Invention: The Care and Feeding of Ideas. Norbert Wiener. MIT Press, 55 Hayward Street, Cambridge, MA 02142, USA. 1994. Price: Hardback $25.00, paperback $9.95. 159 pp.

The world owes a debt of gratitude to Steven Joshia Heims for publishing this manuscript, which Norbert Wiener wrote in 1955 for the Anchor Book Series, but the publication of which was prevented by Wiener himself during his lesser ('noisy') moments. Although invention is dealt with in Wiener's earlier books (refs 1–5 listed at the end of this review) and several papers in his *Collected Works*[6], a coherently connected treatment of this important subject is only to be found in the present book. Thus this book significantly completes the presentation of Wiener's thought on society, science, art, technology and religion. It is beautifully written, and without a trace of 'Wiener noise'.

Wiener hastens to point out that the very concept of 'invention' collapses if we ignore the probabilistic organization of the cosmos. Only if we can consider *small variations from the actual structure of the cosmos*, can we compare 'the relative importance of Newton or Edison for the history of invention' (p. 7). As Wiener has repeatedly emphasized (ref. 1, pp. 37–45; ref. 2, preface), the appropriate concept of a 'stochastic cosmos', emerged from the work of J. W. Gibbs (p. 19).

'Invention' for Wiener means 'the care and feeding of ideas'. One such idea was the positional notation for large integers, which received two very early and important material embodiments in (i) the abacus of different forms (Babylonia, c. 2000 BC), and (ii) the place-value script notation (India, c 400 AD), (pp. 11, 12). As Wiener points out, four stages are discernible in such inventions: (1) some creative intellect or intellects must conceive the idea and record it for the benefit of posterity (p. 8); (2) the material and technique needed for its execution must be available; (3) 'the artisans must become philosophers, or the philosophers, artisans' (p. 8), in order that the idea may pass from the intellectual who conceived it to the artisian who embodies it in the object; and (4) entrepreneurs must exist who decide that the manufacture of this object is a profitable way to make a living.

Wiener's pithy demarcation shows clearly that invention will not thrive in a society that inhibits the articulation of ideas, or hampers the adoption of new materials and new techniques, or separates artisans from philosophers, or which dries up all sources of venture capital for entrepreneurs. Since, as Wiener reminds us, invention is 'a desperate necessity to render any life . . . possible in the future' (p. 1), and that 'we live only by the grace of invention' (p. 3), the reader can almost infer from Wiener's four-stage demarcation the kind of social setting which he felt was viable for man.

Of these four steps, the first, least dependent on the socio-economic system, is the hardest to predict: 'There was no absolute necessity for Euclid to develop the axiomatic theory of geometry, nor for Gibbs to insist so strongly on the notion of probability in thermodynamics. These innovations might easily have occurred somewhat earlier or considerably later, and are no more satisfactorily subject to betting about them, say, than about the particular house in the village which would next be struck by lightning.' (p. 25)

But, unpredictable though it be, the germination of new ideas is influenced by the *intellectual climate*. Essential is respect for discipline in 'the effort of prolonged thinking and study'. A scholarly class, so disciplined, even in matters religious or linguistic, such as the Jews and Brahmins, can switch to the scientific, given the right circumstances (pp. 31–32). Also very conducive is a mathematical climate, for mathematics 'allows us to state the essential and bury the issues of the inessential' (p. 29). The greatest impediment to invention is a climate contemptuous of pure scholarship and adulated to money, such as prevails in all countries today. This climate 'may well be expected to end in lowering the intellectual water table and turning vast areas of the soul . . . into dead and useless deserts' (p. 33).

Turning to the conditioning of invention by availability of materials and techniques, Wiener writes: 'In all engineering, there is a certain family history, a certain genealogy. The smith's hammers were forged by the hammers of an earlier smith' (p. 46). Each new step helps in simplifying later steps. The hand tool made the first steam engine, and this steam engine made the tools for the construction of later steam engines. The 'creaky and fleeting' machines of Leonardo da Vinci were indicative of his dependence on soft materials such as wood and leather. The use of metal became feasible only in the 17th century when the mold of the founder and the hammer of the blacksmith was supplemented by the file of the locksmith (p. 38). With the file began the genealogy of machine tools such as the lathe, and thus the locksmith was the spiritual ancestor of the watchmaker and instrument maker, and indeed of the steam engineer as well. Much as filing was to metal use, so the art of lens grinding had to come before the age-old artistic use of glass could be enlarged into its use in precision optical instruments (p. 41). As for the art of writing and printing, the cuneiform tablets of the Babylonians, the papyri of the Egyptians and Greeks, the palm leaves of the Indians, the parchment and vellum of medieval Europe mark the primitive stage of this art, which came into its own only with the manufacture of *paper* by the Chinese. This material was eminently suited for writing by brush in ink. Only the use of paper made possible the related contribution from China, the printing of books (pp. 48–53).

'The internal ideology of the process of invention', considered so far, materializes only under ripe *social conditions* (p. 55). In Greece in the 4th century BC, for example, the spectacular rise of mathematics and astronomy was accompanied by a barrenness in material invention. The Greek City-State structure, while it encouraged reflection 'with soft hands', prevented philosophers from becoming artisans or artisans from becoming philosophers. This ceased only in the Hellenic period, in less stratified cities such as Alexandria. Rather different was the Chinese society, fundamentally feudal, but where the skilled craftsman was exalted (pp. 47, 48), a condition attained again in Europe during the early Renaissance, after prolonged struggles by guilds of craftsmen in the medieval cities.

In modern Europe, the apple cart of invention was only temporarily upset by the tyranny following the French Revolution. By the 19th century there was a strong nexus between science and industry in England, witness figures such as Michael Faraday and Lord Kelvin. There was then ample scope for pure scientist, craftsman (engineer) and industrialist to maneuver freely. Patents were owned by the inventors.' This situation changed when T. A. Edison started his own industrial scientific laboratory, and corporations such as Westinghouse, General Electric and Bell decided to follow suit. In such laboratories the inventor became anonymous, and both credit and profit went to the laboratory.

The upsurge of the physical sciences in the early 20th century forced the corporations to make changes, in order to reap the possibilities opened up by the newer discoveries coming from outside. The independent engineer, scientifically more astute than the laboratory engineer, posed a problem for the competing corporations. The normal procedure to buy them off, as Westinghouse did with Telsa, did not always work.

A case in point was the telephone industry. Successful urban service was followed by failure at the interurban long-distance level due to attenuation and distortion. The carbon microphone, which in reality was an amplifier, took care of attenuation, but the prevalent belief that distortion stemmed from under-capacity obstructed progress. Fortunately the correct solution to the problem of distortion, viz. the introduction of more inductance on the line, was pointed out by Oliver Heaviside, who 'was born poor, lived poor, and died poor'. Another invention relevant to telephony was the vacuum tube amplifier of Sir John Fleming (1905) and his American counterpart Lee De Forest.

Wiener gives a fascinating account of how the newly-formed AT&T struggled to get patent rights to these inventions, and the ethical complications caused by the incorruptibility of Heaviside and by the fact that the inventions often preceded the understanding of their real potentialities, and had lapsed as suitable patents (pp. 66–76). Wiener's novel *The Tempter* is devoted to the human side of this story. Unfortunately, space limitations prevent comments on Chapter 10 devoted to patents.

The industrial trend to benefit from fresh discovery, begun in telephony, spread during the years, and by the end of World War II, modern industry attained what Wiener calls the 'megabuck' stage: huge investments spread over laboratories owned by corporations, universities and government (Chapters 7, 8). With industrial development heavily dependent on scientific discovery, the millionaire magnates could no longer treat the scientist as a clever freak. The more far-sighted corporations began employing first-rate scientists in their laboratories, giving them free reign to pursue their curiosities. The more short-sighted and bureaucratic took the view that the creative work of individualist scientists might be achieved by an organized mass attack on specific problems. Wiener's demonstration of the shortsightedness of this position is worth recounting.

To be successful, the big invention laboratory must by necessity focus on specific inventions, in which the fundamental underlying ideas are already well understood, i.e. focus only on the 'minimal part of the iceberg of invention which happens to lie above the water level' (p. 132). Great pioneering experimentation, such as Faraday's on electromagnetic induction (1821), is carried out without any foreseeable application. It took a decade or so before the significance of Faraday's work to the electric motor became apparent, and its true depth and appropriate function was understood much later with the advent of the fractional horse-power motor. Likewise it took a long time for the enormous importance of the electric valve as an amplifier to sink in. Thus the mass attack, directed at a specific target is unlikely to yield the most potent inventions. As Wiener points out, the crucial ideas in an invention 'takes one brain, not a thousand cramped half-brains' (p. 96), but it takes the efforts of many before its engineering significance can be gauged. The business-like utilization of a new invention requires that the industrialist wait, and follow the changes that the germinal idea undergoes (p. 116). Only at that stage can the industrial laboratory play its role.

Another shortcoming of such laboratories resides in their insistence on secrecy. This comes from the competitiveness existing within the company, between the officials and their departments. The laboratory scientist is thus obliged to work on a minute segment of the project, without a comprehension of the full project, i.e. to work in a setting that constricts the free exercise of his imagination and innovativeness.

The megabuck also exposes the scientist to the temptation of dividing his loyalties between the irreconcilable tasks of seeking the truth, and of bargaining with industry for money and power. Wiener traces the corroding effect on young scientists of the temptation to seek high paying jobs, not demanding the highest intellectual effort (pp. 80–82). He also laments the half-baked remedies proposed to offset over-specialization, such as the automatic cataloging of research. (Only a good scientist, versed in several areas, can benefit from such catalogues.)

Wiener emphasizes the need for feedback in all policy making, with invention being no exception. Short-time feedbacks (such as are exemplified in steering) are, however, inadequate for policies designed to influence the distant future. Such is the policy of managing a redwood forest or building a long-lasting irrigation system. In such undertakings, contingencies that are very rare but also very destructive have to be faced. These rupture the stationarity on which short-time feedbacks are based.

Wiener reminds us that the viability of capitalist investment is confined to short-time projects. Industries that are to render a long-time service must have non-capitalistically motivated components. 'The bank which spends some of its resources for contingencies more than a century away will be regarded as foolish by the most lenient bank examiner' (p. 124). Understandably, the insurance companies are only able to handle ordinary contingencies, the nature of which is well understood, and the data for which are tabulated in actuarial tables. But for 'Acts of God', i.e infrequent calamities such as earthquakes, these companies deny liability, and assistance has to be sought from organizations such as the Red Cross. As Wiener points out, such organizations operate by the norms of religion and the Church, and not by the norms of capitalism. Here, as in his other writings, Wiener is inexorably led to the view *that religion and the Churches are needed to deal with long-time human problems* (pp. 121–123). Just as we refer to sudden unpredictable catastrophes as 'Acts of God', we should speak of unpredictable and sudden benefits, such as great discovery or great invention as 'Acts of Grace'. 'The conservation of the fertility of human thought is as primary an obligation as the conservation of the fertility of the land' (p. 125). And both types of irrigation are long-time problems which belong to religion, and where the modus operandi has to be inspired by religion rather than by capitalism.

This book, written at the height of the cold war, says much about this war, but it is from the pen of a master whose vision was cosmic. The issues it raises are even more relevant today than when