Lecture 20 : Science, Technology and Society

Perspectives on Science – Technology Relationship: Hierarchical, Symbiotic and Coalescing

Wiens writes about how one study (Project Hindsight), conducted by the U.S. Defense Department, examined 710 events that were essential in the development of 20 major weapon systems during the 20 years following World War II. The investigators found that only two events (a minuscule .3% of the total) were the result of basic scientific research (Volti, 1992).[19] Another study analyzing British firms reported similar findings. However, a more recent analysis found a median delay of nine years between a scientific finding and its conversion to technology, a finding that would have modified the results of Project Hindsight somewhat if the researchers would have extended their study over a longer period (Volti, 1992). While it is true that applied science is generally technology (i.e., it is designed to extend human capability or modify an environment), it is also true that much technology that exists and is practiced is not applied science in the strictest sense of the term. increasingly, the paths of science and technology are not separate or unidirectional as indicated in the Project Hindsight study but illustrate a relationship of mutual dependency, that is, symbiotic.

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Today we can give many examples where science and technology complement each other, where one does not consistently lead or follow the other. It is the contention of the author that few fields of endeavor illustrate the symbiotic relationship between science and technology more clearly than biotechnology and, more specifically, genetic engineering.

Even in name, biotechnology is a marriage of science and technology. By definition, biotechnology is a multidisciplinary applied science that draws on knowledge from biology, chemistry, physics, and engineering to use living organisms to make or modify products, to improve plants or animals, or to develop micro-organisms for specific uses (Office of Technology Assessment, 1984). Biotechnology has applications in a number of fields: medicine, agriculture, botany, waste treatment, marine and aquatic fields, and food and beverages .[20]

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Genetic engineering draws its theory from the scientific field of genetics, which consists of three main branches: (a) Mendelian, classical, or transmission genetics, which is a study of the transmission of traits from one generation to the next; (b) molecular genetics, which is the study of the "chemical structure of genes and how they operate at the molecular level" and (c) population genetics, which addresses the "variation of genes between and within populations" (Weaver & Hedrick, 1992, p. 4). [21]

Following A. Emerson Wiens **we can further explore the nature of science technology relationship in the following manner :**

Table 1. "Timeline of the Science and Technology Events Leading to Genetic Engineering"

Science	**Technology**
5,000 BC	Making of beer in Babylon
1590	First compound microscope - Z. Janssen
1684	Two-lens eyepiece - C. Huygens
1838 ---39 Living Tissue Composed Of cells Schleiden , Schwann	
1853	Dark-field microscope condenser-H. Wenham
1859 On the Origin of the Species - C. Darwin	
1865 Postulated laws of genetic— G. Mendel	
1869 Discovered DNA in trout sperm - F. Miescher	
1865-1890	More microscope improvements - Spencer. Tolles
1882 Chromosomes described - Flemming	Improvementsin specimen preservation, staining

Science	**Technology**
1902 First genetic disease noted- A. Garrond Proposed chromosome theory - W. Sutton, C. Bridges	Modern Binocular eyepiece - F. E. Ives
1910- 1916 **Demonstrated that genes are chromosomes**	Undated: Lab tools improved: centrifuge, vortex mixer, culture incubators, etc.
1920	Beginning of corn hybridization - G. H. Shull, E. M. East, D. F. Jones
1924-1926 Wave length of electrons postulated - Broglie, Schrodinger Magnetic and electric fields act as lense for charged particles - Hans Busch	
1927 Induced mutation by X-rays - H. J. Muller	Ultracentrifuge developed

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Science	**Technology**
1932	Electron microscope system; images produced - Bruche & Johnson, Knoll & Ruska
1935	Phase contrast on a microphone - F. Zernike
	E-microscope resolution exceeded light microscope
1939-45	Improvements, production of E-mircroscope
1940	Rapid increase in artificial insemination of cattle
1944 Evidence that DNA is genetic material - Avery, McLeod, McCarthy	More lab instruments necessary for genetic engineering were developed and improved over time:
1953* Structure of DNA discovered: the double helix - J. Watson, F. Crick, R. Franklin, M. Wilkins	Spectrophotometer, UV and visable light
1957 DNA polymerase I discovered - Kornbe	UV transilluminator
1958 Mode of DNA replication demonstrated	Pipettes, micropipettes

1960 mRNA and role in encoding information for amino acids discovered	Electrophoresis apparatus

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Science	**Technology**
1962* Existance of restriction endonucleases in bacteria demonstrated - Arber, Smith, Nathans	Biological tools such as plasmids, other cloning vectors; restriction endo-nucleases, ligases, and polymerases; hosts for cloned genetic information; etc.
1966* Genetic code completely elucidated- M. Nirenberg, H. G, Khorana and Holley	
1970 First restriciton endonuclease isolated	
1972* First recombinant DNA molecules produced in vitro - P. Berg	
1973 DNA inserted into plasmid vector and transferred to host E. coli - H. Boyer and S. Cohen	
1974 World moratorium of some types of recombinant DNA experiments	
1975 Southern blotting methond discovered for detecting specific DNA sequences	
1976 NIH prepares first guidelines for physical and biological containment	
1977* Determined base sequences of DNA - W. Gilbert, F. Sanger Introns discovered - Sharp and Roberts	First biotech firm established - Genentech
1978	Human insulin cloned in lab - Genentech, licensed to Eli Lilly

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Science	Technology
1979	Human growth hormone cloned - Genentech
1981	Interferon, natural tumor fighting protein cloned – Genetech Transgenic Mice and *Drosophila* flies produced
1982	Eli Lilly produces insulin - first rDNA drug
1984	EPA approved trials of bacteria designed to protect strawberry plants from frost damage Social Activists block "ice-minus" tests until 1987
1985* Polymerase chain reaction developed for in vitro amplification of DNA - Mullins, Smith Mullins, Smith	Growth hormone commercialized - Genentech
1988 Located Huntington disease on C-4 - N. Wexler, M. Conneally, J. Gusella	First genetically engineered animal patented - Omcomouse, wotj camcer gene
1990 Discovered cystic fiberous gene - L. Tsui, F. Collins, J. Riordan Human Genome Project begun - J. Watson and others	Located Huntington disease on C-4 - N. Wexler, M. Conneally, J. Gusella

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Science	Technology
1992	Automated DNA sequencing technologies Field testing of corn hybrid genetically altered to resist European corn borers - Ciba Seeds
1993	Field testing of glyphosphate-tolerant soybeans by adding gene that increases production of EPSP enzyme - Ciba Seeds
1992-94	Genome tools - Lawrence Liverpool Nat'l Lab: High-speed, high-purity chromosome sorter; High-speed flow cytometer; Liquid ion-exchange chromatography
1994	First FDA approved gen. altered food: Flavr-Savr
1995 First complete DNA sequencing of a freeliving organism Haemophilus influenzae	

1995-97 Nine more complete DNA sequences completed including yeast, the first eukaryotic organism	
1997	Nuclear transplanation experiment using nucleus from differentiated cell produces a lamb Dolly Genetic chip to hold personal data being developed

Sources: Barnum, 1998; Mariella & Copeland, 1995; Markert, 1989; Studt, 1998; Watson, 1980;
Weaver & Hedrick ,1992; Winchester & Wejksnora, 1996. *Nobel prizes awarded. “ [22]

“ The symbiotic relationship between science and technology is illustrated convincingly by the parallel and collaborative development of genetics and genetic engineering. This relationship has produced an increasingly powerful force in society with ethical, legal, and political ramifications. Combined, they will be a powerful lobbying group for government funds as well as for favorable legislation.”[23]

Social Shaping of Science and Technology

There is need for a favorable environment, which is conducive for the growth of the scientific spirit and scientific temperament. It should liberate the mind from magic, dogmatism and superstitions, from fear and uncertainty. In the West, Science and Philosophy originated in Greece and it was in Greece that the non magical character of scientific and religious pursuits was given due recognition as it is evident from the following observations:’ …before Greece all religion was magical. Magic was of supreme importance.’[24] '…the human mind played no part at all in the whole business. It was enslaved by fear. A magical universe was mystifying because it was so irrational and therefore, completely incalculable. There was no dependable relationship between cause and effect.’ [25] The liberating force of free enquiry paved way for individual’s emancipation from complete dependence on the group as it encouraged personal and rational approach to matters concerning religion .During the Iron Age, Greek philosophy had this liberating effect as this was speculation of free individuals, mostly craftsmen, who were emancipated from complete dependence on the group by iron tools and coined money. There the craftsmen carried the banner of liberty. So, science, in its major and significant form came into existence only when men had tested a sense of what Matthew Arnold called ‘intellectual deliverance’.

Social Shaping of Science and Technology

In India, the Upanishads carried the liberating light of the Iron Age at a time when during the later period of priest centered orthodoxy, the theology of the Vedas failed to carry the true spirit of religion from superstition to wisdom, from an apology to magic into an ideal representation of moral goods. As Gordon Childe observes:' what was really distinctive in Greek speculation was that the philosophy appealed again and again not to the wisdom of the ancients or divine revelations, but to facts of common experience, and the people of the crafts. Their Hindu contemporaries were hampered by inheriting from the Bronze Age the sacred hymns of the Veda and ritual manuals verbally remembered.'[26]
It was the time when the priests of religion aimed at magically controlling the deity, when religion became a matter of skill and technique rather than prayer of devout hearts. To quote D.P.Chattopadhya,:'…the remarkable similarity between Lokayata and the deeper stratum of the Vedic outlook.'[27] How do these texts (the Brahmanas) look at *Yajna*?As magic or essentially magical.'[28]

Social Shaping of Science and Technology

The point can be made that there was no clear cut dichotomy between the scientific and the magical worldviews as many scientific worldviews developed out of magical beliefs and practices prevalent in some forms of our civilization. The close relationship that existed between mathematics and the number mysticism of Pythagoreans is much evident. Some sort of secrecy and mystery characterized even some forms of scientific knowledge like medicine and law when sometimes these were to be revealed only to the initiates, this stress on science-magic separation is an entirely Greek phenomena. Moreover no Egyptians, let alone any other ancient Near Eastern, medical text contains the type of direct attack on magical practices and beliefs that we find in the Hippocratic corpus. The Egyptian evidence shows quite clearly how even before 'magic' became an issue-as it did in Greece-the emphasis, in practice, in medicine may be very much at the empirical end of what we may call the empirical-magical spectrum. But again the conclusion must be that explicit attacks on magic in medicine are, so far as our information for the ancient Mediterranean and Near East is concerned, an exclusively Greek phenomena."[29]

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What is unique is the Greek way of understanding these two worldviews. Why there is so much stress in magic-science dichotomy in Greek thinking than in any other place? It is

because in Greece between the rival and conflicting worldviews, the better story is to be supported by strong argument and empirical evidence. It was also a search for order and regularity in nature:'

Social Shaping of Science and Technology

Technological analysis and metaphysics are undoubtedly important, both in pre-Socratic philosophy and in Hippocratic medicine, as a means of conveying the idea that nature in general, and particular natural phenomena or processes, are regular and orderly.[31]This quest for truth was inspired not by technological development in Greece to match scientific thinking but socio political developments associated with the rise of the city state. To quote Lloyd", but whereas Homeric society –as described in the Iliad and Odyssey at least operates without any strictly formalized legal, let alone constitutional, framework, the period from the 7th to the 4th century is one of unprecedented activity, throughout the Greek world, in the formation, discussion, revision, and at times, overthrow of legal and constitutional codes."[32] Aristotle observed:' Being masters of the vote, the people became masters of the constitution.'[33].

So a democratic set up in city states like Athens remained favorable to the growth and development of critical spirit of the citizens while in oligarchic cities like Sparta not all but those citizens who had equal (full) political rights could take part in deliberations.

Social Shaping of Science and Technology

This had impact in development of scientific temperament and a critical questioning spirit among the masses:" The notion that the world-whole is a cosmos, that natural phenomena are regular and subject to orderly and determinate sequences of causes and effects, is expressed partly by means of images and analogies from the legal and political domain."[34]In the political sphere, and even outside it, proposals and ideas were not accepted simply or even primarily on the say-so of some particular individual relying on his personal prestige or authority.

Beginning with the *Upanishadic* background, the Buddha altered the scheme of it in certain important respects. The *Upanishadic* tradition continued to remain a liberating force with its free and critical enquiry favoring spiritual dimension over and above the material form of religions some of which is reflected in the teachings of the Buddha and of the *Gita* but the Buddha played a much more significant role in this direction. While the *Upanishads* were accommodated in the orthodox *Brahmanic* tradition, Buddha combined *Upanishadic* heritage with the basic teachings of the heterodox tradition, which could not be harmonized with orthodoxy. Taking for granted the context of the greater Indian civilization, the Buddha played the role of re-formulator of the ancient tradition.