and the degree to which we choose to have figurative representations. Key concepts include the **inscription** of beliefs, practices, relations into technology, which is then said to **embody** them. Key authors include Latour (1997) and Callon (1999).

- Social construction of technology (SCOT) **-** argues that technology does not determine human action, but that human action shapes technology. Key concepts include:

- **interpretive flexibility**: "Technological artifacts are culturally constructed and interpreted ... By this we mean not only that there is flexibility in how people think of or interpret artifacts but also that there is flexibility in how artifacts are designed."
    - **relevant social group**: shares a particular set of meanings about an artifact
    - **closure** and stabilization: when the relevant social group has reached a consensus
    - wider context: "the sociocultural and political situation of a social group shapes its norms and values, which in turn influence the meaning given to an artifact"

  Key authors include Pinch and Bijker (1992) and Kline.

- Structuration theory - defines structures as rules and resources organized as properties of social systems. The theory employs a recursive notion of actions constrained and enabled by structures which are produced and reproduced by that action. Consequently, in this theory technology is not rendered as an artifact, but instead examines how people, as they interact with a technology in their ongoing practices, enact structures which shape their emergent and situated use of that technology. Key authors include DeSantis and Poole (1990), and Orlikowski (1992).

- Systems theory - considers the historical development of technology and media with an emphasis on inertia and heterogeneity, stressing the connections between the artifact being built and the social, economic, political and cultural factors surrounding it. Key concepts include **reverse salients** when elements of a system lag in development with respect to others, differentiation, operational closure, and autopoietic autonomy. Key authors include Thomas P. Hughes (1992) and Luhmann (2000).

Critical theories

- Values in Design - asks how do we ensure a place for values (alongside technical standards such as speed, efficiency, and reliability) as criteria by which we judge the quality and acceptability of information systems and new media. How do values such as privacy, autonomy, democracy, and social justice become integral to conception, design, and development, not merely retrofitted after completion? Key thinkers include Nissenbaum (2001).

Other stances

Additionally, many authors have posed technology so as to critique and or emphasize aspects of technology as addressed by the mainline theories. For example, Steve Woolgar (1991) considers *technology as text* in order to critique the sociology of scientific knowledge as applied to technology and to distinguish between three responses to that notion: the instrumental response (interpretive flexibility), the interpretivist response (environmental/organizational influences), the reflexive response (a double hermeneutic). Pfaffenberger (1992) treats *technology as drama* to argue that a recursive structuring of technological artifacts and their social structure discursively regulate the technological construction of political power. A technological drama is a discourse of technological "statements" and "counterstatements" within the processes of technological regularization, adjustment, and reconstitution.

An important philosophical approach to technology has been taken by Bernard Stiegler, whose work has been influenced by other philosophers and historians of technology including Gilbert Simondon and André Leroi-Gourhan.

Group theories

There are also a number of technology related theories that address how (media) technology affects group processes. Broadly, these theories are concerned with the social effects of communication media. Some (e.g., media richness) are concerned with questions of media choice (i.e., when to use what medium effectively). Other theories (social presence, SIDE, media naturalness) are concerned with the consequences of those media choices (i.e., what are the social effects of using particular communication media).

- Social presence theory (Short, et al., 1976) is a seminal theory of the social effects of communication technology. Its main concern is with telephony and telephone conferencing (the research was sponsored by the British Post Office, now British Telecom). It argues that the social impact of a communication medium depend on the *social presence* it allows communicators to have. Social presence is defined as a property of the medium itself: the degree of acoustic, visual, and physical contact that it allows. The theory assumes that more contact will increase the key components of "presence": greater intimacy, immediacy, warmth and inter-personal rapport. As a consequence of social presence, social influence is expected to increase. In the case of communication technology, the assumption is that more text-based forms of interaction (e-mail, instant messaging) are less social, and therefore less conducive to social influence.

- Media richness theory (Daft & Lengel, 1986) shares some characteristics with social presence theory. It posits that the amount of information communicated differs with respect to a medium's *richness*. The theory assumes that resolving ambiguity and reducing uncertainty are the main goals of communication. Because communication media differ in the rate of understanding they can achieve in a specific time (with "rich" media carrying more information), they are not all capable of resolving uncertainty and ambiguity well. The more restricted the medium's capacity, the less uncertainty and equivocality it is able to manage. It follows that the richness of the media should be matched to the task so as to prevent over simplification or complication.

- Media naturalness theory (Kock, 2001; 2004) builds on human evolution ideas and has been proposed as an alternative to media richness theory. Media naturalness theory argues that since our Stone Age hominid ancestors have communicated primarily face-to-face, evolutionary pressures have led to the development of a brain that is consequently designed for that form of communication. Other forms of communication are too recent and unlikely to have posed evolutionary pressures that could have shaped our brain in their direction. Using communication media that suppress key elements found in face-to-face communication, as many electronic communication media do, thus ends up posing cognitive obstacles to communication. This is particularly the case in the context of complex tasks (e.g., business process redesign, new product development, online learning), because such tasks seem to require more intense communication over extended periods of time than simple tasks.

- Media synchronicity theory (MST, Dennis & Valacich, 1999]) redirects richness theory towards the *synchronicity* of the communication.

- The social identity model of deindividuation effects (or SIDE model, Postmes, Spears and Lea 1999; Reicher, Spears and Postmes, 1995; Spears & Lea, 1994) was developed as a response to the idea that anonymity and reduced presence made communication technology socially impoverished (or "deindividuated"). It provided an alternative explanation for these "deindividuation effects" based on theories of social identity (e.g., Turner et al., 1987). The SIDE model distinguishes cognitive and strategic effects of a communication technology. Cognitive effects occur when communication technologies make "salient" particular aspects of personal or social identity. For example, certain technologies such as email may disguise characteristics of the sender that individually differentiate them (i.e., that convey aspects of their personal identity) and as a result more attention may be given to their social identity. The strategic effects are due to the possibilities, afforded by communication technology, to selectively communicate or enact particular aspects of identity, and disguise others. SIDE therefore sees the social and the technological as mutually determining, and the behavior associated with particular communication forms as the product or interaction of the two.

- Time, interaction, and performance (TIP; McGrath, 1991) theory describes work groups as time-based, multi-modal, and multi-functional social systems. Groups interact in one of the modes of inception, problem solving, conflict resolution, and execution. The three functions of a group are production (towards a goal), support (affective) and well-being (norms and roles).

Analytic theories

Finally, there are theories of technology which are not defined or claimed by a proponent, but are used by authors in describing existing literature, in contrast to their own or as a review of the field.

For example, Markus and Robey (1988) propose a general technology theory consisting of the causal structures of agency (technological, organizational, imperative, emergent), its structure (variance, process), and the level (micro, macro) of analysis.

Orlikowski (1992) notes that previous conceptualizations of technology typically differ over scope (is technology more than hardware?) and role (is it an external objective force, the interpreted human action, or an impact moderated by humans?) and identifies three models:

1. technological imperative: focuses on organizational characteristics which can be measured and permits some level of contingency
2. strategic choice: focuses on how technology is influenced by the context and strategies of decision-makers and users
3. technology as a trigger of structural change: views technology as a social object

DeSanctis and Poole (1994) similarly write of three views of technology's effects:

1. decision-making: the view of engineers associated with positivist, rational, systems rationalization, and deterministic approaches
2. institutional school: technology is an opportunity for change, focuses on social evolution, social construction of meaning, interaction and historical processes, interpretive flexibility, and an interplay between technology and power
3. an integrated perspective (social technology): soft-line determinism, with joint social and technological optimization, structural symbolic interaction theory

Bimber (1998) addresses the determinacy of technology effects by distinguishing between the:

1. normative: an autonomous approach where technology is an important influence on history only where societies attached cultural and political meaning to it (e.g., the industrialization of society)
2. nomological: a naturalistic approach wherein an inevitable technological order arises based on laws of nature (e.g., steam mill had to follow the hand mill).
3. unintended consequences: a fuzzy approach that is demonstrative that technology is contingent (e.g., a car is faster than a horse, but unbeknownst to its original creators become a significant source of pollution)

Chapter- 3

Technological Determinism

Technological determinism is a reductionist theory that presumes that a society's technology drives the development of its social structure and cultural values. The term is believed to have been coined by Thorstein Veblen (1857-1929), an American sociologist. The most radical technological determinist in America in the twentieth century was most likely Clarence Ayres who was a follower of Thorstein Veblen and John Dewey. William Ogburn was also known for his radical technological determinism.

Origin

The term is believed to have been coined by Thorstein Veblen (1857-1929), an American. Veblen's contemporary, popular historian Charles Beard, provided this apt determinist image, "Technology marches in seven-league boots from one ruthless, revolutionary conquest to another, tearing down old factories and industries, flinging up new processes with terrifying rapidity."

Explanation

Most interpretations of technological determinism share two general ideas:

- that the development of technology itself follows a predictable, traceable path largely beyond cultural or political influence, and
- that technology in turn has "effects" on societies that are inherent, rather than socially conditioned or produced because that society organizes itself to support and further develop a technology once it has been introduced.

Strict adherents to technological determinism do not believe the influence of technology differs based on how much a technology is or can be used. Instead of considering technology as part of a larger spectrum of human activity, technological determinism sees technology as the basis for all human activity.

Technological determinism has been summarized as 'The belief in technology as a key governing force in society ...' (Merritt Roe Smith). 'The idea that technological development determines social change ...' (Bruce Bimber). It changes the way people think and how they interact with others and can be described as '...a three-word logical proposition: "Technology determines history"' (Raymond Williams) . It is, '... the belief that social progress is driven by technological innovation, which in turn follows an "inevitable" course.' (Michael L. Smith). This 'idea of progress' or 'doctrine of progress' is centralised around the idea that social problems can be solved by technological advancement, and this is the way that society moves forward. Technological determinists believe that "'You can't stop progress', implying that we are unable to control technology" (Lelia Green). This suggests that we are somewhat powerless and society allows technology to drive social changes because, "societies fail to be aware of the alternatives to the values embedded in it [technology]" (Merritt Roe Smith).

Technological determinism has been defined as an approach that identifies technology, or technological advances, as the central causal element in processes of social change (Croteau and Hoynes). As a technology is stabilized, its design tends to dictate users' behaviors, consequently diminishing human agency. This stance however ignores the social and cultural circumstances in which the technology was developed. Sociologist Claude Fischer (1992) characterized the most prominent forms of technological determinism as "billiard ball" approaches, in which technology is seen as an external force introduced into a social situation, producing a series of ricochet effects.

Rather than acknowledging that a society or culture interacts with and even shapes the technologies that are used, a technological determinist view holds that "the uses made of technology are largely determined by the structure of the technology itself, that is, that its functions follow from its form" (Neil Postman). However, this is not to be confused with the inevitability thesis (Daniel Chandler), which states that once a technology is introduced into a culture that what follows is the inevitable development of that technology.

For example, we could examine why Romance Novels have become so dominant in our society compared to other forms of novels like the Detective or Western novel. We might say that it was because of the invention of the perfect binding system developed by publishers. This was where glue was used instead of the time-consuming and very costly process of binding books by sewing in separate signatures. This meant that these books could be mass-produced for the wider public. We would not be able to have mass literary without mass production. This example is closely related to Marshall McLuhan's belief that print helped produce the nation state. This moved society on from an oral culture to a literate culture but also introduced a capitalist society where there was clear class distinction and individualism. As Postman maintains

"the printing press, the computer, and television are not therefore simply machines which convey information. They are metaphors through which we conceptualize reality in one way or another. They will classify the world for us, sequence it, frame it, enlarge it, reduce it, argue a case for what it is like. Through these media metaphors, we do not see the world as it is. We see it as our coding systems are. Such is the power of the form of information."

Hard and soft determinism

In examining determinism **Hard determinism** can be contrasted with **Soft Determinism**. A compatibilist says that it is possible for free will and determinism to exist in the world together while a incompatibilist would say that they can not and there must be one or the other. Those who support determinism can be further divided.

Hard determinists would view technology as developing independent from social concerns. They would say that technology creates a set of powerful forces acting to regulate our social activity and its meaning. According to this view of determinism we organize ourselves to meet the needs of technology and the outcome of this organization is beyond our control or we do not have the freedom to make a choice regarding the outcome.

Soft Determinism, as the name suggests, is a more passive view of the way technology interacts with socio-political situations. Soft determinists still subscribe to the fact that technology is the guiding force in our evolution, but would maintain that we have a *chance* to make decisions regarding the outcomes of a situation. This is not to say that free will exists but it is the possibility for us to *roll the dice* and see what the outcome is. A slightly different variant of soft determinism is the 1922 technology-driven theory of social change proposed by William Fielding Ogburn, in which society must adjust to the consequences of major inventions, but often does so only after a period of cultural lag.

Technology as neutral

Individuals who consider technology as neutral see technology as neither good nor bad and what matters are the ways in which we use technology. An example of a neutral viewpoint is, "guns are neutral and its up to how we use them whether it would be 'good or bad'" (Green, 2001). Mackenzie and Wajcman believe that technology is neutral only if it's never been used before, or if no one knows what it is going to be used for (Green, 2001). In effect, guns would be classified as neutral if and only if society were none the wiser of their existence and functionality (Green, 2001). Obviously, such a society is non-existent and once becoming knowledgeable about technology, the society is drawn into a social progression where nothing is 'neutral about society' (Green). According to Lelia Green, if one believes technology is neutral, one would disregard the cultural and social conditions that technology was produced (Green, 2001). This view is also referred to as technological instrumentalism.

Criticism

Scepticism about technological determinism emerged alongside increased pessimism about techno-science in the mid-20th century, in particular around the use of nuclear energy in the production of nuclear weapons, Nazi human experimentation during World War II, and the problems of economic development in the third world (also known as the global south). As a direct consequence, desire for greater control of the course of development of technology gave rise to disenchantment with the model of technological determinism in academia.

Modern theorists of technology and society no longer consider technological determinism to be a very accurate view of the way in which we interact with technology, even though determinist assumptions and language fairly saturate the writings of many boosters of technology, the business pages of many popular magazines, and much reporting on technology. Instead, research in science and technology studies, social construction of technology and related fields have emphasised more nuanced views that resist easy causal formulations. They emphasise that "The relationship between technology and society cannot be reduced to a simplistic cause-and-effect formula. It is, rather, an 'intertwining'", whereby technology does not determine but "...operates, and are operated upon in a complex social field" (Murphie and Potts).

In his article "Subversive Rationalization: Technology, Power and Democracy with Technology," Andrew Feenberg argues that **technological determinism** is not a very well founded concept by illustrating that two of the founding theses of determinism are easily questionable and in doing so calls for what he calls democratic rationalization (Feenberg 210-212).

Prominent opposition to technologically determinist thinking has emerged within work on the social construction of technology (SCOT). SCOT research, such as that of Mackenzie and Wajcman (1997) argues that the path of innovation and its social consequences are strongly, if not entirely shaped by society itself through the influence of culture, politics, economic arrangements, regulatory mechanisms and the like. In its strongest form, verging on social determinism, "What matters is not the technology itself, but the social or economic system in which it is embedded" (Langdon Winner).

In his influential but contested article "Do Artifacts Have Politics?", Langdon Winner illustrates a form of technological determinism by elaborating instances in which artifacts can have politics.

Although "The deterministic model of technology is widely propagated in society" (Sarah Miller), it has also been widely questioned by scholars. Lelia Green explains that, "When technology was perceived as being outside society, it made sense to talk about technology as neutral". Yet, this idea fails to take into account that culture is not fixed and society is dynamic. When "Technology is implicated in social processes, there is nothing neutral about society" (Lelia Green). This confirms one of the major problems with "technological determinism and the resulting denial of human responsibility for change. There is a loss of human involvement that shape technology and society" (Sarah Miller).

Another conflicting idea is that of technological somnambulism, a term coined by Winner in his essay "Technology as Forms of Life". Winner wonders whether or not we are simply *sleepwalking* through our existence with little concern or knowledge as to how we truly interact with technology. In this view it is still possible for us to wake up and once again take control of the direction in which we are traveling (Winner 104). However, it requires society to adopt Ralph Schroeder's claim that, "users don't just passively consume technology, but actively transform it".

In opposition to technological determinism are those who subscribe to the belief of social determinism and postmodernism. Social determinists believe that social circumstances alone select which technologies are adopted, with the result that no technology can be considered "inevitable" solely on its own merits. Technology and culture are not neutral and when knowledge comes into the equation, technology becomes implicated in social processes. The knowledge of how to create and enhance technology, and of how to use technology is socially bound knowledge. Postmodernists take another view, suggesting that what is right or wrong is dependent on circumstance. They believe technological change can have implications on the past, present and future. While they believe technological change is influenced by changes in government policy, society and culture, they consider the notion of change to be a paradox, since change is constant.

Media and cultural studies theorist Brian Winston, in response to technological determinism, developed a model for the emergence of new technologies which is centered on the Law of the suppression of radical potential. In two of his books - *Technologies of Seeing: Photography, Cinematography and Television* (1997) and *Media Technology and Society* (1998) - Winston applied this model to show how technologies evolves over time, and how their 'invention' is mediated and controlled by society and societal factors which suppress the radical potential of a given technology.

Notable Technological Determinists

Thomas L. Friedman, American journalist, columnist and author, admits to being a technological determinist in his book *The World is Flat*.

Futurist Raymond Kurzweil's theories about a technological singularity follow a technologically deterministic view of history.

Some interpret Karl Marx as advocating technological determinism, with such statements as "The windmill gives you society with the feudal lord: the steam-mill, society with the industrial capitalist" (*The Poverty of Philosophy,* 1847), but others argue that Marx was not a determinist.

Technological determinist Walter Ong reviews the societal transition from an oral culture to a written culture in his work "Orality and Literacy." He asserts that this particular development is attributable to the use of new technologies of literacy (particularly print and writing,) to communicate thoughts which could previously only be verbalized. He furthers this argument by claiming that writing is purely context dependent as it is a "secondary modelling system" (8). Reliant upon the earlier primary system of spoken language, writing manipulates the potential of language as it depends purely upon the visual sense to communicate the intended information. Furthermore, the rather stagnant technology of literacy distinctly limits the usage and influence of knowledge, it unquestionably effects the evolution of society. In fact, Ong asserts that “more than any other single invention, writing has transformed human consciousness” (Ong 1982: 78).

Subset of Technological Determinism

Media determinism, a subset of technological determinism, is a philosophical and sociological position which posits the power of the media to impact society. As a theory of change, it is seen as a cause and effect relationship. New media technologies bring about change in society. Much like the "magic bullet" theories of mass communication, media determinism provides a somewhat simplistic explanation for very complicated scenarios. Cause and effect relationships are reduced to their most basic premise, and explained as such. Techno-centrist theories make everything explainable in light of the media's relation to technological developments. Two leading media determinists are the Canadian scholars Harold Innis and Marshall McLuhan.

Chapter- 4

Social Construction of Technology

Social construction of technology (also referred to as **SCOT**) is a theory within the field of Science and Technology Studies. Advocates of SCOT -- that is, social constructivists -- argue that technology does not determine human action, but that rather, human action shapes technology. They also argue that the ways a technology is used cannot be understood without understanding how that technology is embedded in its social context. SCOT is a response to technological determinism and is sometimes known as technological constructivism.

SCOT draws on work done in the constructivist school of the sociology of scientific knowledge, and its subtopics include actor-network theory (a branch of the sociology of science and technology) and historical analysis of sociotechnical systems, such as the work of historian Thomas P. Hughes. Leading adherents of SCOT include Wiebe Bijker and Trevor Pinch.

SCOT holds that those who seek to understand the reasons for acceptance or rejection of a technology should look to the social world. It is not enough, according to SCOT, to explain a technology's success by saying that it is "the best" -- researchers must look at how the criteria of being "the best" is defined and what groups and stakeholders participate in defining it. In particular, they must ask who defines the technical criteria success is measured by, why technical criteria are defined this way, and who is included or excluded.

SCOT is not only a theory, but also a methodology: it formalizes the steps and principles to follow when one wants to analyze the causes of technological failures or successes.

Legacy of the Strong Programme in the Sociology of Science

At the point of its conception, the SCOT approach was partly motivated by the ideas of the Strong Programme in the Sociology of Science (Bloor 1973). In their seminal article, Pinch and Bijker refer to the *Principle of Symmetry* as the most influential tenet of the Sociology of Science, which should be applied in historical and sociological investigations of technology as well. It is strongly connected to Bloor's theory of social causation.

Symmetry

The *Principle of Symmetry* holds that in explaining the origins of scientific beliefs, that is, assessing the success and failure of models, theories, or experiments, the historian/sociologist should deploy the same *kind* of explanation in the cases of success as in cases of failure. When investigating beliefs, researchers should be impartial to the (a posteriori attributed) truth or falsehood of those beliefs, and the explanations should be unbiased. The strong programme adopts a position of relativism or neutralism regarding the arguments that social actors put forward for the acceptance/rejection of any technology. All arguments (social, cultural, political, economic, as well as technical) are to be treated equally.

The symmetry principle addresses the problem that the historian is tempted to explain the success of successful theories by referring to their "objective truth", or inherent "technical superiority", whereas s/he is more likely to put forward sociological explanations (citing political influence or economic reasons) only in the case of failures. For example, having experienced the obvious success of the chain-driven bicycle for decades, it is tempting to attribute its success to its "advanced technology" compared to the "primitiveness" of the Penny Farthing, but if we look closely and symmetrically at their history (as Pinch and Bijker do), we can see that at the beginning bicycles were valued according to quite different standards than nowadays. The early adopters (predominantly young, well-to-do gentlemen) valued the speed, the thrill, and the spectacularity of the Penny Farthing - in contrast to the security and stability of the chain-driven Safety Bicycle. Many other social factors (e.g., the contemporary state of urbanism and transport, women's clothing habits and feminism) have influenced and changed the relative valuations of bicycle models.

A weak reading of the *Principle of Symmetry* points out that there often are many competing theories or technologies, which all have the potential to provide slightly different solutions to similar problems. In these cases, sociological factors tip the balance between them: that's why we should pay equal attention to them.

A strong, social constructivist reading would add that even the emergence of the questions or problems to be solved are governed by social determinations, so the Principle of Symmetry is applicable even to the apparently purely technical issues.

Core concepts

Interpretative Flexibility

Interpretative Flexibility means that each technological artifact has different meanings and interpretations for various groups. Bijker and Pinch show that the air tire of the bicycle meant a more convenient mode of transportation for some people, whereas it meant technical nuisances, traction problems and ugly aesthetics to others. Sport cyclists were concerned by the speed reduction caused by the air tire.

These alternative interpretations generate different *problems* to be solved. Aesthetics, convenience or speed should be prioritized? What is the best tradeoff between traction and speed?

Relevant Social Groups

The most basic relevant groups are the *users* and the *producers* of the technological artifact, but most often many subgroups can be delineated - users with different socioeconomic status, competing producers, etc. Sometimes there are relevant groups who are neither users, nor producers of the technology - journalists, politicians, civil groups, etc. (Just think of inter-continental ballistic missiles, for example) The groups can be distinguished based on their shared or diverging interpretations of the technology in question.

Design Flexibility

Just as technologies have different meanings in different social groups, there are always multiple ways of constructing technologies. A design is only a single point in the large field of technical possibilities, reflecting the interpretations of certain relevant groups.

Problems and Conflicts

The different interpretations often give rise to conflicts between criteria that are hard to resolve technologically (in the case of the bicycle, one such problem was: how can women ride the bicycle decently, in skirt?), or conflicts between the relevant groups (the "Anti-cyclists" lobbied for the banning of the bicycles). Different groups in different societies construct different problems, leading to different designs.

The first stage of the SCOT research methodology is to reconstruct the alternative interpretations of the technology, analyze the problems and conflicts these interpretations give rise to, and connect them to the design features of the technological artifacts. The relations between groups, problems, and designs can be visualized in diagrams.

Closure

Over time, as technologies are developed, the interpretative and design flexibility collapse through closure mechanisms. Two examples of closure mechanisms:

1. **Rhetorical Closure**: When social groups *see* the problem as being solved, the need for alternative designs diminishes. This is often the result of advertising.
2. **Redefinition of the Problem**: A design standing in the focus of conflicts can be stabilized by inventing a new *problem*, which is solved by this very design. The aesthetic and technical problems of the air tire diminished, as the technology advanced to the stage where air tire bikes started to win the bike races. Tires were still considered cumbersome and ugly, but they provided a solution to the "speed problem", and this overrode previous concerns.

Closure is not permanent. New social groups may form and reintroduce interpretative flexibility, causing a new round of debate or conflict about a technology. (For instance, in the 1890s automobiles were seen as the "green" alternative, a cleaner environmentally-friendly technology, to horse-powered vehicles; by the 1960s, new social groups had introduced new interpretations about the environmental effects of the automobile, eliciting the opposite conclusion.)

The second stage of the SCOT methodology is to show how closure is achieved.

Relating the content of the technological artifact to the wider sociopolitical milieu

This is the third stage of the SCOT methodology, but the seminal article of Pinch and Bijker does not proceed to this stage. Many other historians and sociologists of technology nevertheless do. For example, Paul N. Edwards shows in his book "The Closed World: Computers and the Politics of Discourse in Cold War America" the strong relations between the political discourse of the Cold War and the computer designs of this era.

Criticism

In 1993, Langdon Winner published an influential critique of SCOT entitled "Upon Opening the Black Box and Finding it Empty: Social Constructivism and the Philosophy of Technology." In it, he raises a few problems with social constructivism:

1. It explains how technologies arise, but ignores the effects of the technology after the fact.
2. It is a social construction of knowledge in itself, subject to the same limitations as it postulates ("Who says what are relevant social groups and social interests?")
3. It disregards dynamics not due to its "preferred conceptual strawman: technological determinism."

Other critics include Stewart Russell with his letter in the journal "Social Studies of Science" titled "The Social Construction of Artifacts: A Response to Pinch and Bijker"

Chapter- 5

Environmental Technology

Environmental technology (abbreviated as *envirotech*) or green technology (abbreviated as *greentech*) or clean technology (abbreviated as *cleantech*) is the application of the environmental science to conserve the natural environment and resources, and to curb the negative impacts of human involvement. Sustainable development is the core of *environmental technologies*.

Examples

- Biofiltration
- Biosphere Technology
- Bioremediation
- Composting toilet
- Desalination
- Doubly-fed electric machine
- Energy Conservation
- Energy Saving Modules
- Hydrogen fuel cell
- Ocean Thermal Energy Conversion
- Solar power
- Thermal depolymerization

Recycling

Recycling is a Worldwide Phenomenon, which is a basic application towards the concept of Green Technology. It shows and encourages people to reuse items that can be reusable. Items like saving cans of food or drinks, Paper etc. have been encouraged by the governing bodies around the world, to be recycled so that it can be used in the future for several other purposes. It can thus help protect the environment and cause less waste/pollution.

Water Purification

Water purification: The whole idea of having dirt/germ/pollution free water flowing throughout the environment. Many other phenomenons lead from this concept of purification of water. Water pollution is the main enemy of this concept, and various campaigns and activists have been organized around the world to help purify water. Considering the amount of water usage that is under current consumptions, this Concept is of utter Importance.

Air Purification

Air Purification: basic and common green plants can be grown indoors to keep air fresh because all plants remove CO_2 and convert it into oxygen. The best examples are: *Dypsis lutescens*, *Sansevieria trifasciata*, and *Epipremnum aureum*.

Sewage treatment

Sewage treatment is a concept that is really close to Water Purification. Sewage treatments are very important as it purifies water in levels of its pollution. The more the water is polluted, it's not used for anything, the least polluted water is supplied to places where water is used affluently. It may lead to vaious other concepts of environmental protection, sustainability etc.

Environmental remediation

Environmental remediation is the removal of pollutants or contaminants for the general protection of the environment. This is accomplished by various chemical, biological, and bulk movement methods, in conjunction with environmental monitoring. (encyclopedia of medical concepts)

Solid waste management

Solid waste management is the purification, Consumption, Reuse, Disposal and Treatment of solid waste that is looked after by the government or the ruling bodies of a city/town.

Renewable energy

Renewable energy is energy that can be replenished easily. For years we have been using sources like wood, sun, water, etc. for means for producing energy. Energy that can be produced by natural objects like wood, sun, wind, etc. is considered to be renewable.

eGain forecasting

Egain forecasting is a method using forecasting technology to predict the future weather's impact on a building. By adjusting the heat based on the weather forecast, the system eliminates redundant use of heat, thus reducing the energy consumption and the emission of greenhouse gases.

Energy Conservation

Energy conservation is the utilization of devices that require smaller amounts of energy in order to reduce the consumption of electricity. Reducing the use of electricity causes less fossil fuels to be burned to provide that electricity.

Alternative and clean power

Principles:

- Green syndicalism
- Sustainability
- Sustainable design
- Sustainable engineering

Scientists continue to search for clean energy alternatives to our current power production methods. Some technologies such as anaerobic digestion produce renewable energy from waste materials. The global reduction of greenhouse gases is dependent on the adoption of energy conservation technologies at industrial level as well as this clean energy generation. That includes using unleaded gasoline, solar energy and alternative fuel vehicles, including plug-in hybrid and hybrid electric vehicles.

Since electric motors consume 60% of all electricity generated, advanced energy efficient electric motor (and electric generator) technology that are cost effective to encourage their application, such as the brushless wound-rotor doubly-fed electric machine and energy saving module, can reduce the amount of carbon dioxide (CO_2) and sulfur dioxide (SO_2) that would otherwise be introduced to the atmosphere, if electricity is generated using fossil fuels. Greasestock is an event held yearly in Yorktown Heights, New York which is one of the largest showcases of environmental technology in the United States.

Criticism

Extreme radical environmentalism, exhibited in publications such as Green Anarchy, criticizes the concept of environmental technology. From this viewpoint, technology is seen as a system rather than a specific physical tool. Technology, accordingly, *requires* the exploitation of the environment through the creation and extraction of resources, and the exploitation of people through labor, specialization and the division of labor. Thus, no "neutral" form of technology; things are always created in a certain context with certain aims and functions. Green technology is rejected as an attempt to reform this exploitative system, merely changing it on the surface to make it seem environmentally friendly, despite continued unsustainable levels of human and natural exploitation.

Chapter- 6

Appropriate Technology

The Universal Nut Sheller in use in Uganda, an example of appropriate technology

Appropriate technology (AT) is technology that is designed with special consideration to the environmental, ethical, cultural, social, political, and economical aspects of the community it is intended for.

With environmental and ethical goals in mind, AT proponents claim their methods require fewer resources, are easier to maintain, and have less of an impact on the environment compared to techniques from mainstream technology, which they contend is wasteful and environmentally polluting.

The term is usually used to describe simple technologies proponents consider suitable for use in developing nations or less developed rural areas of industrialized nations. This form of "appropriate technology" usually prefers labor-intensive solutions over capital-intensive ones, although labor-saving devices are also used where this does not mean high capital or maintenance cost. In practice, appropriate technology is often something described as using the simplest level of technology that can effectively achieve the intended purpose in a particular location. In industrialized nations, the term *appropriate technology* takes a different meaning, often referring to engineering that takes special consideration of its social and environmental ramifications.

Background and definition

Sustainable portable classroom design proposal

The term *appropriate technology* came into some prominence during the 1973 energy crisis and the environmental movement of the 1970s. The term is typically used in two arenas: utilizing the most effective technology to address the needs of developing areas, and using socially and environmentally acceptable technologies in industrialized nations.

Appropriate technology founders

In the modern world appropriate technology is supposed to commence from Mahatma Gandhi who advocated small, local, mostly village-based technology to help India's villages become self reliant and thus aid in the freedom struggle against British and wealthy Indians. Gandhi's philosophies on technology were contrary to the belief that technological development was inherently synonymous with progress. He believed the powers of technology should be produced and used artfully and the benefits should be close to the individual and widely produced and distributed in a decentralised fashion. Gandhi claimed that his favorite technologies were the sewing machine, because it was invented out of love, and the bicycle, because it kept one's feet close to the ground. He felt that the paradigm of technology should not be one that disenfranchises people and be used in the pursuit of violence, rather, it should be used in a way that empowers people broadly. Integrated with the movement for self-rule, which was based on local economies, Gandhi championed the spinning wheel, or *charka*, employed in the khadi movement in the 1920s, which produced cloth locally in an act of civil disobedience of the imperial system, causing the British monopoly on textiles to collapse. However, in the movement for *Swaraj*, or home rule, Gandhi believed in a total revolution of production, saying that "It is not about getting rid of the tiger and keeping the tiger's nature". Having said "it is better for a machine to be idle than a man to be idle", Gandhi rejected the factory model of industrialisation, which valued production over the worker. He raised money to offer a reward for someone to invent a spinning wheel that could employ people in the same way, while producing more thread.

E. F. Schumacher who was very strongly influenced by Gandhi's philosophy took his village development further and coined "intermediate technology" in early 1970s. It is Schumacher through his book Small is Beautiful and later by creating the Intermediate Technology Development Group, now known as Practical Action, that really started the appropriate technology movement.

Stewart Brand, editor of the Whole Earth Catalog aided in popularizing the movement's roots and contributed ideas which inspired it, to the point where he is sometimes listed as a founder.

Appropriate technology practitioners

Some of the well known practitioners of the appropriate technology-sector include: M K Ghosh, B.V. Doshi, Buckminster Fuller, William Moyer (1933–2002), Amory Lovins, Sanoussi Diakité, Victor Papanek, Johan Van Lengen and Arne Næss (1912–2009)

Appropriate technology in developing areas

The term has often been applied to the situations of developing nations or underdeveloped rural areas of industrialized nations. The use of appropriate technology in these areas seeks to fill in the gaps left by conventional development which typically focuses on capital-intensive, urban development.

Appropriate technologies are not necessarily "low" technology, and can utilize recent research, for example cloth filters which were inspired by research into the way cholera is carried in water. A type of high-efficiency, white LED lights is used by the Light Up the World Foundation in remote areas of Nepal to replace more traditional forms of lighting that cause health problems associated with kerosene lamps or wood fires.

Intermediate technology

Coined by E. F. Schumacher, the term **intermediate technology** is similar to appropriate technology. It refers specifically to tools and technology that are significantly more effective and expensive than traditional methods, but still an order of magnitude (one tenth) cheaper than developed world technology. Proponents argue that such items can be easily purchased and used by poor people, and according to proponents can lead to greater productivity while minimizing social dislocation. Much intermediate technology can also be built and serviced using locally available materials and knowledge. This intermediate technology is conducive to decentralization, compatible with the laws of ecology, gentle in its use of scarce resources, and designed to serve the human person instead of making him the servant of machines.

Appropriate hard and soft technologies

According to Dr. Maurice Albertson and Faulkner, appropriate hard technology is "engineering techniques, physical structures, and machinery that meet a need defined by a community, and utilize the material at hand or readily available. It can be built, operated and maintained by the local people with very limited outside assistance (e.g., technical, material, or financial). it is usually related to an economic goal." Some have explored the use of classroom projects for university-level physics students to research, develop and test appropriate hard technology.

Albertson and Faulkner consider Appropriate soft technology as technology that deals with "the social structures, human interactive processes, and motivation techniques. It is the structure and process for social participation and action by individuals and groups in analyzing situations, making choices and engaging in choice-implementing behaviors that bring about change."

Appropriate technology in developed countries

The term *appropriate technology* is also used in developed nations to describe the use of technology and engineering that results in less negative impacts on the environment and society. E. F. Schumacher asserts that such technology, described in the book *Small is Beautiful* tends to promote values such as health, beauty and permanence, in that order.

Often the type of appropriate technology that is used in developed countries is "Appropriate and Sustainable Technology" (AST); or appropriate technology that, besides being functional and relatively cheap (though often more expensive than true AT), is also very durable and lasts a long time.

Determining a sustainable approach

Features such as low cost, low usage of fossil fuels and use of locally available resources can give some advantages in terms of sustainability. For that reason, these technologies are sometimes used and promoted by advocates of sustainability and alternative technology.

Besides using natural, locally available resources (e.g. wood or adobe), waste materials imported from cities using conventional (and inefficient) waste management may be gathered and re-used to build a sustainable living environment. Use of these cities' waste material allows the gathering of a huge amount of building material at a low cost. When obtained, the materials may be recycled over and over in the own city/community, using the cradle to cradle design method. Locations where waste can be found include landfills, junkyards, on water surfaces and anywhere around towns or near highways. Organic waste that can be reused to fertilise plants can be found in sewages. Also, town districts and other places (e.g. cemeteries) that are subject of undergoing renovation or removal can be used for gathering materials as stone, concrete, or potassium.

City construction

In order to increase the efficiency of a great number of city services (efficient water provisioning, efficient electricity provisioning, easy traffic flow, water drainage, decreased spread of disease with epidemics, ...), the city itself must first be built correctly. In the developing world, many cities are expanding rapidly and new ones are being built. Looking into the cities design in advance is a must for every developing nation.

Building construction

- Adobe (including the variation called Super Adobe),
- Rammed earth,
- Compressed earth block,
- Dutch brick,
- Animal products,
- Cob
- and/or other green building materials could be considered appropriate earth building technology for much of the developing world, as they make use of materials which are widely available locally and are thus relatively inexpensive.

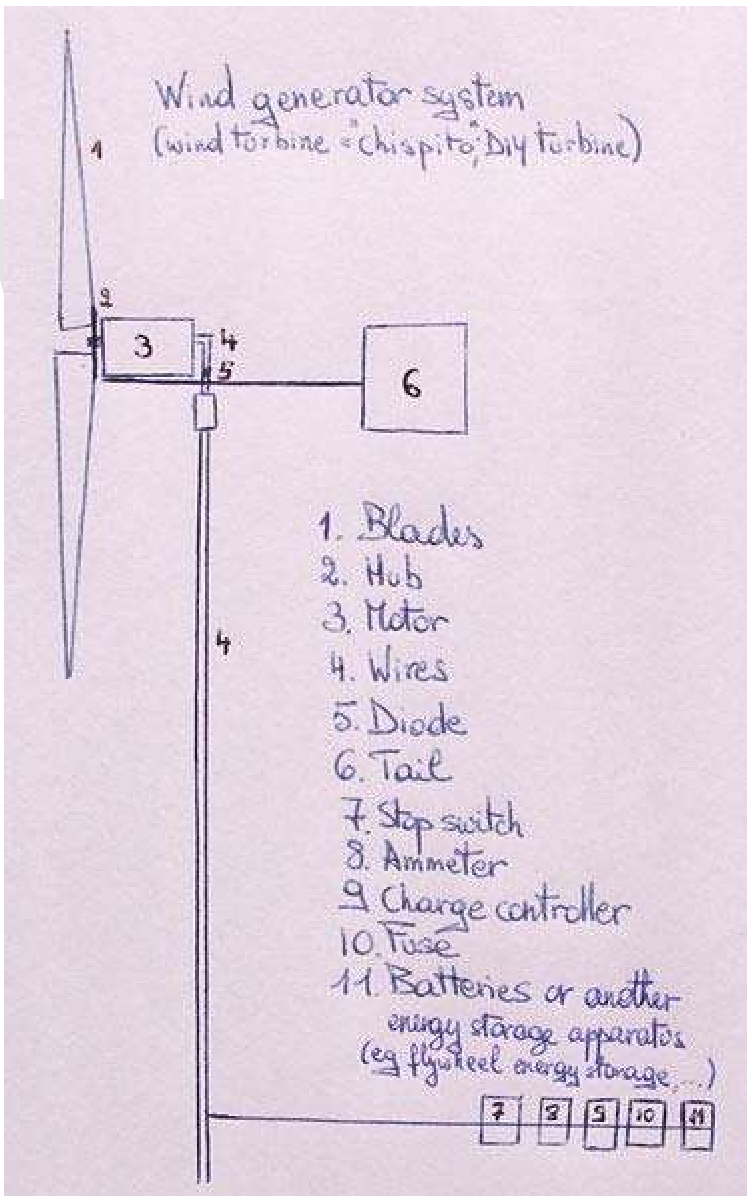
The local context must be considered as, for example, mudbrick may not be durable in a high rainfall area (although a large roof overhang and cement stabilisation can be used to correct for this), and, if the materials are not readily available, the method may be inappropriate. Other forms of natural building may be considered appropriate technology, though in many cases the emphasis is on sustainability and self-sufficiency rather than affordability or suitability. As such, many buildings are also built to function as autonomous buildings (e.g. earthships, ...). One example of an organisation that applies appropriate earthbuilding techniques would be Builders Without Borders.

The building structure must also be considered. Cost-effectiveness is an important issue in projects based around appropriate technology, and one of the most efficient designs herein is the public housing approach. This approach lets everyone have their own sleeping/recreation space, yet incorporate communal spaces e.g. mess halls, Latrines, public showers, ...

In addition, to decrease costs of operation (heating, cooling, ...) techniques as Earth sheltering, Trombe walls, ... are often incorporated.

Organizations as Architecture for Humanity also follows principles consistent with appropriate technology, aiming to serve the needs of poor and disaster-affected people.

Energy



Small-scale (DIY) generation system

The term soft energy technology was coined by Amory Lovins to describe "appropriate" renewable energy. "Appropriate" energy technologies are especially suitable for isolated and/or small scale energy needs. Electricity can be provided from:

- Photovoltaic (PV) solar panels, and (large) Concentrating solar power plants. PV solar panels made from Low-cost photovoltaic cells or PV-cells which have first been concentrated by a Luminescent solar concentrator-panel are also a good option. Especially companies as Solfocus make appropriate technology CSP plants which can be made from waste plastics polluting the surroundings.
- Solar thermal collector
- wind power (home do-it yourself turbines and larger-scale)
- micro hydro, and pico hydro
- human-powered handwheel generators
- other zero emission generation methods

Some intermediate technologies include:

- Biobutanol,
- biodiesel,
- and straight vegetable oil can be appropriate, direct biofuels in areas where vegetable oil is readily available and cheaper than fossil fuels.
- Anaerobic digestion power plants
- Biogas is another potential source of energy, particularly where there is an abundant supply of waste organic matter. A generator (running on biofuels) can be run more efficiently if combined with batteries and an inverter; this adds significantly to capital cost but reduces running cost, and can potentially make this a much cheaper option than the solar, wind and micro-hydro options.
- Feces (e.g. cow dung, human, etc.) can also be used. For example DEKA's Project Slingshot stirling electricity generator works this energy source to make electricity.
- Biochar is another similar energy source which can be obtained through charring of certain types of organic material (e.g. hazelnut shells, bamboo, chicken manure, ...) in a pyrolysis unit. A similar energy source is terra preta nova.

Finally, urine can also be used as a basis to generate hydrogen (which is an energy carrier). Using urine, hydrogen production is 332% more energy efficient than using water.

Electricity distribution could be improved so to make use of a more structured electricity line arrangement and universal AC power plugs and sockets (e.g. the CEE 7/7 plug). In addition, a universal system of electricity provisioning (e.g. universal voltage, frequency, ampère; e.g. 230 V with 50 Hz), as well as perhaps a better mains power system (e.g. through the use of special systems as perfected single wire earth returns; e.g. Tunisia's MALT-system, which features low costs and easy placement)

Electricity storage (which is required for autonomous energy systems) can be provided through appropriate technology solutions as deep-cycle and car-batteries (intermediate technology), long duration flywheels, electrochemical capacitors, compressed air energy storage (CAES), liquid nitrogen and pumped hydro. Thanks to Daniel Nocera, low-cost hydrogen storage is now also possible as a mid to short-term storage solution. Many solutions for the developing world are sold as a single package, containing a (micro) electricity generation power plant and energy storage. Such packages are called remote-area power supply

Water supply and treatment

Hand-operated, reciprocating, positive displacement, water pump in Košice-Tahanovce, Slovakia (walking beam pump).

As of 2006, waterborne diseases are estimated to cause 1.8 million deaths each year while about 1.1 billion people lack proper drinking water.

Water generally needs treatment before use, depending on the source and the intended use (with high standards required for drinking water). The quality of water from household connections and community water points in low-income countries is not reliably safe for direct human consumption. Water extracted directly from surface waters and open hand-dug shallow wells nearly always requires treatment.

Appropriate technology options in water treatment include both community-scale and household-scale point-of-use (POU) designs.

The most reliable way to kill microbial pathogenic agents is to heat water to a rolling boil. Other techniques, such as varying forms of filtration, chemical disinfection, and exposure to ultraviolet radiation (including solar UV) have been demonstrated in an array of randomized control trials to significantly reduce levels of waterborne disease among users in low-income countries.

Over the past decade, an increasing number of field-based studies have been undertaken to determine the success of POU measures in reducing waterborne disease. The ability of POU options to reduce disease is a function of both their ability to remove microbial pathogens if properly applied and such social factors as ease of use and cultural appropriateness. Technologies may generate more (or less) health benefit than their lab-based microbial removal performance would suggest.

The current priority of the proponents of POU treatment is to reach large numbers of low-income households on a sustainable basis. Few POU measures have reached significant scale thus far, but efforts to promote and commercially distribute these products to the world's poor have only been under way for a few years.

On the other hand, small-scale water treatment is reaching increasing fractions of the population in low-income countries, particularly in South and Southeast Asia, in the form of water treatment kiosks (also known as water refill stations or packaged water producers). While quality control and quality assurance in such locations may be variable, sophisticated technology (such as multi-stage particle filtration, UV irradiation, ozonation, and membrane filtration) is applied with increasing frequency. Such microenterprises are able to vend water at extremely low prices, with increasing government regulation. Initial assessments of vended water quality are encouraging.

Whether applied at the household or community level, some examples of specific treatment processes include:

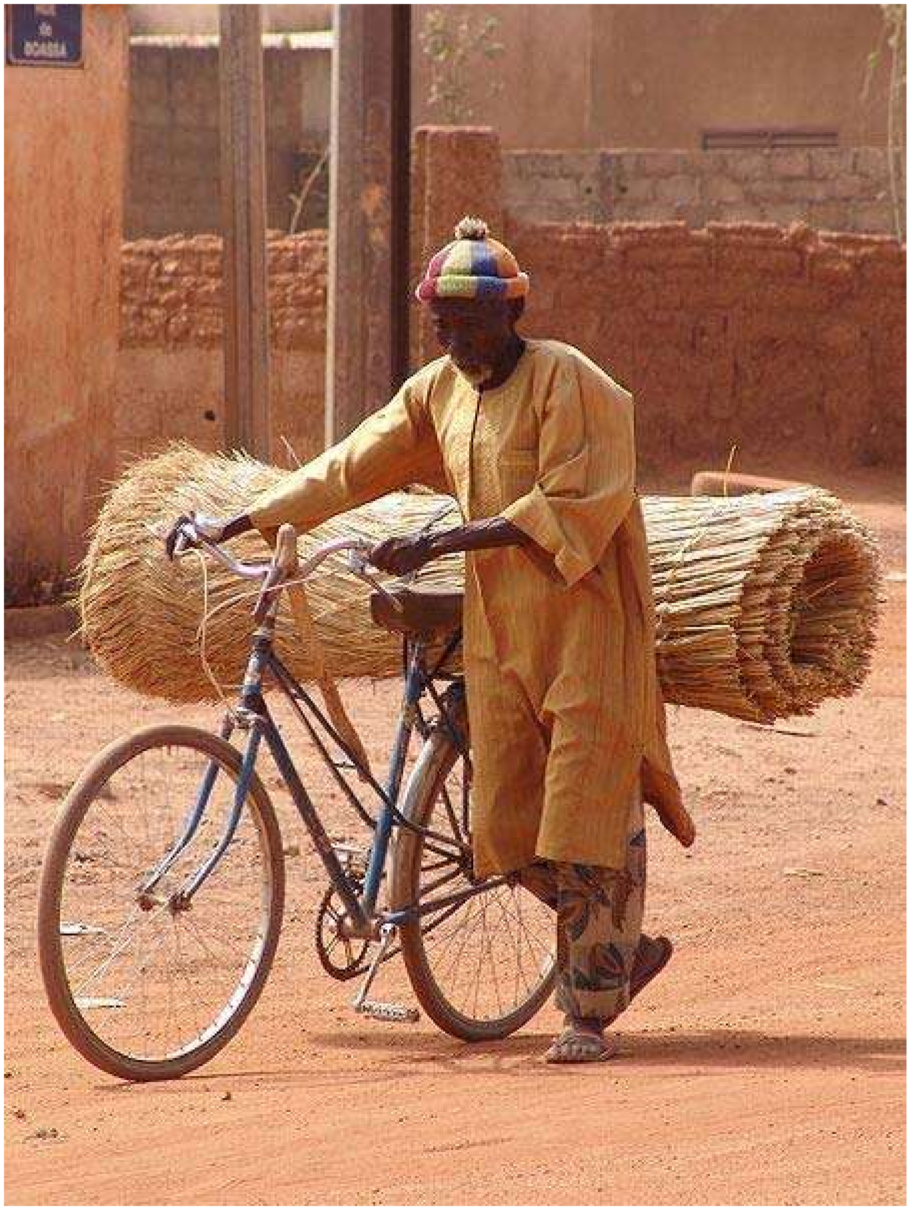
- Porous ceramic filtration, using either clay or diatomaceous earth, and oriented as either cylinder, pot, or disk, with gravity-fed or siphon-driven delivery systems. Silver is frequently added to provide antimicrobial enhancement
- Intermittently operated slow-sand filtration, also known as biosand filtration

- Chlorine disinfection, employing calcium hypochlorite powder, sodium hypochlorite solution, or sodium dichloroisocyanurate (NaDCC) tablets
- Chemical flocculation, using either commercially produced iron or aluminum salts or the crushed seeds of certain plants, such as Moringa oleifera
- Mixed flocculation/disinfection using commercially produced powdered mixtures
- Irradiation with ultraviolet light, whether using electric-powered lamps or direct solar exposure
- membrane filtration, employing ultrafiltration or reverse osmosis filter elements preceded by pretreatment

Some appropriate technology water supply measures include:

- Deep wells with submersible pumps in areas where the groundwater (aquifers) are located at depths >10 m.
- Shallow wells with lined walls and covers.
- rainwater harvesting systems with an appropriate method of storage, especially in areas with significant dry seasons.
- Fog collection, which is suitable for areas which experience fog even when there is little rain.
- Air well, a structure or device designed to promote the condensation of atmospheric moisture.
- Handpumps and treadle pumps are however only an option in areas is located at a relatively shallow depth (e.g. 10 m). For deeper aquifers (>10 m), submersible pumps placed inside a well) need to be used. Treadle pumps for household irrigation are now being distributed on a widespread basis in developing countries. The principle of Village Level Operation and Maintenance is important with handpumps, but may be difficult in application.
- Condensation bags and condensation pits can be an appropriate technology to get water, yet yields are low and are (for the amount of water obtained), labour intensive. Still, it may be a good (very cheap) solution for certain desperate communities.
- The hippo water roller allows more water to be carried, with less effort and could thus be a good alternative for ethnic communities who do not wish to give up water gathering from remote locations, assuming low topographic relief.
- The roundabout playpump, developed and used in southern Africa, harnesses the energy of children at play to pump water.

Transportation

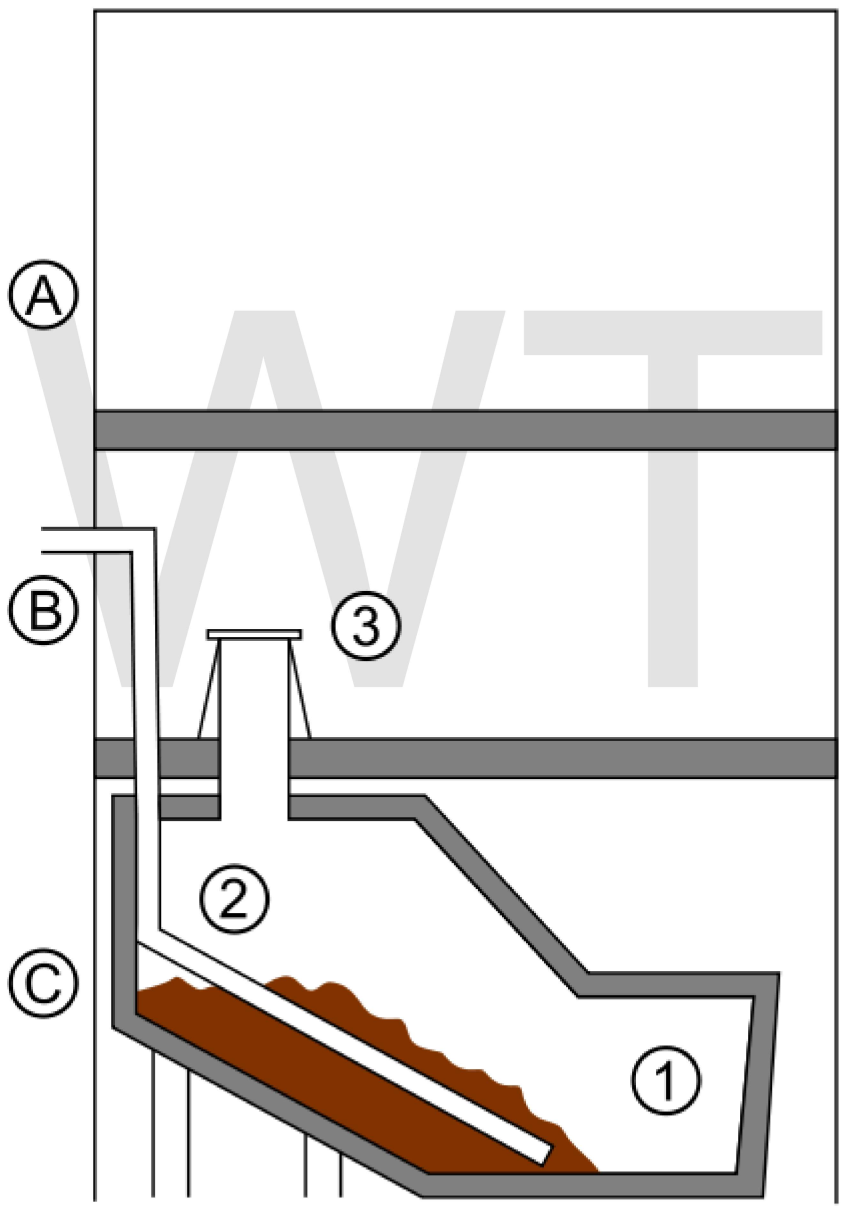


A man uses a bicycle to cargo goods in Ouagadougou, Burkina Faso (2007)

Human powered-vehicles include the bicycle, which provides general-purpose, human-powered transportation at a lower cost of ownership than motorized vehicles, with many gains over simply walking, and the whirlwind wheelchair, which provides mobility for disabled people who cannot afford the expensive wheelchairs used in developed countries. Animal powered vehicles/transport may also be another appropriate technology. Certain zero-emissions vehicles may be considered appropriate transportation technology, including compressed air cars, liquid nitrogen and hydrogen-powered vehicles. Also, vehicles with internal combustion engines may be converted to hydrogen or oxyhydrogen combustion.

Bicycles can also be applied to commercial transport of goods to and from remote areas. An example of this is Karaba, a free-trade coffee co-op in Rwanda, which uses 400 modified bicycles to carry hundreds of pounds of coffee beans for processing. Other projects for developing countries include the redesign of cycle rickshaws to convert them to electric power. However recent reports suggest that these rickshaws are not plying on the roads

Sanitation



A clivus Multrum composting toilet
A. Second floor, B. First floor, C. Ground floor, 1. Humus compartment, 2. Ventilation pipe, 3. Water closet.

As of 2006, waterborne diseases are estimated to cause 1.8 million deaths each year, marking the importance of proper sanitation systems. It is clear that the developing world is heavily lacking in proper public sanitation and that solutions as sewerages (or alternatively small-scale treatment systems) need to be provided.

Ecological sanitation can be viewed as a three-step process dealing with human excreta: (1) Containment, (2) Sanitization, (3) Recycling. The objective is to protect human health and the environment while limiting the use of water in sanitation systems for hand (and anal) washing only and recycling nutrients to help reduce the need for synthetic fertilizers in agriculture.

Small scale systems include:

- Composting toilets are the most environmental form of excrement disposal systems. In addition, the toilets design allows the nutrients to be reused (e.g. for fertilising food crops). Also, DIY composting toilets can be build at a very low cost.
- BiPu is a portable system suitable for disaster management, while other forms of latrine provide safe means of disposing of human waste at a low cost. The Orangi Pilot Project was designed based on an urban slum's sanitation crisis. Kamal Kar has documented the latrines developed by Bangladeshi villagers once they became aware of the health problems with open defecation.
- Treatment ponds and constructed wetlands can help to purify sewage and greywater. They consist mostly of plants (e.g. reed, ...) and therefore require only little power, and are hugely self-sufficient.
- Certain other options as Slow sand filters, UV filters, ... may also be employed

Lighting

LED Lamp with GU10 twist lock fitting, intended to replace halogen reflector lamps

- White LEDs and a source of renewable energy (such as solar cells) are used by the Light Up the World Foundation to provide lighting to poor people in remote areas, and provide significant benefits compared to the kerosene lamps which they replace. Certain other companies as Powerplus also have LED-flashlights with imbedded solar cells.
- Organic LEDs made by roll-to-roll production are another source of cheap light that will be commercially available at low cost by 2015.
- Compact fluorescent lamps (as well as regular fluorescent lamps and LED-lightbulbs) can also be used as appropriate technology. Although they are less environmentally friendly then LED-lights, they are cheaper and still feature relative high efficiency (compared to incandescent lamps).
- The Safe bottle lamp is a safer kerosene lamp designed in Sri Lanka. Lamps as these allow relative long, mobile, lighting. The safety comes from a secure screw-

on metal lid, and two flat sides which prevent it from rolling if knocked over. An alternative to fuel or oil-based lanterns is the Uday lantern, developed by Philips as part of its Lighting Africa project (sponsored by the World Bank Group).

- The Faraday flashlight is a LED flashlight which operates on a capacitor. Recharging can be done by manual winching or by shaking, hereby avoiding the need of any supplementary electrical system.
- HID-lamps finally can be used for lighting operations where regular LED-lighting or other lamps will not suffice. Examples are car headlights. Due to their high efficiency, they are quite environmental, yet costly, and they still require polluting materials in their production process.

Food production

Food production has often been included in autonomous building/community projects to provide security. Skilled, intensive gardening can support an adult from as little as 15 square meters of land. Some proven intensive, low-effort food-production systems include urban gardening (indoors and outdoors). Indoor cultivation may be set-up using hydroponics with Grow lights, while outdoor cultivation may be done using permaculture, forest gardening, no-till farming, Do Nothing Farming, etc. In order to better control the irrigation outdoors, special irrigation systems may be created as well (although this increases costs, and may again open the door to cultivating non-indigenous plants; something which is best avoided). One such system for the developing world is discussed here.

Crop production tools are best kept simple (reduces operating difficulty, cost, replacement difficulties and pollution, when compared to motorized equipment). Tools can include scythes, animal-pulled plows (although no-till farming should be preferred), dibbers, wheeled augers (for planting large trees), kirpis, hoes, ...

Greenhouses are also sometimes included. Sometimes they are also fitted with irrigation systems, and/or heat sink-systems which can respectively irrigate the plants or help to store energy from the sun and redistribute it at night (when the greenhouse starts to cool down).

Food preparation

According to proponents, Appropriate Technologies can greatly reduce the labor required to prepare food, compared to traditional methods, while being much simpler and cheaper than the processing used in Western countries. This reflects E.F. Schumacher's concept of "intermediate technology," i.e. technology which is significantly more effective and expensive than traditional methods, but still an order of magnitude (10 times) cheaper than developed world technology. Key examples are:

- the Malian peanut sheller
- the fonio husking machine
- the screenless hammer mill

- the ISF corn mill
- the ISF rice huller
- all other types of electrical or hand-operated kitchen equipment (grinders, cutters, ...) Special multifunctional kitchen robots that are able to perform several functions (e.g. grinding, cutting, and even vacuum cleaning and polishing) are able to reduce costs even more. Examples of these devices were e.g. the (now discontinued) Piccolo household appliance from Hammelmann Werke (previously based in Bad Kissingen.) It was equipped with a flexible axis, allowing a variety of aids to be screwed on.

Cooking

In Ghana, Zouzugu villagers use solar cookers for preparing their meals

- Solar cookers are appropriate to some settings, depending on climate and cooking style. They are emission-less and very low-cost. Hybrid variants also exist that incorporate a second heating source such as electrical heating or wood-based.
- Hot plates are 100% electrical, fairly low cost (around 20€) and are mobile. They do however require an electrical system to be present in the area of operation.
- Rocket stoves and certain other woodstoves (e.g. Philips Woodstove) improve fuel efficiency, and reduce harmful indoor air pollution. The stoves however still make use of wood. However, briquette makers can now turn organic waste into fuel, saving money and/or collection time, and preserving forests.

Refrigeration

- Solar, special Einstein refrigerators and thermal mass refrigerators reduce the amount of electricity required. Also, solar and special Einstein refrigerators do not use haloalkanes (which play a key role in ozone depletion), but use heat pumps or mirrors instead. Solar refrigerators have been built for developing nations by Sopology.

- The pot-in-pot refrigerator is an African invention which keeps things cool without electricity. It provides a way to keep food and produce fresh for much longer than would otherwise be possible. This can be a great benefit to the families who use the device. For example, it is claimed that girls who had to regularly sell fresh produce in the market can now go to school instead, as there is less urgency to sell the produce before it loses freshness.

Ventilation and air conditioning

Chunche, naturally ventilated sheds for drying raisins in Xinjiang

- Natural ventilation can be created by providing vents in the upper level of a building to allow warm air to rise by convection and escape to the outside, while cooler air is drawn in through vents at the lower level.
- Electrical powered fans (e.g. ceiling fans) allow efficient cooling, at a far lower electricity consumption as airconditioning systems.
- A solar chimney often referred to as *thermal chimney* improves this natural ventilation by using convection of air heated by passive solar energy. To further maximize the cooling effect, the incoming air may be led through underground ducts before it is allowed to enter the building.

- A windcatcher (*Badgir*; بادگیر) is a traditional Persian architectural device used for many centuries to create natural ventilation in buildings. It is not known who first invented the windcatcher, but it still can be seen in many countries today. Windcatchers come in various designs, such as the uni-directional, bi-directional, and multi-directional.
- A passive down-draft cooltower may be used in a hot, arid climate to provide a sustainable way to provide air conditioning. Water is allowed to evaporate at the top of a tower, either by using evaporative cooling pads or by spraying water. Evaporation cools the incoming air, causing a downdraft of cool air that will bring down the temperature inside the building.

Health care

According to the Global Health Council, rather than the use of professionally schooled doctors, the training of villagers to remedy most maladies in towns in the developing world is most appropriate. Trained villagers are able to eliminate 80% of the health problems. Small (low-cost) hospitals - based on the model of the Jamkhed hospital – can remedy another 15%, while only 5% will need to go to a larger (more expensive) hospital.

- Before being able to determine the cause of the disease or malady, accurate diagnosis is required. This may be done manually (through observation, inquiries) and by specialised tools.
- Herbalist medicines (e.g. tinctures, tisanes, decoctions, ...) are appropriate medicines, as they can be freely made at home and are almost as effective as their chemical counterparts. A previous program that made use of herbal medicine was the Barefoot doctor program.
- A phase-change incubator, developed in the late 1990s, is a low cost way for health workers to incubate microbial samples.
- Birth control is also seen as an appropriate technology, especially now, because of increasing population numbers (overpopulating certain areas), increasing food prices and poverty. It has been proposed to a certain degree by PATH (program for appropriate technology in health).
- Jaipur leg was developed by Dr. P. K. Sethi and Masterji Ram Chander in 1968 as an inexpensive prosthetic leg for victims of landmine explosions.
- Natural cleaning products can be used for personal hygiene and cleaning of clothing and eating utensils; in order to decrease illnesses/maladies (as they eliminate a great amount of pathogens).

Note that many Appropriate Technologies benefit public health, in particular by providing sanitation and safe drinking water. Refrigeration may also provide a health benefit. (These are discussed in the following paragraphs.) This was too found at the Comprehensive Rural Health Project and the Women Health Volunteers projects in countries as Iran, Iraq and Nepal.

Information and communication technology

Netbooks as the Eee PC allow low cost information sharing and communication

- The OLPC XO, Simputer, Eee PC, and other low cost computers are computers aimed at developing countries. Besides the low price, other characteristics include resistance to dust, reliability and use of the target language.
- Eldis OnDisc and The Appropriate Technology Library are projects that use CDs and DVDs to give access to development information in areas without reliable and affordable internet access.
- The Wind-up radio and the computer and communication system planned by the Jhai Foundation are independent from power supply.
- There is also GrameenPhone, which fused mobile telephony with Grameen Bank's microfinance program to give Bangladeshi villagers access to communication.
- Mobile telephony is appropriate technology for many developing countries, as it greatly reduces the infrastructure required to achieve widespread coverage. However, mobile phone network may not always be available (it depends on the location) and may not always provide both voice and data services.
- Loband, a website developed by Aptivate, strips all the photographic and other bandwidth-intensive content from webpages and renders them as simple text, while otherwise allowing one to browse them normally. The site greatly increasing the speed of browsing, and is appropriate for use on low bandwidth connections as generally available in much of the developing world.
- An increasing number of activists provide free or very inexpensive web and email services using cooperative computer networks that run wireless ad hoc networks. Network service is provided by a cooperative of neighbors, each operating a router as a household appliance. These minimize wired infrastructure, and its costs and vulnerabilities. Private Internet protocol networks set up in this way can operate without the use of a commercial provider.
- Rural electrical grids can be wired with "optical phase cable", in which one or more of the steel armor wires are replaced with steel tubes containing fiber optics.
- Satellite Internet access can provide high speed connectivity to remote locations, however these are significantly more expensive than wire-based or terrestrial wireless systems. Wimax and forms of packet radio can also be used. Depending on the speed and latency of these networks they may be capable of relaying VoIP

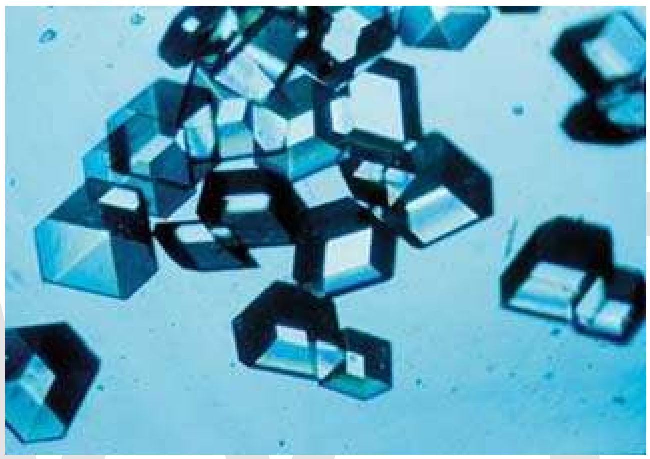
traffic, negating the need for separate telephony services. Finally, the Internet Radio Linking Project provides potential for blending older (cheap) local radio broadcasting with the increased range of the internet.
- satellite-based telephone systems can also be used, as either fixed installations or portable handsets and can be integrated into a PABX or local IP-based network.

Money lending and finance

Through financial systems envisioned especially for the poor/developed world, many companies have been able to get started with only limited capital. Often banks lend the money to people wishing to start a business (such as with microfinance). In other systems, people for a Rotating Savings and Credit Association or ROSCA to purchase costly material together (such as Tontines and Susu accounts). Organisations, communities, cities or individuals can provide loans to other communities/cities (such as with the approach followed by Kiva.org, MicroPlace and LETS). Finally, in certain communities (usually isolated communities such as small islands or oases) everything of value is shared. This is called gift economy.

Chapter- 7

Biotechnology



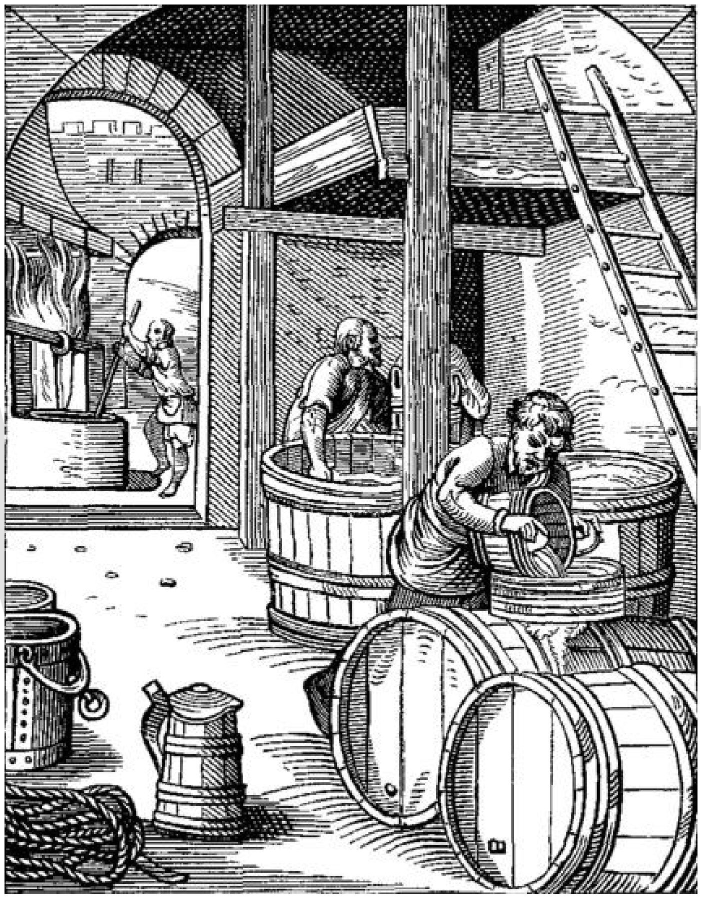
Insulin crystals

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.

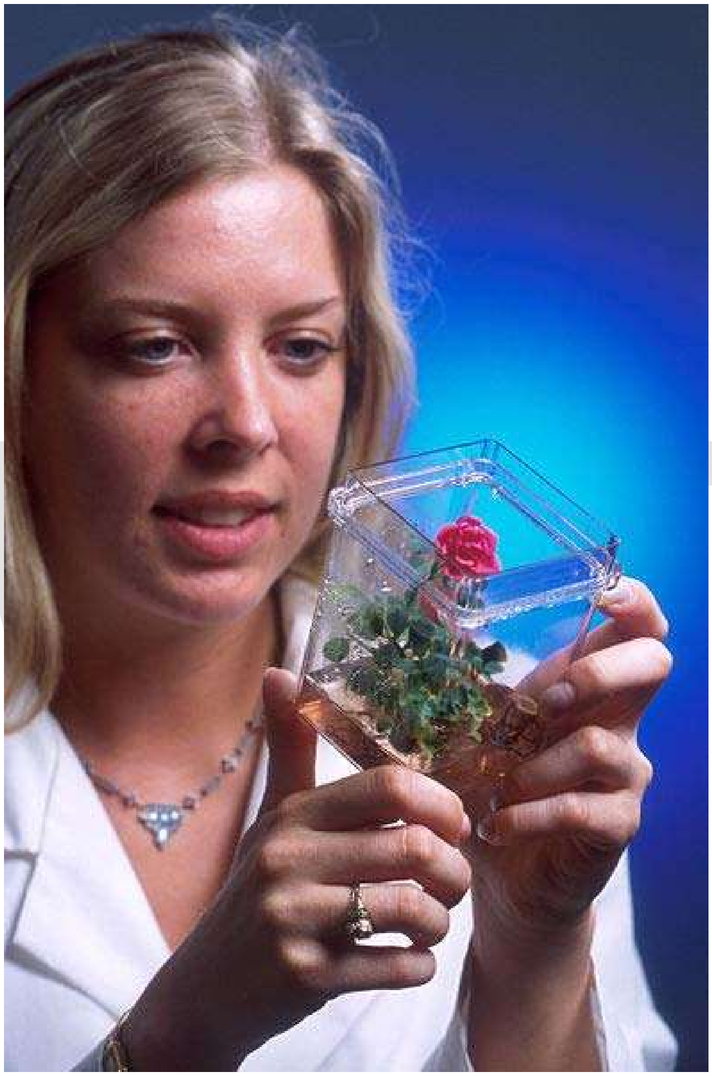
Biotechnology has led to the development of antibiotics. In 1928, Alexander Fleming discovered the mold Penicillium. His work led to the purification of the antibiotic by Howard Florey, Ernst Boris Chain and Norman Heatley penicillin. In 1940, penicillin became available for medicinal use to treat bacterial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

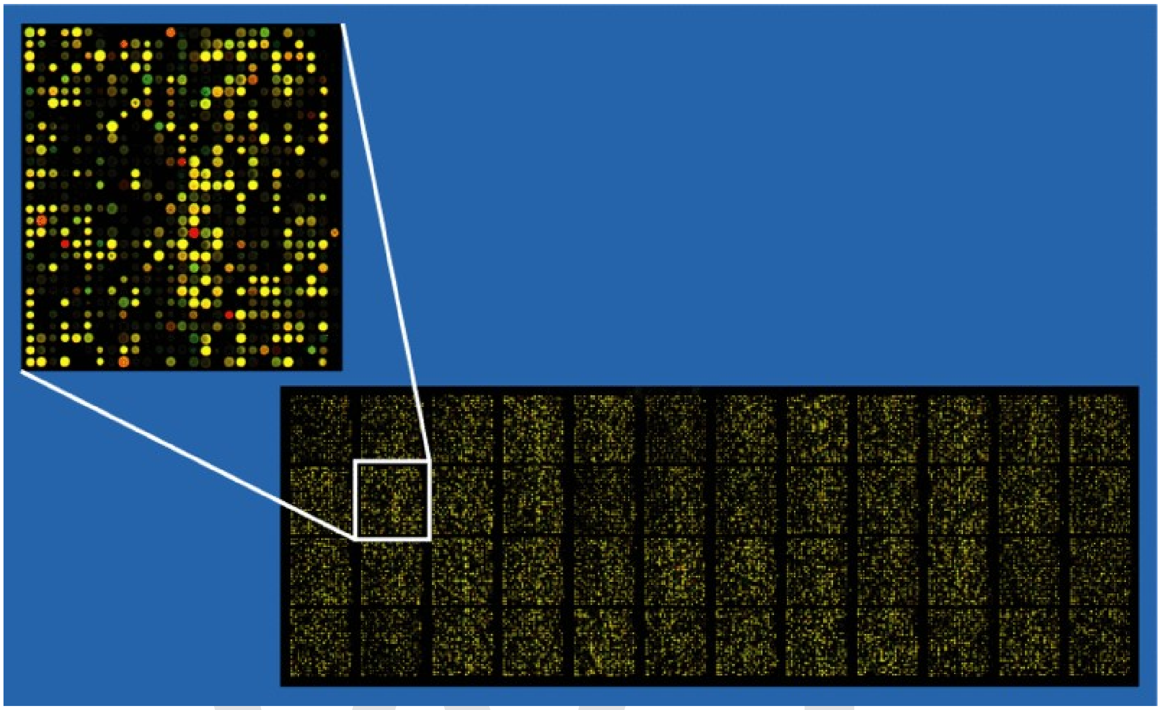
- **Bioinformatics** is an interdisciplinary field which addresses biological problems using computational techniques, and makes the rapid organization and analysis of biological data possible. The field may also be referred to as *computational biology*, and can be defined as, "conceptualizing biology 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

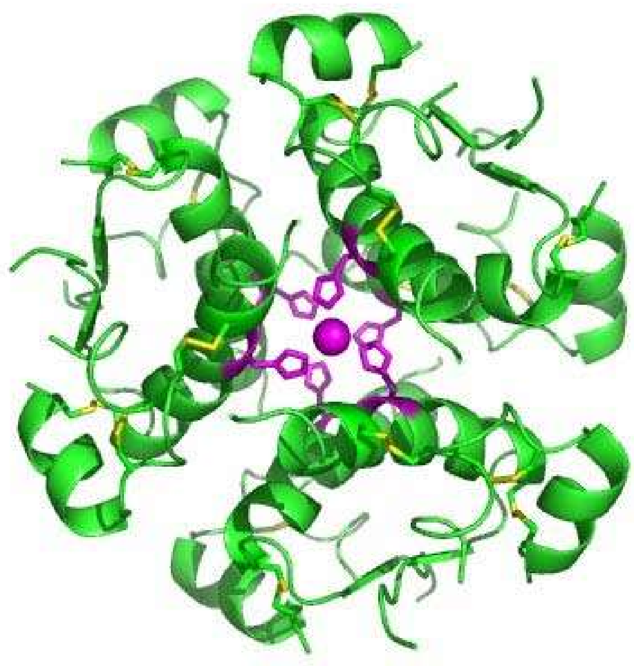
Pharmacogenomics is the study of how the genetic inheritance of an individual affects his/her body's response to drugs. It is a coined word derived from the words "pharmacology" and "genomics". It is hence the study of the relationship between pharmaceuticals and genetics. The vision of pharmacogenomics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

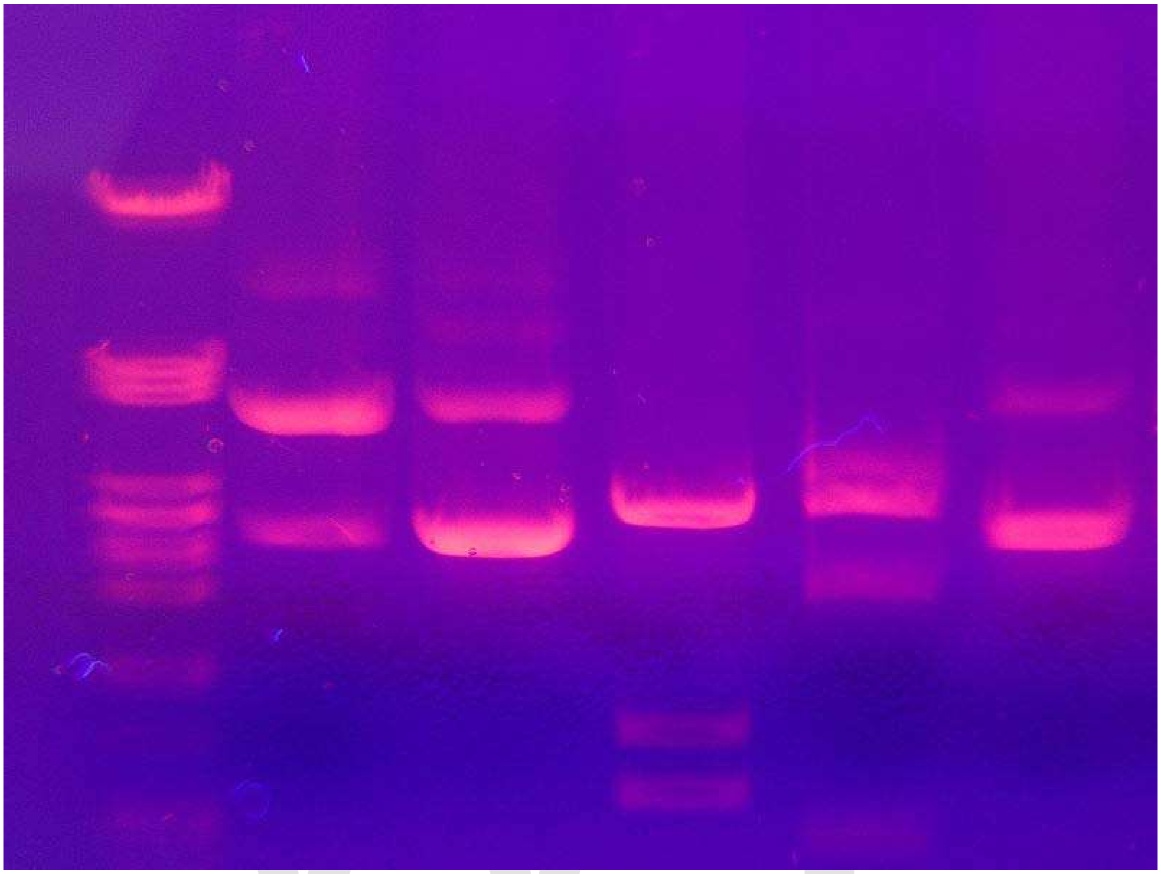
Modern biotechnology is often associated with the use of genetically altered microorganisms such as *E. coli* or yeast for the production of substances like synthetic insulin or antibiotics. It can also refer to transgenic animals or transgenic plants, such as Bt corn. Genetically altered mammalian cells,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

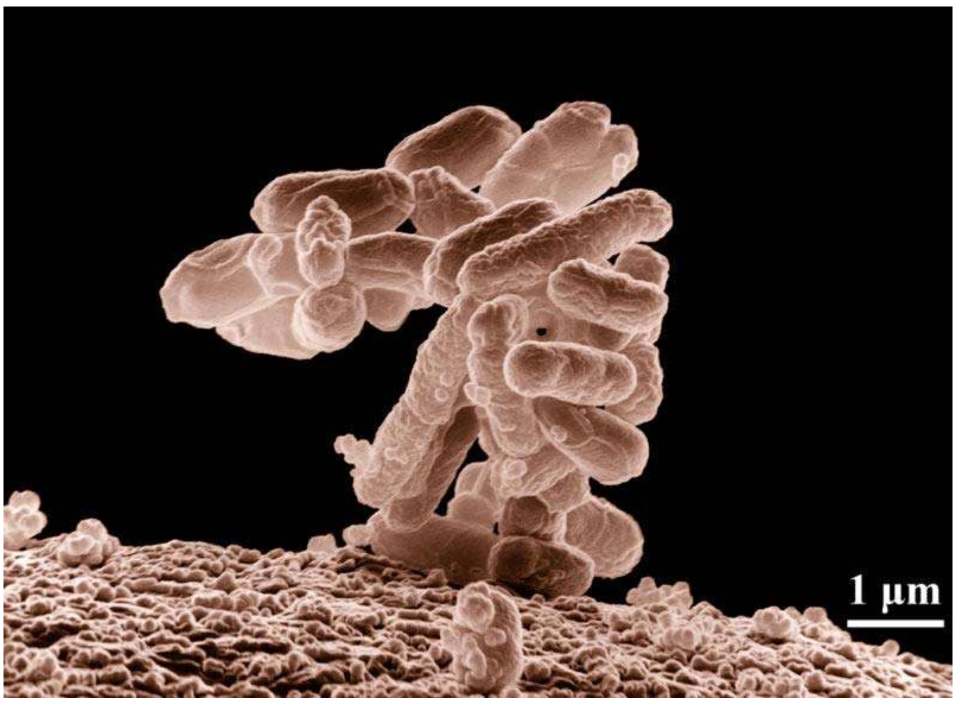
Genetic testing is now used for:

- 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.

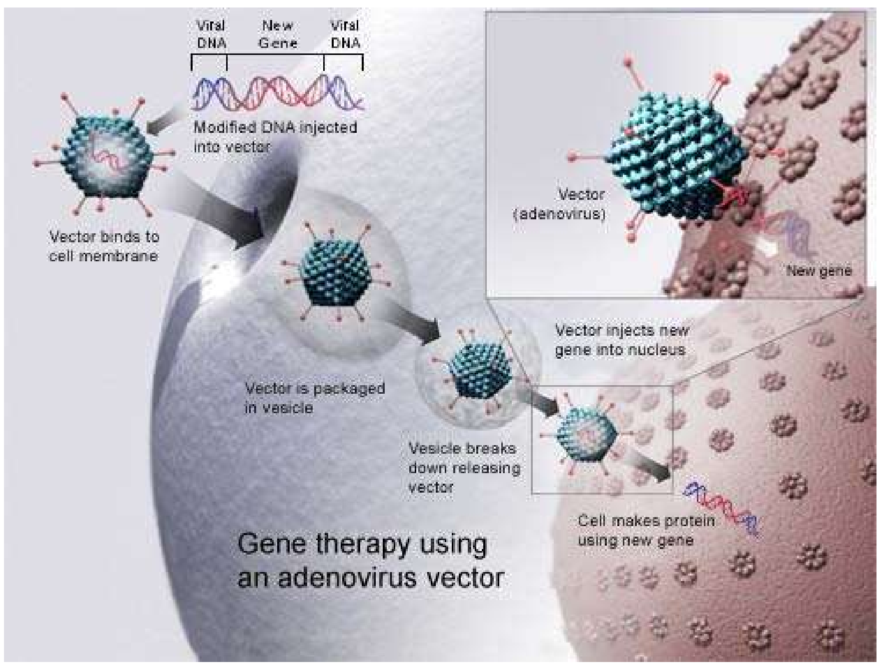
The absence of privacy and anti-discrimination legal protections in most countries can lead to discrimination in employment or insurance or other use of personal genetic information. This raises questions such as whether genetic privacy is different from medical privacy.

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:

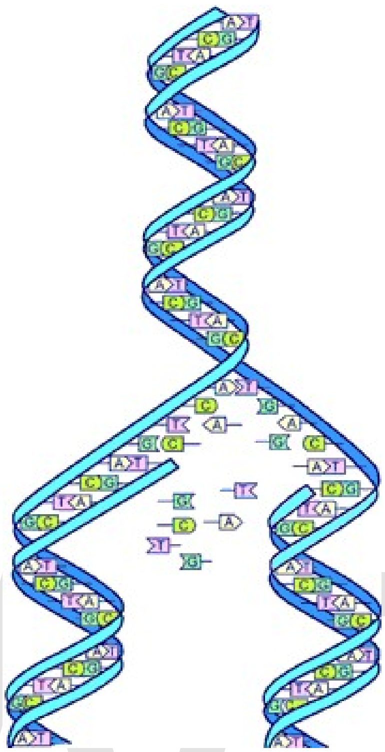
1. *Ex vivo*, which means "outside the body" – Cells from the patient's blood or bone marrow are removed and grown in the laboratory. They are then exposed to a virus carrying the desired gene. The virus enters the cells, and the desired gene becomes part of the DNA of the cells. The cells are allowed 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- 8

Sociology of Scientific Knowledge

The **sociology of scientific knowledge** is the study of science as a social activity, especially dealing "with the social conditions and effects of science, and with the social structures and processes of scientific activity." The sociology of knowledge, by contrast, focuses on the production of non-scientific ideas and social constructions.

Sociologists of scientific knowledge study the development of a scientific field and attempt to identify points of contingency or interpretative flexibility where ambiguities are present. Such variations may be linked to political, corporate, cultural or economic factors. Crucially, the field does not set out to promote relativism, or to attack the scientific project in general. The aim of the researcher is simply to explain why one interpretation rather than another succeeds due to external social and historical circumstances.

The field emerged in the 1970s and early 1980s, and at that time was an almost exclusively British practice. Major theorists include Barry Barnes, David Bloor, Gaston Bachelard, Paul Feyerabend, Thomas Kuhn, Martin Kusch, Bruno Latour, Anselm Strauss, Lucy Suchman, Harry Collins, Mike Mulkay and Steve Fuller.

Programmes and schools

The sociology of scientific knowledge (or *SSK*) in its anglophone versions emerged in the 1970s in self-conscious opposition to the sociology of science associated with the American Robert K. Merton, generally considered one of the seminal authors in the sociology of science. Merton's was a kind of "sociology of scientists," which left the cognitive content of science out of sociological account; SSK by contrast aimed at providing sociological explanations of scientific ideas themselves, taking its lead from aspects of the work of Thomas S. Kuhn, but especially from established traditions in cultural anthropology (Durkheim, Mauss) as well as the later Wittgenstein. David Bloor, one of SSK's early champions, has contrasted the so-called 'weak programme' (or 'program' — either spelling is used) which merely gives social explanations for erroneous beliefs, with what he called the 'strong programme', which considers sociological factors as influencing all beliefs.

The *weak* programme is more of a description of an approach than an organised movement. The term is applied to historians, sociologists and philosophers of science who merely cite sociological factors as being responsible for those beliefs that went wrong. Imre Lakatos and (in some moods) Thomas Kuhn might be said to adhere to it. The *strong* programme is particularly associated with the work of two groups: the 'Edinburgh School' (David Bloor, Barry Barnes, and their colleagues at the Science Studies Unit at the University of Edinburgh) in the 1970s and '80s, and the 'Bath School' (Harry Collins and others at the University of Bath) in the same period. "Edinburgh sociologists" and "Bath sociologists" promoted, respectively, the Strong Programme and Empirical Programme of Relativism (EPOR). Also associated with SSK in the 1980s was discourse analysis as applied to science (associated with Michael Mulkay at the University of York), as well as a concern with issues of reflexivity arising from paradoxes relating to SSK's relativist stance towards science and the status of its own knowledge-claims (Steve Woolgar, Malcolm Ashmore).

The sociology of scientific knowledge (SSK) has major international networks through its principal associations, 4S and EASST, with recently established groups in Japan, South Korea, Taiwan and Latin America. It has made major contributions in recent years to a critical analysis of the biosciences and informatics.

The sociology of mathematical knowledge

Studies of mathematical practice and quasi-empiricism in mathematics are also rightly part of the sociology of knowledge, since they focus on the community of those who practice mathematics and their common assumptions. Since Eugene Wigner raised the issue in 1960 and Hilary Putnam made it more rigorous in 1975, the question of why fields such as physics and mathematics should agree so well has been debated. Proposed solutions point out that the fundamental constituents of mathematical thought, space, form-structure, and number-proportion are also the fundamental constituents of physics. It is also worthwhile to note that physics is nothing but a modeling of reality, and seeing causal relationships governing repeatable observed phenomena, and much of mathematics, especially in relation to the growth of the calculus, has been developed precisely for the goal of developing these models in a rigorous fashion. Another approach is to suggest that there is no deep problem, that the division of human scientific thinking through using words such as 'mathematics' and 'physics' is only useful in their practical everyday function to categorize and distinguish.

Fundamental contributions to the sociology of mathematical knowledge have been made by Sal Restivo and David Bloor. Restivo draws upon the work of scholars such as Oswald Spengler (The Decline of the West, 1926), Raymond L. Wilder and Lesley A. White, as well as contemporary sociologists of knowledge and science studies scholars. David Bloor draws upon Ludwig Wittgenstein and other contemporary thinkers. They both claim that mathematical knowledge is socially constructed and has irreducible contingent and historical factors woven into it. More recently Paul Ernest has proposed a social constructivist account of mathematical knowledge, drawing on the works of both of these sociologists.

The sociology of scientific knowledge has traditionally used a number of methods, including bibliometrics methods.

Criticism

SSK has received criticism from the French school called Actor-network theory (ANT) which belongs to the research field called Science and Technology Studies. The main theorists in the ANT-school are Michel Callon, Bruno Latour and John Law.

SSK has been criticised for sociological reductionism and a human centered universe. SSK is said to rely too heavily on human actors and social rules and conventions settling scientific controversies. The ANT-school, instead, proposes that non-human actors (actants) play an integral role. For example instruments, measurement scales, laboratories and so forth have the unintentional capacities of closing a scientific controversy.

These criticisms can be seen as rather misdirected since the strong programme does not deny the influence of the physical universe in the formulation of knowledge but takes it for granted. What the strong programme seems to stress, however, is that the knowledge that human beings acquire does not come straight from nature to the human mind unfiltered. What we call knowledge is a product of sensations from physical world mixed up with and transformed by the socially recognized ways of interpreting those sensations.

The argument of the strong programme seems to be that these ways of interpreting what comes through our sense organs is not given with the physical world but socially constructed by groups of human beings interacting with each other. Whilst the physical world is not socially constructed, our knowledge of the physical world is in this sense socially constructed. The physical universe does not reduce to sociology or just human interaction so an allegation of sociological reductionism does not seem to be well aimed. Instruments, measurement scales, laboratories, nature and so forth, therefore, do not have the capacities of closing scientific controversies *by themselves*. They must be seen or interpreted as doing so by human beings in interaction. This seems to be what David Bloor of the strong programme says in his article Anti-Latour in response to criticisms.

The Sokal affair

In 1996, postmodern theorists of the sociology of scientific knowledge (SSK) were the targets of a hoax paper by Alan Sokal in the journal *Social Text*, under the title *Transgressing the Boundaries: Toward a Transformative Hermeneutics of Quantum Gravity*. The ensuing debate led to these thinkers being accused of "relativism"--a charge that at least some proponents of the view embrace. The supposed 'relativism' prevalent within the SSK, especially in the work of 'strong sociologists' such as Barry Barnes and David Bloor, may be regarded as a misnomer even though these sociologists themselves assent to the label. This is because the strong programme does not deny the existence of a human-independent reality. Neither does it affirm that all knowledge claims are 'really true' just because the relevant community accepts them as true. The position of strong sociology is that sociologically interesting knowledge (e.g. institutionalised forms of knowledge) are human products even when they have been formulated as a result of interaction with a human-independent physical world as is the case in the so-called natural sciences. Such sociologically interesting knowledge is not given with the physical world but is a product of group/social processes. They claim that passively observing the world will not convince 'rational' individuals to assent to such knowledge.

Chapter- 9

Other Theories of Technology

Social shaping of technology

According to Williams and Edge, "Central to **Social Shaping of Technology** (SST) is the concept that there are `choices' (though not necessarily conscious choices) inherent in both the design of individual artifacts and systems, and in the direction or trajectory of innovation programs."

If technology does not emerge from the unfolding of a predetermined logic or a single determinant, then innovation is a 'garden of forking paths'. Different routes are available, potentially leading to different technological outcomes. Significantly, these choices could have differing implications for society and for particular social groups.

SST is one of the models of the technology:society relationship which emerged in the 1980s with MacKenzie and Wajcman's influential 1985 collection, alongside Pinch and Bijker's Social construction of technology framework and Callon and Latour's Actor-Network Theory. These have a common feature of criticism of the Linear Model of Innovation and Technological determinism. It differs from these notably in the attention it pays to the influence of the social and technological context of development which shapes innovation choices. SST is concerned to explore the material consequences of different technical choices, but criticises Technological determinism, which argues that technology follows its own developmental path, outside of human influences, and in turn, influences society. In this way, social shaping theorists conceive the relationship between technology and society as one of 'mutual shaping'.

Technology Dynamics

Technology Dynamics is broad and relatively new scientific field that has been developed in the framework of the postwar Science and Technology Studies field. It studies the process of technological change. Under the field of Technology Dynamics the process of technological change is explained by taking into account influences from "internal factors" as well as from "external factors". Internal factors relate technological change to unsolved technical problems and the established modes of solving technological problems and external factors relate it to various (changing) characteristics of the social environment, in which a particular technology is embedded.

Overview

For the last three decades, it has been argued that technology development is neither an autonomous process, determined by the "inherent progress" of human history, nor a process completely determined by external conditions like the prices of the resources that are needed to operate (develop) a technology, as it is theorized in neoclassical economic thinking. In mainstream neoclassical economic thinking, technology is seen as an exogenous factor: at the moment a technology is required, the most appropriate version can be taken down from the shelf based on costs of labor, capital and eventually raw materials.

Conversely, modern Technology Dynamics studies generally advocate that technologies are not "self-evident" or market-demanded, but are the upshot of a particular path of technology development and are shaped by social, economic and political factors. In this sense, Technology Dynamics aims at overcoming distinct "internal" and "external" points of views by presenting co-evolutionary approach regarding technology development.

In general, technology dynamics studies, besides giving a "thick description" of technology development, uses constructivist viewpoints emphasizing that technology is the outcome of particular social context. Accordingly, Technology Dynamics emphasizes the significance and possibility of regaining social control of technology, and by the same token it provides mechanisms needed to adapt to and steer the development of certain technologies. In that respect, it uses insights from retrospective studies to formulate hypotheses of a prospective nature on technology development of emerging technologies, besides formulating prescriptive policy recommendations.

An important feature of relevant theories of technological change therein is that they underline the quasi-evolutionary character of technological change: change based on technological variation and social selection in which technological knowledge, systems and institutions develop in interaction with each other. Processes of 'path dependence' are crucial in explaining technological change. Following these lines, there have been different approaches and concepts used under the field of Technology Dynamics.

Different frameworks to analyze the dynamics of technology

- Social Construction of Technology
- Actor-network theory
- Systems theory
- Normalization Process Theory

• Quasi-evolutionary theories
• Innovation system
• Technological innovation system

Based on the analysis of the various perspectives, one can aim at developing interventions in the dynamics of a technology. Some approaches have been developed targeting on interventions in technological change:

• Technology assessment
• Backcasting
• Strategic Niche Management
• Transition Management

Technicism

Technicism is an over reliance or overconfidence in technology as a benefactor of society.

Taken to the extreme, some argue that technicism is the belief that humanity will ultimately be able to control the entirety of existence using technology. In other words, human beings will eventually be able to master all problems, supply all wants and needs, possibly even control the future. Some, such as Monsma, et al., connect these ideas to the abdication of religion as a higher moral authority.

More commonly, technicism is a criticism of the commonly held belief that newer, more recently-developed technology is "better." For example, more recently-developed computers are faster than older computers, and more recently-developed cars have greater gas efficiency and more features than older cars. Because current technologies are generally accepted as good, future technological developments are not considered circumspectly, resulting in what seems to be a blind acceptance of technological developments.

Technocapitalism

Technocapitalism (a portmanteau word combining "technology" and "capitalism," two of the most commonly used words in the social sciences) is a term used to describe the changes in capitalism brought about by the emergence of high technology sectors in the economy.

Luis Suarez-Villa, in his 2009 book *Technocapitalism: A Critical Perspective on Technological Innovation and Corporatism* argues that it is a new version of capitalism that generates new forms of corporate organization designed to exploit *intangibles* such as creativity and new knowledge. The new organizations, which he refers to as *experimentalist organizations* are deeply grounded in technological research, as opposed to manufacturing and services production, and in the appropriation of research outcomes as intellectual property. Under technocapitalism, creativity and new knowledge become the most valuable resources, much as raw materials and factory labor were under industrial capitalism. His book argues that new technology sectors such as nanotechnology, biotechnology and its many fields such as synthetic bioengineering, bioinformatics, biopharmacology and agro-biotech, the emerging new field of biomimetics and its transformation of robotics, and the introduction of molecular processors in computing and communications, among various new sectors and technologies, will become symbolic of the 21st century, in much the same way that aviation and mass production were of the 20th century.

Dinesh D'Souza, writing about Silicon Valley, used the term to describe the corporate environment and venture capital relationships of the high tech economy. The term technocapitalism was also used by philosopher Douglas Kellner in an examination of trends in production from the perspective of the Frankfurt School, to describe the use of technology and its social relationships.