# Social technology and human health

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## Abstract

This paper sets out to explore the relationship between technology and health.

Part One of the paper uses the history of penicillin to demonstrate how the complex processes involved in getting a new technology to market are at least as important as the technology itself. Penicillin went through three stages: discovery, development and distribution – each crucial to the drug's success. The discovery of the technology would have been useless without effective systems for both turning it into a usable package and ensuring that doctors and their patients could gain access to it.

Part Two expands the idea that technology alone has little impact on health. The 20th century struggle against tuberculosis (TB) highlights the part society can play in improving its health. Knowledge of the causes of TB helped people to mobilize against the disease, with impressive results. The discovery of a vaccine reinforced society's efforts and was instrumental in driving the disease down to vanishingly small levels, but it also led to public complacency and the latter part of the century saw TB on the rise again.

The third section of the paper shows how society's efforts to improve health must be backed up by governments. Contrasting results in the global battle against HIV/AIDS highlight the importance of strategic government action directed at making the best use of technology. Governments have a vital role to play both in steering the development of new technologies and facilitating their use. Again, technology by itself will not solve health problems – its interaction with all levels of society is the key to its success.

Part Four of the paper delves further into the idea that governments must take a strategic view on technology. It examines the potential of public/private partnerships for developing technology, as well the scope for new technologies such as information technology and the internet for empowering people to take control of their health.

The paper concludes that, although technology has had some astonishing successes in the last 100 years, these achievements have been facilitated by society's use of them. The concept of "social technology" places technology at the center of the myriad of social forces that mediate its use. The advances created by technology, it argues, "*can* truly be transformative – it is the job of 'social technology' to make sure that they *are*."

## One Lessons from the past

*All to gain, nothing to lose*

On 17 January 1941, Mrs. Elva Akers, a 50 year-old woman with terminal breast cancer, was given 100 mg of penicillin. She was the first person ever to be given a purified version of the new antibiotic. After the injection, intended to establish whether the drug was toxic to humans, Mrs. Akers "at once said she had a curious musty taste in her mouth, but otherwise suffered no harm." (Fletcher, 1984). As a result, the drug was declared ready for its first therapeutic test.

Penicillin research team member Charles Fletcher reports that the first therapeutic subject was "an unfortunate policeman aged 43". From a simple "sore on his lips" (otherwise reported as a scratch from a rose bush or a shaving cut), the policeman had become seriously ill over the course of four months:

> "He had developed a combined staphylococcal and streptococcal septicemia. He had multiple abscesses on his face and his orbits (for which one eye had been removed): he also had osteomyelitis of his right humerus with discharging sinuses, and abscesses in his lungs. He was in great pain and was desperately and pathetically ill. There was all to gain for him in a trial of penicillin and nothing to lose." (Fletcher, 1984)

On 12 February 1941, he was treated with 200 mg of penicillin, followed by 300 mg every three hours. To medical staff, the effect was astounding. An improvement was noticeable after just a day and after 5 days the patient was "vastly better". The antibiotic era had begun.

Antibiotics epitomize the impact of science and technology on health. Aspirin, perhaps the first modern pharmaceutical product, was manufactured and marketed in 1893, its forerunners a handful of 19$^{th}$ century drugs, such as morphine, strychnine, quinine, caffeine, nicotine and codeine (David, 1997). The 20$^{th}$ century saw technological innovation of an unprecedented pace and breadth. Sulphonamides were introduced in 1935, a large number of antibiotics in the years following the war, steroids from 1949, psychotropics from 1952, and oral contraceptives from 1960. The revolution was about more than drugs. A whole array of machines was introduced. Some were life sustaining, such as the ventilator, the pacemaker or the kidney dialysis machine; some diagnostic, such as advanced imaging techniques, ultrasound and cardiac catheterization; and some surgical, such as the Zeiss operating microscope, Charnley's hip replacement, and Hopkins endoscope. On the back of this technology, a number of previously inconceivable procedures were developed:

coronary bypass, organ transplantation and the test tube baby, to name but a few of the more newsworthy (Le Fanu, 1999).

Modern medicine was vastly different from anything that had come before (see Figure 1: *Modern Medical Milestones*). Ill health could now be systematically tackled, through a 'biomedical model' based in science. A growing number of diseases could be reliably cured or, through vaccination, prevented or even eradicated. In rich countries, at least, the 20th century hospital was able to make increasingly aggressive interventions, *treating* patients, rather than providing long-term care for the chronically sick. Patients had their blood and urine tested, were X-rayed and scanned, given drugs and operated on. Data were collected and systematic records kept. These changes occurred remarkably quickly. As Joel Howell argues in his analysis of the transformation of patient care in the first quarter of the last century: "by around 1925 the people who ran and financially supported the general hospital in the United States, as well as those who delivered health care within it, had come to see science as the essential tool for making the institution a central part of twentieth century medicine." Medicine had become "quite actively and self-consciously based on science." (Howell, 1995)

*Three themes: discovery, development and distribution*

The scientific basis of modern medicine makes 20th century health care an essentially cumulative endeavor, with each advance building on previous ones. Julius Comroe and Robert Dripps demonstrate this by asking why James Gibbon did not perform the first successful operation on an open heart with complete cardiopulmonary bypass until 1955 – 108 years after the introduction of ether anesthesia. Their answer gives a clear impression of the many innovations that were needed:

> "First of all, the surgeon required precise postoperative diagnosis in every person whose heart needed repair. That required selective angiocardiography which, in turn, required the earlier discovery of cardiac catheterization, which required the still earlier discovery of X-rays. But the surgeon also needed an artificial heart-lung apparatus (pump oxygenator) to take over the function of the patient's heart and lungs while he stopped the patient's heart in order to open and repair it. For pumps, this required a design that would not damage the blood; for oxygenators, this required basic knowledge of the exchange of $O_2$ and $CO_2$ between gas and blood. However, even a perfect pump oxygenator would be useless if the blood in it clotted. Thus, the cardiac surgeon had to await the discovery and purification of a potent nontoxic anticoagulant – heparin." (Comroe and Dripps , 1976)

In all, they list 25 essential “bodies of knowledge” in which significant advances necessary to James Gibbon’s achievement (see Figure 2: *25 Essential Bodies of Knowledge*).

The importance of scientific progress to medicine is undeniable, but this should not be taken to mean that medical technology advances in an orderly and programmable fashion. First, it should be remembered that penicillin, like many 20th century medical discoveries, owed as much to chance as it did design. Alexander Fleming *had* been studying means of inhibiting bacterial growth in 1928, but his breakthrough came unprompted, when a rare penicillium mould “wafted through the window” into a petri dish which had been left out of the incubator while he was on holiday. Nine unusually cool days followed, providing the perfect temperature for the mould to grow, and, on his return, Fleming happened to pick up the dish before it was washed and noticed how the staphylococci’s growth had been inhibited (Le Fanu, 1999). Most of the drug discoveries that have followed have also relied on chance – the difference being that researchers have played the chemical roulette systematically and repeatedly, with thousands of chemicals being tested on animals to see whether they are (a) effective; (b) safe to use and (c) capable of effective delivery. This “chemical roulette” is clearly scientific, but there are limits to what it can achieve. While the hard technology of medical machinery may be *designed*, pharmaceutical products generally have to be *discovered*. Furthermore, many drugs are used because they work, not because of a deep understanding of how and why they work. The result is an inevitably patchy armory, with antibiotics offering a “magic bullet” for use against bacteria, but nothing of similar potency emerging to combat the threat of viruses. The sequencing of the human genome opens up the possibility of a new era of drug development, based on a more rational and systematic approach. However, this promise is as yet unproven and meanwhile the old trial and error approach continues to be a staple of pharmaceutical development.

Second, the *discovery* of penicillin would have been worthless without considerable further (if less lauded) *development*. Fleming published his results but was not successful in making anything of his discovery and, as a result, there is a curious thirteen-year hiatus in the penicillin story. As Sir Ian Fraser, a surgeon who led the original clinical trials, puts it: “Fleming had put penicillin on the map, but [Howard] Florey really put it on the market.” (Fraser, 1984) Together with a team that included Ernest Chain and Norma Heatley, Florey succeeded in extracting sufficient quantities of the drug for therapeutic use, but only with great difficulty. The mold could only be grown as a surface culture and, at some risk to his reputation, Florey turned his laboratory into a small (and somewhat unsafe) factory, collecting penicillin for use in “stacks of bedpans,” the only suitable receptacle he could find in sufficient quantities. Even so, early supplies of penicillin were so precious that the first patient’s urine was collected each night, so that the penicillin it contained could be extracted and given back to him. Despite this measure, supplies only lasted for five days

and the unfortunate policeman "gradually deteriorated and died a month later." (Fletcher, 1984) There were further technical problems to overcome even to administer the drug to the first patients. As Fletcher explains, new equipment was needed to control the flow of drug into the patient's body: "Marriott and Kekwick had just described a reliable flow control device…I quickly made up two or three of these gadgets and they functioned admirably." (Fletcher 1984)[4] Basic scientific research may make the most visible – and best remembered – contribution to any new discovery, but it is only the start of a painstaking, time-consuming and expensive development process. Without this development, however brilliant the discovery, it is destined to languish on the laboratory shelf.

Third, without the means of producing and distributing the new drug, there would be little wider benefit. Britain's pharmaceutical industry had insufficient capacity to invest in developing techniques to extract sufficient quantities of the new drug for production. Florey's team could only extract one part of penicillin per million of culture medium and even this was of insufficient purity (patients preferred receiving taking penicillin that had been extracted from their urine – it was purer and therefore caused less irritation when injected). The drug was also unstable and soon became ineffective when stored. In 1941, therefore, Florey and Heatley, funded by the Rockefeller Foundation, flew to the United States, where they tried, and initially failed, to interest American pharmaceutical companies in their project. Eventually, as the US focused its energies on the Second World War, the pair started to work with the U.S. Department of Agriculture's Northern Regional Research Laboratory in Peoria, Illinois. A new species of *Penicillium* (apparently found on a moldy cantaloupe bought in a Peoria market) was used for production, after being mutated until it produced much higher quantities of the drug. In addition, a new method was developed for growing the mold, using 25,000-gallon tanks aerated in order that the mold would grow throughout the entire tank (Wong, 1998).

As a result of these developments, Merck, Pfizer and Squibb agreed to collaborate on the production of the drug. By 1943, an extraordinary industrial effort had led to some 21 billion dosages being produced every month (Lesney et al, 2000). Undoubtedly, there was huge untapped demand for antibiotics, but it took war to crystallize this demand into a viable market; a command economy to set the wheels of industry rolling; and the orderly nature of modern armies to create an effective distribution channel. Even so, there were disparities in access, with British soldiers less likely to receive the drug than their American counterparts. Over 50 years later, these inequalities continue. Across the world, an unknown number of

[4] The case of cortisone was similar. Edward Kendall and Howard Hench had done the ground work by 1936, however there was no incentive for any pharmaceutical company to fund further development until a false wartime rumor that the Germans were planning to use hormones to create super-pilots capable of flying at 40,000 feet led to significant government interest in hormone research. It was not until 1948 that Merck was finally able to isolate enough pure cortisone to test its therapeutic potential. See James Le Fanu, 1999.

people die each year as a result of bacterial infections amenable to quick, easy and cheap cure with antibiotics. In this – as with many other medical technologies – farm animals in developed countries are more likely to receive benefits than people in developing countries, with the World Health Organization estimating that 50% of all antibiotics are now used in agriculture (WHO 2000a).

*Understanding technology*

Donald Schon's influential analysis of technological change, Technology and Change,[5] usefully defines technology as "any tool or technique, any product or process, any physical equipment or method of doing or making, by which human capability is extended." Meanwhile the term 'social technology' has been in use for several years, and several organisations[6] are involved in projects using that term. While little consensus exists, social technology here tends to be considered as that technology which is engaged in solving social problems. This school also covers those considering how technologies are embedded and used in a social context. Thus, "instead of treating technology *per se* as the locus of historical agency, the soft determinists locate it in a far more various and complex social, economic, political and cultural matrix".[7]

In this paper, we argue that there is a new space opening up between the schools of technological determinists, who have tended to emphasise tools and techniques rather than the hands and minds that use them, and social determinists, who have tended to do the reverse. Both technology and society influence each other in complex ways, and are often functionally indivisible, like the chicken and the egg. For example, in the case of tuberculosis (TB) outlined in this paper, social and technological knowledge preceded the development of technologies with which to tackle TB, while those technologies in turn preceded their social utilization. Hospitals, meanwhile, are both a reflection of a kind of society and its attitude to health, but once created have also helped to change the direction of societies in which they exist. 'Social technology' is thus used here as a phrase demonstrating that neither social nor technological factors have primacy, for both are intertwined as intimately as the double helix of DNA.

The story of penicillin demonstrates the complex relationship between medical science, technology and health. Technological innovation *can* have an enormous impact on health, but discoveries have never come easily and the "designer drug," developed in a purposeful fashion from first principles, remains relatively rare. Successful research is only half the

[5] Donald A. Schon (1967), Technology and Change: The impact of invention and innovation on American social and economic development, Delacorte Press, New York.
[6] Including the North Karelian Social Technology Development Project in Finland, and Thailand's Institute for Social Technology at Suranaree Technical University.
[7] Smith & Marx Editors, 1996, Does Technology Drive History, The MIT Press

story – many potentially life-saving innovations are never exploited because critical development work is not undertaken. Finally, there is the problem of how to create a viable market that allows a technological innovation to have maximum effectiveness. Need must typically be expressed as demand, which raises fundamental challenges for societies and the way they are organized.

Technology therefore cannot automatically remove obstacles that keep people from enjoying better health and, in some cases, it may help erect new barriers. As Eric Drexler puts it: “People who confuse science with technology tend to become confused about limits… they imagine that new knowledge always means new know-how; some even imagine that knowing *everything* would let us do anything.” (Drexler,1986)

## Two "Standardized packages of treatment"

*The forgotten plague*

Tuberculosis (TB), once more commonly known as consumption because it is caused by a bacterium that literally consumes the body, is one of humanity's oldest and most powerful scourges. Egyptian mummies from 2400 BCE show pathological signs of tubercular decay, while Hippocrates identified it as the most widespread disease of the time in 460 BCE (NJMS National Tuberculosis Center, 1996). According to the World Health Organization (WHO), TB currently kills around 2 million people each year. Unless it is more effectively controlled, nearly one billion people will be newly infected with the disease between 2000 and 2020. In the same period, 200 million people will get sick and 35 million will die. Most of those will be in poor countries (WHO, 2000b). Currently, only two of 22 countries accounting for 80% of TB cases, Peru and Viet Nam, have reached WHO targets for case detection and treatment success. Meanwhile, in almost all countries, multi-drug resistant TB is a growing problem (WHO, 2000c).

TB has been described as the "forgotten plague," because many countries dismantled their TB control programs in the latter half of the twentieth century in the belief that the disease had been – or would soon be – defeated. In the 20th Century, over a dozen anti-TB drugs were developed. Equally impressive diagnostic methods were also invented. However, as Paul Farmer argues, despite these technologies "tuberculosis has not really emerged so much as *reemerged from the ranks of the poor*… We indeed have the scientific knowledge – but the hard truth is that the "we" in question does not include the vast majority of the… people who [die] from tuberculosis." Unequal access prevented a decisive strike against the disease. Now that window of opportunity seems to have closed, a synergistic relationship between HIV and TB, alongside growing drug resistance, is causing a resurgence of the disease. According to Farmer, both rich and poor now face "truly novel problems," with the probability of pan-resistant strains to come (Farmer, 1999).

At the turn of the last century, TB was an uncontrolled problem for the world's industrial countries with around 1 in 10 Americans dying of the disease. However, between 1900 and 1920, that fell by a factor of ten, and by a further factor of ten between 1920 and 1950 (Ruggiero, 2000). 1950 was also the year in which results were published showing that the first effective cure for the disease (a combination therapy of PAS, a relative of aspirin, and the antibiotic streptomycin) had been discovered. Before that, the only technological intervention was to collapse the lung (artificial pneumothorax) or undertake some equivalent surgical technique. This drastic, but partially effective, intervention, based on the theory that the lung would heal if it was able to rest, could only be used in relatively few cases. The war against TB, therefore, began with a highly successful *pre-technological*

battle, where the weapons deployed were *social* ones. Public health, not biomedical science, was the dominant model. New institutional constraints, new forms of organization and a mass mobilization of the public all played a significant role. Given knowledge about the threat TB presented, the US proved capable of protecting itself even with inadequate technology at its disposal. The availability of effective technology allowed a second assault against TB to be mounted, but this demonstrated that technology is not enough on its own. As resistance increased, a third battle has been necessary, focusing on the social context of the technology, by paying renewed attention to the way that patients use TB drugs.

*The first battle*

Without an understanding of what TB was, and how it spread, societies had little ability to combat it. This knowledge emerged slowly. The earliest reference to the infectious nature of TB was made in a 1699 edict from the Republic of Lucca, Italy, which stated that, “henceforth, human health should no longer be endangered by objects remaining after the death of a consumptive. The names of the deceased should be reported to the authorities, and measures undertaken for disinfection.” In 1720, Benjamin Marten, an English physician, speculated that the disease was possibly caused by “wonderfully minute living creatures”, observing that by “conversing so nearly as to draw in part of the breath he emits from the Lungs, a consumption may be caught by a sound person.” In 1865, the French doctor Jean-Antoine Villemin demonstrated that consumption could be passed from humans to cattle and from cattle to rabbits and postulated that the disease was caused by a microorganism. Finally, in 1882, Robert Koch invented a staining technique that enabled him to see the TB bacillus and provide a convincing description of how TB is spread (Ruggiero, 2000).

This knowledge was enough to launch the first battle against TB in the US. In 1893, just eleven years after Koch’s discovery, a pioneering report by Dr Hermann Michael Biggs to the New York City Board of Health brought the new knowledge about the infectious nature of TB to the attention of US policymakers. This report explored the implications for public health of the theory that TB was communicable – and therefore preventable. Dr Hermann Biggs, widely regarded as a public health visionary, was quite explicit about at least one aspect of the relationship between health and economics: “Public health is purchasable.” He continued, “Any community can determine its own death rate.” (Garey & Hott, 1995) The Biggs report led to a concerted effort to change US society and provide US citizens with the “public good” of a TB-free environment. New health organizations were created to service novel testing and reporting regimes, while the consumptive hospital movement used isolation to inhibit transmission.

A number of non-governmental organizations (NGOs) were also born, indicating the breadth of involvement or "participation" in the early parts of the war against TB. Chief among these was the National Association for the Study and Prevention of Tuberculosis, which was founded in 1904 and later renamed the National Tuberculosis Association and finally the American Lung Association. Together with other organizations, it mobilized the public through mass fund-raising campaigns, reporting at the time that "no nationwide program has rested for so many years on so broad a base made up of millions of small gifts."[8] Public and civil sectors also helped to drive behavioral change at an individual level. Hospitals carried signs saying "spit is poison", while notices in public places warned that spitting on the floor spread disease (Ruggiero, 2000). (See Figure 4: *A Century of Advances in Tuberculosis Control, United States*). Popular culture also played a part with, for example, blues artist Victoria Spivey recording no less than three songs on the subject, "TB Blues", "Dirty TB Blues" and "TB's Got Me".[9]

*The second battle*

The second battle against TB used a *technological* solution to intensify the campaign, as the biomedical model took over from these pioneering public health interventions. In the first battle, knowledge about how to prevent the spread of TB was interpreted time and again, through a range of social structures. This effort required a vast amount of determination, cohesion and unity of purpose, especially important against a disease that was so easy to catch (a single cough can contain 3000 infective droplets, with fewer than 10 mycobacterial bacilli sufficient to initiate a pulmonary infection) (Li and Brainard, 2000). Technology, on the other hand, encapsulates this knowledge, providing a relatively *reliable* interpretation intervention that can be reproduced countless times. A drug or a machine has demonstrated efficacy. In theory, consistent manufacture ensures consistent performance, producing what Peter David calls "standardized packages of treatment" that can be used in similar ways across the world (David, 1997).

The second battle against TB drove the disease down to vanishingly small levels in the US, showing the efficacy of technology in creating positive health outcomes. However, this battle also demonstrates some of the other factors needed in play for such results to be achieved. A drug is not created to consistently high levels of quantity and quality without great effort, a battle still not won in many countries, where medical technologies are

[8] The March of Dimes provides another well-known, if later, example. Established in 1938 by President Roosevelt to eradicate polio, the March of Dimes led to the development of the polio vaccine within twenty years, using funds raised by thousands of volunteers.

[9] The enduring legacy of disease in popular culture is a subject of considerable interest in its own right, given culture's capacity to act as an effective communication medium. See, for example, Paul Oliver and Richard A. Wright, 1994. *Blues Fell This Morning: Meaning in the Blues*. Second Edition, Cambridge University Press.

frequently manufactured to inadequate standards, either by accident or through deliberate fraud (Silverman, Lydecker and Lee, 1992). In the West, according to Theodore Porter, the pharmaceutical industry went through a preparatory period in the early twentieth century when the principal use of science was not to create new products, but to find ways of standardizing and testing existing ones. This was a tricky, time-consuming and sometimes even comic process. As one frustrated observer commented on the plethora of biological tests (where a drug's purity or toxicity was tested against its ability to induce a reaction in a laboratory animal): "we have cat units, rabbit units, rat units, mouse units, dog units, and, latest addition of all, pigeon units. The field of tame laboratory animals having been nearly exhausted, it remains for the bolder spirits to discover methods in which a lion or elephant unit may be described." (Porter, 1995)

As well as new forms of quality control for manufacture, it was also necessary to invent new methods of measuring efficacy. The testing of the cure for TB brought the clinical trial into the mainstream. Austin Bradford Hill, Professor of Medical Statistics at the London School of Hygiene and Tropical Medicine (who himself had survived TB through bed rest and an artificial collapse of the lung), first performed a trial of streptomycin on its own, arguing that a trial should be conducted because there were insufficient quantities of the drug in Britain for it to be made available for widespread treatment. "I could argue in this situation," he commented, "it would not be immoral to do a trial – it would be immoral not to, since the opportunity would never come again as there would be plenty of streptomycin."[10] This trial offered a dramatic vindication of statistical methods. Initially, streptomycin seemed to offer dramatic benefits, but these soon diminished as resistance to the drug increased. It was not until PAS and streptomycin were tested together from 1948-1950 that survival rates increased to over 80%. The double blind clinical trial – where patients are randomly allocated to receive and not receive a new therapy, without either patient or physician aware who has been allocated to which group – had proved its worth and would soon be in common use across medicine (Le Fanu, 1999).

Over time, the social control of medical technology has been enshrined in legislation, providing a semi-permanent guarantor of a technology's provenance, efficacy and production standards. In the US, the Biological Controls Act in 1902, and the Pure Food and Drugs Act in 1906, were pioneers. International procedures were first formalized when L'Office International d'Hygiène Publique was established in Paris in 1907. By the 1940s, the Federal Trade Commission in the US was forcing drug manufacturers to both prove any

[10] It is interesting to remember that arguments about the ethics of trials date back to Bradford Hill's work. If a potentially life-saving drug is available, it is questionable whether the intervention should be denied to patients who may die before a trial has been completed. In recent years, as a result of pressure from AIDS advocacy groups, the FDA has showed an increasing willingness to fast track drugs through the approval process.

claims made for their products and show that they were safe. By 1962, following the thalidomide disaster, standards for clinical research were tightened considerably. In 1964, the Declaration of Helsinki set international standards for research and informed consent. The pharmaceutical industry is now so highly regulated that the ethics of lengthy testing of potentially life-saving medicines is now in question. However, the need for the strong governance of medical technologies is universally accepted. While the development of some technologies has been increasingly deregulated, social control of medical technology necessarily remains strong.

*The third battle*

The need for the US to gather forces for a third battle against TB shows that, while in a well-functioning society the development and production of technology can be effectively controlled, the *use* of that technology is much less susceptible to legislation. Whether used by professionals or lay people, inconsistencies in the use of technologies are almost inevitable and the opportunity for misuse ever present. This may be the result of poor instruction, for example the inadequate or deliberately misleading labeling of a pharmaceutical (common in many developing world countries) (Silverman et al, 1992), or it may result from predictable variations in human behavior. Even if treatment was without cost of any kind – in terms of side effects and time, as well as financially (which, of course, it never is) – some patients will, inevitably, cease treatment before a cure is completed. Even in clinical trials, where patients are presumably more carefully monitored and controlled, a large number of patients do not use test medicines as instructed. In one recent study, patients with respiratory problems were given metered-dose inhalers with detectors to find out how many were taking the dose correctly. 30% of those not told about the detector did not follow instructions (New Scientist, 26 August 2000).

With TB, the infection remains long after the symptoms have disappeared and the treatment is long and unpleasant. The result of a failure to complete courses of treatment has been the inevitable rise of drug resistant strains across the world (WHO 2000d).[11] In the US, the issue achieved prominence in 1991, when it was revealed that 19% of all TB cases in New York City were resistant to the two most effective TB drugs (Isoniazid and

[11] According to the World Health Organisation: “Treatment failures occur when patients are either dosed with poor quality drugs, have limited access to, or are non-compliant with existing therapies. Insufficient treatment results in a roller-coaster ride of brief reprieves followed by relapses that grow ever more impregnable to available medications each time the TB organism rallies Currently, a single treatment course of six months for regular tuberculosis costs as little as US$ 20. With MDR-TB, the costs shoot upward to US$ 2 000, or even more… The ability of HIV to accelerate the onset of acute MDR-TB has serious implications for humanity. In crowded hospitals filled with immuno-suppressed individuals, resistant TB has the potential to stalk relentlessly through a population, afflicting patients, health care workers and physicians alike. War, poverty, overcrowding, mass migration and the breakdown of existing medical infrastructures all contribute to MDR-TB's development, transmission and spread.” See: Overcoming Antimicrobial Resistance – World Health Report in Infectious Diseases 2000, World Health Organisation, 2000

Rifampin). Half of these patients had already been treated at least once and some for many months. In Central Harlem, at the time, only 11% of patients finished their treatment (Fujiwara & Frieden, 2000). Americans found themselves oddly ill-equipped to re-engage in the battle against TB. Few doctors had experience dealing with the disease and public health structures had suffered years of neglect and under-investment (Garrett, 2000).

At the heart of the third battle lie attempts to redesign anti-TB technology from the user's point of view. This redesign could have been encapsulated within the technology itself – for example, a delivery mechanism that would steadily release its payload over a sufficient period of time (as in a contraceptive implant). However, in the case of TB, redesigning the social context of delivery proved more practicable and resulted in directly observed treatment (DOTs), where the patient is observed taking each treatment. With DOTs, the patient is, according to a former director of the New York City TB control problem, "the VIP." (Fujiwara & Frieden 2000). The "comprehensive, convenient, and user-friendly" approach is intended to increase compliance levels (Farmer, 1999). As the Mississippi TB controller describes it: "The public health nurse persists through heat or snow, wind or rain, dogs, gangs, or alligators and finds the patients and persistently guides, cajoles, or bribes them through treatment. If, along the way, that means baking a few extra cookies, making an extra trip after work to deliver a home-cooked meal to a homeless or lonely patient… that's nothing special. That's just the way DOT happens." (Holcombe , 2000) DOTs is now recommended by the WHO for all countries, with 43% of the global population having access to DOTs in 1998, double the figure in 1995 (WHO 2000c).

*Knowledge, health and wealth*

The three battles against TB show some of the strengths and weaknesses of technology. The first battle demonstrates that technology is only one vehicle for knowledge about health, but as the second battle shows, it is a vehicle with important advantages, providing results that are less reliant on the vagaries of human behavior. However, as the third battle demonstrates, "less reliant" does not mean "not reliant". How a technology is used, or its "market-orientation", is ultimately critical to its efficacy. Used in the wrong way a problem can be exacerbated, as drug resistance, for example, rises. However, the failure to use a technology widely enough can also be disastrous. It is the survival of vast pockets of TB among the world's poor that has led to the prospect that the disease may once again trouble those who are relatively wealthier.

The war against TB also indicates that communities can be good or bad at using the knowledge that leads to health. The public health effort of the first half of the century was an extraordinary one, requiring massive social mobilization and change. The reverses at the end of that century show how easy it is to squander a technology's potential.

Knowledge is not destiny, technology even less so. Herman Bigg's assertion still holds true today – a society must choose how healthy it will be.

## Three The problems we face

*A challenge refused*

According to the world's largest scientific society, the American Chemical Society: "the influenza pandemic of 1918-1920 demonstrated the inability of medical science to stand up against disease. More than 20 million people worldwide were killed by a flu that attacked not just the old and frail but also the young and strong. This was a disease that no magic bullet could cure and no government could stamp out… Monopoly capitalism and renewed conservatism battled against government intervention in health care… The continued explosive growth of cities obviated many of the earlier benefits in sanitation and hygiene with a host of new "imported" diseases." (Lesney et al, 2000)

As with flu in 1918, so with HIV/AIDS today (Bloom 2000). The disease first surfaced in 1981, when the *New York Times* reported an outbreak of a rare cancer among gay men in California and New York, although the oldest HIV sequence yet discovered dates from the 1950s and the current best guess is that the virus crossed from chimpanzees to humans in 1930 (Korber et al, 2000). Since the 1980s the HIV/AIDS epidemic has grown with phenomenal speed. According to the latest figures, 5.3 million people were infected with HIV in 2000 and 36.1 million people are now living with HIV/AIDS. There were an estimated 3 million AIDS deaths in 2000 and the epidemic has probably now killed more than the 1918 flu epidemic, claiming some 21.8 million victims. Simple mathematics indicates that this figure will rise above 50 million, in the absence of a cure, the infected die. The epidemic seems to be peaking in Sub-Saharan Africa, where such a large proportion of adults are now infected (8.8%) that it is hard for the situation to grow much worse. The situation is still deteriorating in Eastern Europe, the current rise in Russia is described as exponential, and the situation in China is worsening. Only in rich countries is the epidemic under any form of control and even then, mini-epidemics thrive in deprived communities (UNAIDS 2000).

HIV/AIDS raises fundamental questions about the world we live in. HIV spreads along economic pathways, with openness to trade leading to vulnerability to disease (Bloom & River Path Associates, 2000). It therefore represents the dark side of economic globalization, raising fundamental questions about the benefits of an inter-dependent world system (Garrett 2000).[12] While the world is able to mobilize to protect oil supplies in the Gulf, it currently lacks the institutional capability to tackle existing and new health threats.

[12] It is interesting to compare the reaction to a reported outbreak of plague in Surat, India. According to Laurie Garrett: "In less than a week 500,000 residents of Surat had fled, forming a diaspora of Suratis that, thanks to India's vast train system, now stretched from the Himalayas to Sri Lanka. An estimated 600,000 day workers and business travellers who normally visited the gem and fabric districts of Surat stayed away. Thus, less than half of Surat's typical daily census of 2.2 million remained. They were the poorest of the Gujarat State's poor." See Garrett 2000 op cit.

The UN system did not manage the early epidemic very effectively, while UNAIDS – a new organization that took over responsibility for the epidemic in 1996 – has a patchy if improving record. Even if these organizations had responded impeccably, however, their efforts would still have been inadequate. The resources and the political will are simply not available for an international response to match, in the early 21st century, the scale and intensity of America's mobilization against TB one hundred years ago.

*Knowledge is not enough*

The example of TB demonstrated the power of knowledge about health, not just as a precursor to technological development, but as an effective tool in the battle against a disease or other health problem. The World Bank has tried to quantify the importance of the impact of knowledge, estimating that the generation and utilization of knowledge accounts for 45% of the fall in the under-5 mortality rate in 115 low and middle-income countries. Another 38% of the fall is attributed to improved education among women, who are thus enabled to act as more effective receptors and conduits for knowledge about health. Meanwhile, only 17% of the decline is attributed to income (See Figure 2: Contributors to Falling Mortality Rates). Such estimates are just that – estimates – but nevertheless provide a clear *pointer* to the importance of key factors. WHO research, analyzing data from 1952-1992, provides a similar finding. In the period studied, average per capita income increased from $1530 to $2560 (in 1985 international dollars). If the income-mortality relationship had remained as it was in 1952, infant mortality would have dropped from 144 per thousand to 116 per thousand by 1992. In reality, however, it fell much more sharply to 55 per thousand, with factors other than rising wealth affecting the outcome (WHO 1999).

However, the spread of HIV demonstrates clearly that the *existence* of knowledge about a disease is not enough. Such knowledge was generated relatively quickly. Early suspicions that AIDS was caused by drug abuse quickly proved unfounded and, by 1983, a retrovirus had been identified as the possible cause of the syndrome (Bloom, Bloom and River Path Associates 2000). HIV infection is relatively hard to acquire, so within only two years of the disease hitting the front pages, communities were handed the knowledge necessary for self-protection.

Armed with this information, some communities proved remarkably successful at protecting themselves. In the United States and other rich countries, for example, the gay community was hit first and hardest by the epidemic. However, despite the fact that their sexual behavior was significantly more risky than that found among most other populations, gay communities responded rapidly and effectively (Bloom & Glied). As with the war against TB, new organizations sprung up and behavioral change was facilitated. Indeed, in some ways the disease seemed to galvanize and strengthen these communities. It is not only rich

communities that have taken effective action. Senegal, Uganda and Thailand provide examples of poorer countries acting decisively. In Senegal, for example, condom use has increased rapidly, with approximately two thirds of men and half of women using them during from casual sex, up from around 1 percent at the start of the epidemic.

The contrast with countries where the disease has run uncontrolled is painful. In such countries, awareness of HIV/AIDS is generally now high, but this awareness has not translated into social mobilization or behavioral change. According to Jack Caldwell: “there is less public or media discussion of AIDS in Zimbabwe, with an adult seroprevalence level approaching 30 percent, than there is in Thailand, with a level of 2 percent.” (Caldwell 2000) Such countries now seem locked into a vicious spiral. Their inability to absorb and utilize knowledge about preventing the spread of HIV can be seen as a reflection of the inadequacies of their social organization. In turn, the epidemic is corroding social and economic structures. AIDS kills wage earners and leaves orphans to fend for themselves. It weakens government, the education system and health services. All three forms of capital – physical, social and human – disappear at once.

The example of HIV shows how societies vary in their ability to acquire and utilize knowledge. As Jared Diamond has argued, this variation is political, not innate, and liable to short term change as conservative and progressive factions compete for leadership (Diamond 1997). Knowledge about health will only make a difference within a sympathetic political or policy environment. Significant and sustained health improvements across a society cannot be expected to follow *automatically* from knowledge. It is only in those societies where broad investment in health is a priority where health has consistently improved.

*The failure of science*

As with TB, knowledge about HIV/AIDS has been more immediately applicable through public health measures than it has been through medical intervention. And, as with the 1918 flu epidemic, we still face “the inability of medical science to stand up against disease.” Although frequently promised, a technological solution has not arrived and still seems far off.

Most medical advances have occurred in helping treat (though not cure) those who have already fallen sick with AIDS. The US Food and Drug Administration (FDA) now lists over 40 approved therapies that slow or disrupt viral replication or treat opportunistic infections

(FDA).[13] These treatments represent a remarkably poor fit with what those suffering from AIDS really need. A treatment regime with highly active anti-retroviral therapy (HAART) costs up to $20,000 per year and is currently available to only 1% of those living with HIV (Bloom and River Path Associates, 2000).[14] The most effective drugs are unavailable where they are needed most, a situation that has mired rich and poor governments, multilateral agencies and pharmaceutical companies, nongovernmental organizations and AIDS activists in increasingly bitter controversy. Even for those who can get treatment, the available drugs are far from ideal. They do not provide a cure and the side effects can be dramatically unpleasant (everything from a disfiguring redistribution of body fat to liver disease). Doctors are not even certain how these "standardized packages" should best be used. US doctors have ridiculed UK doctors for conservative treatment protocols, but the US Department of Health and Human Services has just announced more cautious prescribing guidelines, in what the New Scientist describes as a "humiliating U-turn" from its early "hit hard, hit early" treatment advice. In the absence of a stunning breakthrough, AIDS treatment seems likely to remain as much therapeutic art as medical science.

Technology's record in aiding prevention is even less impressive, with the humble condom still the most effective preventive tool by many orders of magnitude. The International AIDS Vaccine Initiative (IAVI) is scathing about the lack of investment in vaccine development, with only US$300-350 million spent annually - just 2% of the total money spent on the AIDS epidemic. "Much of this is from national research agencies for basic research," it comments. "It is industry that makes products and industry has not had the incentives to invest heavily in product development and has had virtually negative incentives to invest in creating products for developing countries. As a result, the vaccine pipeline is narrow and few products are moving forward." (IAVI , 2000)

The World Bank concurs, identifying two problems. First, our understanding of how to induce HIV immunity is inadequate. Many different approaches will therefore have to be tested in parallel, with little certainty about their effectiveness, a "try-and-see" approach that shows how medical science is still some way from being able to reliably build vaccines from the ground up. Second, the *need* for a vaccine has not been expressed as a *demand* strong enough to galvanize either the public or private sector (World Bank 2000). Not much, it seems, has changed from the days of the development of penicillin. Although the septic wards were full and the suffering of the patients they contained immense, this in itself was not a sufficient incentive for the development of antibiotics. A catalyst – in the case of

[13] For a complete list, see FDA, "Approved Drugs for HIV/AIDS or AIDS-Related Conditions," last updated 6 July 1999 (available at http://www.fda.gov/oashi/aids/stat_app.html); "Antiretroviral Drugs Approved by FDA for HIV," last updated 2 March 2000 (available at http://www.fda.gov/oashi/aids/virals.html).
[14] For a fuller discussion of access to AIDS treatment see David E. Bloom and River Path Associates (2000), Something To Be Done: Treating HIV/AIDS, *Science*, Vol. 288, 23 June 2000.

penicillin, war – was needed to crystallize demand and encourage a range of actors to pull in the same direction. Just expecting change to happen was not enough.

*Public goods and private benefits*

For medical science to have a greater impact on AIDS – and on many other uncontrolled health problems – substantial changes are needed in the way science is practiced. Most urgently, incentives must be created to ensure investment is directed at those problems which have the most dramatic impact on global health. Health is a "public good" i.e. the sum of benefits provided by good health to a community is greater than the sum of private benefits accruing to each community member. Market failures are therefore inevitable without corrective action.

Two kinds of incentive are possible: mechanisms which aim either to 'push' or 'pull' desired outcomes. Push mechanisms, such as public investment in research, are relatively common. However, it is uncertain whether, in the past, the public has received adequate return for its investment in technologies that have ended up in private hands (AZT provides one controversial example). Experimental new approaches must therefore be developed. IAVI's investment in AIDS vaccine development provides one example. The initiative was founded in 1996 with $120 million from public and private sources to be spent on research aimed at finding a vaccine for AIDS. IAVI's founder Seth Berkley describes it as a model of "social venture capital", with investments made in private sector research on the basis of differential pricing for developing countries. In other words, questions surrounding the distribution of new products have been at least partially settled before the research has commenced.

In contrast, 'pull' mechanisms, where payment is made for research outputs, aim to mimic the market and harness the private sector's well-deserved reputation for innovation. An early example of a 'pull' incentive was the prize of £20,000 offered in 1714 by the British Parliament for anyone who could come up with a sufficiently accurate method to measure longitude, needed because of the significant loss of life and merchandise cause by the inability of ships to accurately gauge their position. Parliament was responding to a petition signed by "Captains of Her Majesty's Ships, Merchants of London, and Commanders of Merchant-Men," which demanded that "the government pay attention to the longitude problem – and hasten the day when longitude shall cease to be a problem – by offering rich rewards to anyone who could find longitude at sea accurately and practicably." (Sobel, 1996) In its latest development report, the World Bank uses similar reasoning: "[to] ensure a large market for vaccines in poor countries, [the international community] could create a fund or other credible precommitment mechanism for purchasing, for the poorest countries, many doses of vaccines shown to be cost effective and affordable." (WDR 2000)

Incentive mechanisms have the added advantage of being highly visible. Push mechanisms, such as the Manhattan Project, have secured wide public support. Pull mechanisms can also capture the public imagination, as the competitive element creates and sustains the kind of strong narrative that is attractive to the media. Pull mechanisms have the added advantage of being fresh and under-utilized. Political leaders have repeatedly promised to galvanize researchers to defeat a particular disease and have, oftentimes, failed to deliver on this promise. Harnessing the competitive instincts of the private sector has been tried much less often.

As the example of TB shows, widespread involvement in the war against ill health is of incalculable value. A high profile incentive to tackle a key global health problem could focus international public attention on health, motivate further investment and stimulate desperately needed institutional innovation. As Ravi Kanbur and Todd Sandler have argued: “at a time when development assistance is on the decline owing to a disillusionment with past results and domestic demands for the associated resources, a public goods rationale can ignite a renewed interest in some kinds of development assistance activities. (Kanbur, Sandler, Morrison, 1999)  The challenge is to find at an international level what malariologist Leonard Bruce-Chwatt calls “a great deal of steady devotion to a very distant goal.”

*A new model*

AIDS will not be the last new health challenge we face. Indeed, as antibiotics decline in efficacy, it is possible that the world faces a return to an era where a growing, rather than shrinking, number of infectious diseases become uncontrollable. In addition, the world is aging and faces a growing non-infectious health burden, with health systems struggling to cope with an increasing number of conditions that have traditionally been expensive to treat.

The lessons of AIDS point to the need to take an increasingly strategic view of the development of health systems, and of the technology that will enable them both to be technically effective and cost effective. Scientists are justly proud of their ability to innovate rapidly, but the effort to develop technologies to combat AIDS has clearly been hampered by an inability to confront new challenges. Increasingly, however, scientific research will be directed towards clear goals, with funders insisting that problems are tackled according to the types of “real world” solutions required (Gibbons, Limoges, Nowotny, Schwartzman, Scott and Trow, 1994). Inevitably, much of this strategic direction will be imposed by private companies, as a direct result of the scale of their investment in research and development. This risks further exacerbating the tendency for the problems that have the most serious effect on the largest number of people to receive an inadequate share of funding and

development effort. Governments, international institutions and NGOs are therefore likely to feel increasing pressure: first to protect and advance the public good offered by widespread access to the technologies that promote health; and, second, to strengthen relationships with the private sector in order to influence and direct the private sector agenda. Progress towards improving the health of all people is possible, but it is a reasonable assumption that neither public nor private sector can achieve this on its own.

## Four Social Technology

*Crucial questions*

As medical research becomes increasingly goal oriented, the key question is who will set the goals and whether those goals will lead to new technologies that make healthcare more efficient, equitable and cost effective.

The eventual answer to this question will rely both on *what* new technologies are discovered and on *how* new and existing technologies are used. For the former, the development of the relationship between the public and private sectors will be crucial, as will the ability of new types of research to deliver on their undoubted promise. The latter relies on measures to improve the availability and suitability of technologies, but also on the ability of societies, communities and individuals to organize to make the most of the benefits new technology offers. In both cases, in other words, a consideration of the relationship between technology and health requires an exploration of both “narrow” and “broad” issues. The narrow issues involve the nature of technology itself and its development - the broad ones how human beings generate and utilize knowledge.

Health advocates must therefore emphasize the importance of investment in knowledge and in technologies likely to improve health. It is hard to see how today’s health problems will be solved without further technological development – and, as AIDS has shown, new health problems are likely to continue to make improving health a moving target. But advocates must also argue for the institutional innovations that allow a society to use knowledge and new technologies to achieve lasting benefits. Without modernization and, in some cases, root and branch reform – at national and international levels, and in the developed and developing world – progress is unlikely. Equally, the role of the individual within health systems is essential. Technological solutions can increase the tendency to see the patient as a passive receiver of care, but as the example of AIDS and TB has shown, health is much more likely to be achieved when it is actively pursued both from the top-down and the bottom-up.

We therefore look at how public and private sectors work together to produce knowledge, and also at the nature and promise of new types of biomedical research. We also examine information technology, a technology that has the potential to have as great a potential on the way that medical technologies are used, as it is already having on the way that new technologies are produced. Finally we introduce the concept of social technology, which attempts to tie together the concept of technology and its use. On its own, a technological approach is insufficient, but this does not mean that one that excludes medical science and

concentrates on social change will be more useful. The two must be considered together if it is to fulfill its potential for progress in the area of human health.

*Public and private*

It is at the boundary of the public and private sectors that many of the decisive battles over health will be fought. Private sector influence over the provision of health is growing even in countries such as the United Kingdom with a strong history of public health provision. Meanwhile, in many countries, including most of the poorest, much health care is already privately delivered and funded. However, as the lessons of penicillin, TB, and HIV/AIDS show, health is not something that the market provides efficiently or equitably on its own. In a purely private system, market failures are inevitable and individual health-seeking behavior within a market system will often be antithetical to a community's longer-term interest in good health.

Co-operation between public and private sectors is therefore essential at the national and international levels. However, achieving true public/private partnership is no trivial matter, as shown by one attempt at building co-operation at a global level. The Children's Vaccine Initiative (CVI), launched in 1990, was conceived as a response to the fact that investment levels in the development of some of the most cost-effective technologies – vaccines – had fallen to absurdly low levels. In addition, as shown in by Appendix 1, existing vaccines were (and, in many cases, continue to be) poorly distributed. The CVI was conceived as an "end to end mission" to get vaccines from the laboratory bench to the field. It was intended to focus on the technology (how to develop new vaccines), as well as the social context (what kind of vaccines could be most effectively distributed).

William Muraskin's account of the rise and fall of the CVI demonstrates the huge distance that still exists between the public and private sector, even when a cause as powerful as children's health is at stake. In many ways, the lessons of penicillin had still not been learned, and the CVI faced a tough task in persuading public sector scientists, who excel in basic research, of the importance of the development work carried out in the private sector. Public sector scientists had low levels of awareness of the "long, laborious, unglamorous, and unheralded" work of "creating high quality batches of a candidate vaccine for testing, carrying out clinical trials to demonstrate safety and efficacy, finding appropriate doses, meeting complex licensing requirements, solving the problems of scale-up to high volume manufacturing, and arranging for packaging, shipping and marketing." Muraskin reports a "great gulf of distrust, often bordering on outright contempt" between people in the public and private sectors. Those in the public sector often saw themselves as on a crusade to save lives and regarded profit as immoral. For those in the private sector, meanwhile, "profit was the engine of innovation." They regarded public sector organizations as untrustworthy

partners, who were wasteful of resources, all too prepared to indulge in endless turf wars, and capricious in their decision-making (Muraskin, 2000).

Unfortunately, the brief history of the CVI involved each sector essentially acting up to its stereotype. American pharmaceutical companies, for example, refused even to stay in the room when the issue of differential pricing of vaccines for developing countries was discussed, while WHO was never happy with the existence of the CVI – an organization it ran, but which it believed had been poorly conceived from the start. The initiative was finally closed down by WHO in 1999, after a decade of bureaucratic maneuvering, negotiations conducted in bad faith, and declining effectiveness. The breakdown left supporters of the initiative demoralized. Industry was especially upset, convinced the public sector had once again shown its basic untrustworthiness. “There were many who felt that the atmosphere was so charged with animosity and recrimination,” writes Muraskin, “that there was a danger that it could never be repaired.”

There had been some successes. Multilateral organizations, such as UNICEF and WHO, began to take the role of research more seriously. The importance of incremental innovations – such as one that makes a vaccine easier to administer – became clear. And important steps were made in tackling the problems of manufacturing high quality vaccines in developing countries. In addition, the CVI now has two successors. The International Vaccine Institute (IVI) in Korea is planning to move into a $50 million laboratory on the campus of Seoul National University in late 2001, where research projects will be continued on Japanese encephalitis, rotavirus and pneumococcal infections, as well as an oral cholera vaccine that will cost only 20 cents a dose (Science Magazine, 1999). And the Global Alliance on Vaccines and Immunization (GAVI) has been created with essentially the same remit as the CVI, but with the marked advantage of the philanthropy of the Bill and Melinda Gates Foundation which has, to date, donated $100 million to the initiative.

The IVI, GAVI and IAVI are all just beginning their work. They all have ambitious objectives and all expect to involve both public and private actors, as well as funders. Only time will tell whether they too will leave a record of disappointed expectations. If they do, the judgment of international public opinion is likely to be harsh. The public sector will have shown that despite repeated promises of reform, it is incapable of effective delivery. Big business, meanwhile, will have shown that it will never shoulder the responsibilities its size demands. As the ongoing controversy over access to AIDS drugs has shown, global health can quickly become a powerful political issue, especially when it is placed within the context of wider protests about the perceived iniquities of globalization. The cost of a failure of public and private sectors to co-operate successfully is therefore likely to be great.

*Big tech/small tech*

The American Chemical Society's review of "the pharmaceutical century" argues that "the rise of molecular biology, with its promise of genetic engineering, fostered a new way of looking at drug design. Instead of an empirical " trial and error" method, pharmaceutical designers [in the 1980s] began to compare knowledge of human physiology and the causes of medical disorders with knowledge of drugs and their methods of physiological action to conceptualize and synthesize the right molecules." (Lesney, 2000)

Biotechnology exemplifies the uncertainty about predicting what innovations lie ahead in health and medicine. There are now 65 drugs on the market that have emerged from biotechnology laboratories and 140 more in the regulatory process. In 1996, Michael Johns wrote: "It is difficult to overestimate how much we will know about our genome in 10-20 years and the impact that this knowledge will have on our capacities to cure and prevent disease." (Johns, 1996) In fact, however, it seems remarkably *easy* to overestimate the immediate potential of biotechnology, as repeated disappointments in attempts to apply genetic knowledge have shown. Indeed, many commentators now believe that big breakthroughs are still some way off and that, as with the discovery of the infectious nature of disease in the 19th century, new knowledge about health may lead initially to non-technological advances. In this paradigm, as Baruch Blumberg explains it: "intervention for prevention, and possibly treatment as well, is based not on changing the host's genome, but in intervening to protect against environmental factors." (Blumberg, 1996)

In the absence of big breakthroughs, the less glamorous work of refining or adapting existing technologies may have the greatest impact on global health. Six vaccines – diphtheria, tetanus, whooping cough, measles, polio, TB – are included in the WHO expanded program on immunization (EPI), with two more – Hepatitis B and yellow fever – included in the so called EPI-plus. The EPI vaccines currently require 5 contacts: at birth, 6 weeks, 10 weeks, 14 weeks and 9 months. Take-up for the final dose is particularly low – one reason why measles continues to take around a million lives each year. A single dose vaccine would clearly increase take-up considerably, while also reducing costs.

Similarly, vaccine vial monitors (VVMs) – heat-sensitive colored discs that indicate whether a vaccine has exceeded a particular temperature – are a recent innovation that has been successful in reducing vaccine wastage resulting from the high temperatures and lack of consistent refrigeration facilities in parts of many developing countries. Previously 60% of vaccines were thrown away, because health care workers were unsure as to whether they were still effective (WHO 1996).

Donald Stokes has referred to the concept of “strategic research,” where “informed judgments of research promise and societal need” are brought together. Nationally, governments are increasingly initiating debate in order to set just such a strategy for their investment in science. It seems clear, if push and pull incentives are to be used to correct market failures and to create new health technologies, that a similar debate is needed on a global level to decide what types of technologies would have the greatest impact on global health and what innovations seem possible within a reasonable time frame. Even the most basic technological road map would allow public funders to start debating and evaluating the relative cost effectiveness of potential big and small breakthroughs, allowing a more strategic approach to technological development to emerge.

*Only connect*

Health benefits can, and often have, been delivered by non-health interventions, such as the provision of water and sanitation, or the provision of education (Bloom and Canning, 2000). Information technology (IT) is a new technological innovation, that is already having the same kind of dramatic impact, affecting: health systems and how they run; health professionals and how they develop their skills; medical science and how it collects, analyses, stores and develops knowledge; and individual patients and how they conceptualize and cope with health problems. In addition, it is challenging organizations of all kinds to innovate as well as facilitating new patterns of communication, education and commerce. While top-down health reform and medical innovation proceed slowly, the explosive bottom-up growth of information technology may have the most profound effect on tomorrow’s health.

Relatively inexpensive computing facilities deliver quick and powerful benefits, from reducing the burden of paperwork, capturing vital evidence (supporting evidence-based medicine) and helping control and standardize drug inventories to promoting knowledge-sharing – even at a great distance, for example via telemedicine. Professional health workers at all levels, in almost all environments, can benefit enormously from these new technologies. The economic benefits of such systematized knowledge, supported through IT, are non-trivial. For example, according to the World Bank, patients in Africa’s public health facilities receive benefits worth only $12 for every $100 of tax revenue spent on drugs.  The main sources of waste are non-competitive procurement ($27), poor storage and management ($19), inappropriate prescriptions ($15), poor projections of requirements ($13), inadequate buying practices ($10) and incorrect use by patients ($3). IT could contribute to improvements across all these areas (World Bank, 2000).

IT also challenges both the biomedical and the public health models, with their sharp divisions between professional and patient on the one hand, and individual and community

on the other. In rich countries, the Internet is already bestowing new power and benefits on those "consumers" of health who have the education and wealth to enjoy the new technology. AIDS.ORG, for example, is one of many HIV/AIDS resources on the net. It serves 100,000 users a month, with visitors coming from 120 countries. As well as providing accredited training courses, it also hosts numerous discussion groups, demonstrating true peer-to-peer knowledge sharing. HIV/AIDS, with its history of activism in the USA, is perhaps the disease that has been most extensively affected by the Internet, but most other diseases are being discussed in one form or another. The CLL (Chronic Lymphatic Leukemia) group, for example, sees scores of posts a day – the vast majority from patients with the disease or family members. As the analysis in Appendix 2 shows, the discussion is highly sophisticated, with lay people able to access information that would previously have been unavailable even to most professionals (Bloom & River Path Associates, 2000). [15]

There is, it should be said, deep ambivalence about this trend among health professionals. In 2000, President Mbeki of South Africa opened a major rift with the world's scientific community when he questioned the link between HIV and AIDS, based on information he had picked up from "dissident science" websites on the web. The WHO, meanwhile, has recently tried to impose order on the information available by proposing to set up a "health" top level domain for Internet sites that had been approved for the public by WHO officials (approved domains would be named, for example, www.familyplanning.health). As "the recognized leading international agency in health, and with over 50 years' experience in setting standards", it described itself as uniquely qualified to decide what health information people should and should not read on the web (WHO 2000e). The Internet Corporation for Assigned Names and Numbers (ICANN), which had received many proposals for a limited number of new top-level domains, rejected the proposal, without explanation. However, the debate about the accuracy and usefulness of Internet-based health information is certain to continue and will probably intensify, as more patients use web-based information to influence their health decisions.

There is also the question of whether IT will further increase inequities in access to health. Only time will tell whether this is true, though it is noticeable that many third world towns that have waited years for a decent road now find Internet cafés opening in the centre of town. Certainly, many health professionals in developing countries are already using the Internet to gain access to information of a previously unavailable quality and currency. As Internet-use increases, health professionals will certainly have a powerful new channel for

[15] Search engine requests for health-related issues consistently come second only to those related to sex. Some of the implications of this trend are explored in: David E. Bloom & River Path Associates, *Social Capitalism & Human Diversity,* published in OECD (2000), *The Creative Society of the 21st Century*.

health education information and the ability to contribute content that is specific to the country in which they work.

*Social Technology*

Technology has undoubtedly caused a revolution in health, with medical science helping drive astonishing reductions in mortality and morbidity. As we have argued, however, new technologies have not arrived in an orderly or consistent fashion. Making significant discoveries has proved hard; developing a discovery into a useful innovation has proved harder; and bringing that innovation to the widest possible market has proved hardest of all. Social context, economic environment, and the willingness of a society to invest in improving health all contribute to determining the success of a new health technology.

Nor is technology the only way that knowledge can affect health. The public health model has used knowledge to affect health with minimal technology and, on occasion, extraordinary results. But technology has many advantages. Properly used, it brings a new level of reliability and standardization to the production of good health. On occasion, its successes have been astonishing. The abolition of smallpox, for example, was only possible when a simple, reliable and cheap vaccine was employed through a well organized, focused and widespread health initiative.

As HIV/AIDS shows, there are clear limits to our current ability to defend global health standards. Most international and national institutions were unable to use knowledge about health to erect defenses against the disease (though some communities *were* able to protect themselves relatively effectively). Medical science has also been unable to translate knowledge about the disease into relevant technological developments. There have been breakthroughs, but of a nature only bringing benefits to a tiny minority of those affected. For a long period, vaccine development was almost forgotten – a failure for which both public and private sectors must share the blame.

The future of global health will rely on a better understanding of the impact of knowledge on health, and on mechanisms that finally allow public and private sectors to work together, with each playing to its comparative advantage. It will require a more directed model of health research, one that looks to the eventual needs of the market – the many people who are expected to eventually benefit – both directly and indirectly – from the technology. Finally, it will almost certainly involve a considerable shift in the degree of responsibility people take for their own health. Both the biomedical and the public health models have tended to disempower the individual. But as with education, economic development and practically any human activity, without the willing participation of individuals, success will almost always remain elusive.

The concept of “social technology” places technology at the center of the many social forces that mediate its use. It does not downplay the significance of a technological advance – especially a “magic bullet” of the power of an antibiotic. Such advances *can* truly be transformative – it is the job of ‘social technology’ to make sure that they *are*.

Tables

**Figure 1: Definitive Moments of Modern Medicine**

| | |
|---|---|
| 1935 | Sulphonamides |
| 1941 | Penicillin<br>'Pap' smear for cervical cancer |
| 1944 | Kidney dialysis |
| 1946 | General anesthesia with curare |
| 1947 | Radiotherapy (the linear accelerator) |
| 1948 | Intraocular lens implant for cataracts |
| 1949 | Cortisone |
| 1950 | Smoking identified as the cause of lung cancer<br>Tuberculosis cured with streptomycin and PAS |
| 1952 | The Copenhagen polio epidemic and birth of intensive care<br>Chlorpromazine in the treatment of schizophrenia |
| 1954 | The Zeiss operating microscope |
| 1955 | Open Heart surgery<br>Polio vaccination |
| 1956 | Cardiopulmonary resuscitation |
| 1957 | Factor VIII for hemophilia |
| 1959 | The Hopkins endoscope |
| 1960 | Oral contraceptive pill |
| 1961 | Levodopa for Parkinson's<br>Charnley's hip replacement |
| 1963 | Kidney transplant |
| 1964 | Prevention of strokes<br>Coronary bypass graft |
| 1967 | First heart transplant |
| 1969 | The pre-natal diagnosis of Down's syndrome |
| 1970 | Neonatal intensive care<br>Cognitive therapy |
| 1971 | Cure of childhood cancer |
| 1973 | CAT scanner |
| 1978 | First test tube baby |
| 1979 | Coronary angioplasty |
| 1984 | Helicobacter as the cause of peptic ulcer |
| 1987 | Thrombolysis (clot-busting) for heart attacks |
| 1996 | Triple therapy for AIDS |
| 1998 | Viagra for the treatment of impotence |

Source: James Le Fanu (1999) *The Rise & Fall of Modern Medicine*

**Figure 2: Contributors to Falling Mortality Rates**

| **Reduction in:** | **Percentage contribution of gains in:** | | |
|---|---|---|---|
| | *Income* | *Educational level of adult females* | *Generation and utilization of new knowledge* |
| *Under 5 mortality rate* | 17 | 38 | 45 |
| *Female adult mortality rate* | 20 | 41 | 39 |
| *Male adult mortality rate* | 25 | 27 | 49 |
| *Female life expectancy at birth* | 19 | 32 | 49 |
| *Total fertility rate* | 12 | 58 | 29 |
| | | | |
| Based on analysis of data from 115 low and middle income countries. | | | |
| Source: Wang J et al, *Measuring country performance on health: selected indicators for 115 countries,* Washington DC, The World Bank 1999 (Human Development Network, Health, Nutrition and Population Series) | | | |

**Figure 3:**

**25 'Essential Bodies of Knowledge' required for successful open-heart surgery**

| |
|---|
| **Preoperative diagnosis of cardiac defects** |
| Anatomic and clinical |
| Physiologic: electrocardiography, other non-invasive tests |
| Physiologic: cardiac catheterization |
| Radiologic: selective angiocardiography |
| **Preoperative care and preparation** |
| Blood groups and typing: blood preservation; blood bank |
| Nutrition |
| Assessment of cardiac, pulmonary, renal, hepatic, and brain function |
| Management of heart failure |
| **Intraoperative management** |
| Asepsis |
| Monitoring ECG, blood pressure, heart rate, EEG, and blood O2, C O2, and pH |
| Anesthesia and neuromuscular blocking agents |
| Hypothermia and survival of ischemic organs |
| Ventilation of open thorax |
| Anticoagulants |
| Pump-oxygenator |
| Elective cardiac arrest; defibrillation |
| Transfusions; fluid and electrolytes; acid-base balance |
| Surgical instruments and materials |
| Surgical techniques and operations |
| **Postoperative care** |
| Relief of pain |
| General principals of intensive care; recording and warning systems |
| Management of infection |
| Diagnosis and management of circulatory failure |
| Diagnosis and management of other postoperative complications |
| Wound healing |

Source: Julius H Comroe Jr and Robert D Dripps, *Scientific Basis for the Support of Biomedical Science,* Science, Vol 192, April 9 1976, 105-111

## Appendix 1

**(Excel file, attached)**

## Appendix 2:

**Two Days in the Life of the CLL (Chronic Lymphatic Leukemia) Discussion Group (1-2 November 2000)**

| | |
|---|---|
| Number of contributors | 69 |
| Number of posts | 112 |
| | |
| Posts giving latest news on developments in treatment of the disease (see below for details) | 5 |
| Posts giving technical advice on medical issues | 4 |
| Posts discussing possible causes of CLL | 9 |
| Posts discussing and describing conventional treatment methods and results | 27 |
| Posts discussing plans and making arrangements for imminent meetings or conferences | 6 |
| Posts discussing alternative therapies such as Tea Tree Oil | 9 |
| Posts giving practical advice on health insurance and grants | 5 |
| Posts giving or requesting emotional support or advice | 48 |

As can be seen, the level of activity on such newsgroups is frequently highly sophisticated, as the following news postings sharing the latest news about treatment demonstrate:

30 October announcement from Human Genome Sciences (HGSI) and Dow Chemical that they have formed an alliance to target CLL. HGSI has developed a B-cell stimulator "BLYSS" treatment, and Dow Chemical has agreed to provide the capital.

Dr Freda Stevenson of Southampton University, UK, is working on a vaccine designed to use the patient's own immune system. Human trials are now under way after successful trials on mice (details of vaccine supplied).

Preliminary report from University College, London, about a possible cure for arthritis, with possible implications for leukemia treatments.

New York Times article on the discovery of a protein that stimulates B-cells to produce antibodies. This could aid with auto-immune diseases, immune deficiency diseases and B-cell lymphoma.

One contributor had been trading e-mails with botanist Dr James Duke, who said that ATLV is the virus most commonly associated with leukemia.

Discussion Group Location: Association of Cancer Online Resources (ACOR) http://www.acor.org/.

Source: Analysis, for this background paper, conducted by River Path Associates, http://www.riverpath.com

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