MAN AND MACHINE*

ONE of the greatest Swedish poets—and I should like to add: in my opinion one of our deepest thinkers—Erik Johan Stagnelius (born 1793) writes in the wonderful poem "Suckarnes Myster" ("Mystery of Sighs"):

> Menska! vill du lifvets vishet lära,
> O, så hör mig! Tvenne lagar styra
> Detta lif. *Förmågan att begära*
> Är den första. *Tvånget att försaka*
> Är den andra. Adla du till frihet,
> Detta tvång, och helgad och försonad,
> Öfver stoftets kretsande planeter,
> Skall du ingå genom ärans portar.

("Man, if thou wantest to learn the wisdom of life, oh, listen to me. Two laws govern this life. *The urge to demand* is the first. *The necessity to resign* the second. Ennoble thou to freedom this constraint, and sanctified and reconciled, thou shalt enter through the gates of honor above the circling planets of the dust.")

A modern American author, Martin Flavin, returns to Stagnelius' trend of thought in one of his novels (*Mr. Littlejohn*): "The desire to *possess*—land and houses, wealth and power, people and affection, everything in fact—and to lock up all these things in your individual cell whence they were always struggling to escape. And this of course brought *fear* —fear that they'd get away as they nearly always did. Even your very life you tried to lock up too in your individual self. But you couldn't keep it there and you always knew you couldn't, and the knowledge was a constant living terror."

*A public lecture delivered at the Rice Institute, May 21, 1946, by Dr. The Svedberg of the University of Upsala.

The technics of our day, has it helped us to satisfy *the urge to demand?* Has it eased *the constraint to resign?* Has it diminished our fear? Has it made us brave?

We are just at the end of a war which has shaken the foundations of the world. We have seen the curtain drop on the last act of a tragedy without parallel in the history of mankind.

The machine has been predominant in this struggle. Those nations that managed to create the most effective machines have won—and we believe that victory is on the right side.

The urge to demand and the fear to lose have caused the wars: both offensive and defensive wars.

Not the existing war machine of the moment but the potential, the ability to produce war machines, has always in the long run gained the victory. And so the mondial, oceanic powers have won and the central powers, Germany and Italy, have lost. Not the copying of an existing war machine but the ability to invent and construct new and more efficient types of war machines gives victory. There Japan failed.

In the last act of this world war an entirely new war machine, entirely new in principle, has appeared on the scene: the atomic bomb. The instinct to defend, the fear to lose, has called forth a means of destruction of quite another order of magnitude than anything experienced before. Will this new source of energy teach us how to master *the urge to demand*, how to ennoble *the necessity to resign?* We believe that the knowledge of handling this new means of destruction is at present in the possession of nations conscious of their responsibility. But such knowledge cannot be kept secret forever. What will happen when it becomes known to other nations, aggressive nations?

All nations, and each individual, must check the urge to demand, must be freed from the fear of losing what they possess. In my opinion the only way to achieve this is by real penetration of the phenomena of nature. Each one of us must realize the plain truth: that we are doomed if we fail to use the resources of nature to our common good.

Primitive man fought an everlasting battle against his surroundings: against the beasts and the elements. Now we have harnessed these powers. Animals and plants have been domesticated and improved by breeding; they are on the way to becoming machines for producing necessities. We have of old harnessed the elements and forced them to drive our machines. The wind was the most important driving force. The sailing ships trusted in it, and it ground the corn in the winged mills. The water in streams and falls drove other mills and smithies until we learned to use turbines for driving electric generators. The coal and the oil in steam boilers and motors are important but limited sources of energy.

All this—wind, waterfalls, coal, oil—draws on solar energy. But the sun itself? We have been wondering where its never-ceasing power comes from. Now we believe that solar energy has its origin in the annihilation of mass through nuclear reactions in the atoms. The coal under the boilers, the oil and gasoline in the internal-combustion engines, the electricity in our power lines ultimately come, then, from transformed atomic energy.

With the appearance of the atomic bomb we have, for the first time, to face the problem of harnessing atomic energy. We have succeeded in creating a veritable solar machine on earth.

The knowledge of our soon having at our disposal a machine which wrongly used might destroy the whole human race, perhaps the whole earth, ought to induce serious reflection. It should remind us of the necessity of reconciling *the urge to demand* with *the constraint to resign.*

Suppose that we now, after these general remarks, focus our attention on a few special aspects of the relation: man and the machine.

In order to call into existence machines for the service of man—machines for good and evil—we have to study in detail the world of natural phenomena around us. This is done by means of basic research. The enormous importance of research has only recently been fully realized by the governing authorities. The belligerent nations in World War Two, especially the Western allies and Russia, have employed their whole available research capacity in the war effort. Definite proposals have now been put forward for the employment of this research organization in the service of peace. In this country President Roosevelt as early as November, 1944, commissioned Dr. Vannevar Bush to work out a plan for the organization of post-war research. In his letter of instruction Roosevelt said: "New frontiers of the mind are before us, and if they are pioneered with the same vision, boldness and drive with which we have waged this war, we can create a fuller and more fruitful life." The recommendations made by Dr. Bush include a five-year plan and an expenditure which shows that the American people now realize the enormous importance of scientific and technical research. The European governments also are becoming aware of the necessity of promoting research on a larger scale than before the war. In Sweden committees have been appointed by the government for the encouragement of both scientific and technical research. A number of new institutes and laboratories have been established for wood and cellulose research, metallographic research, textile research, and so on.

The bond uniting basic research and its technical applications has become more and more apparent. The interval of time between a scientific discovery and the corresponding

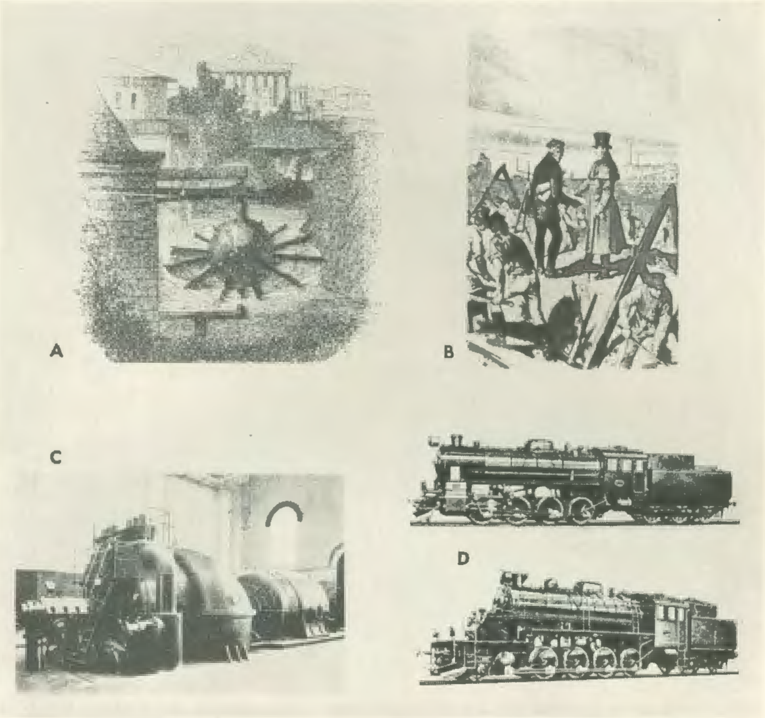

FIGURE 1

A. Heron's steam-driven ball (second century B.C.).
B. Stephenson and his first locomotive.
C. Modern steam turbine plant.
D. Modern steam locomotives.

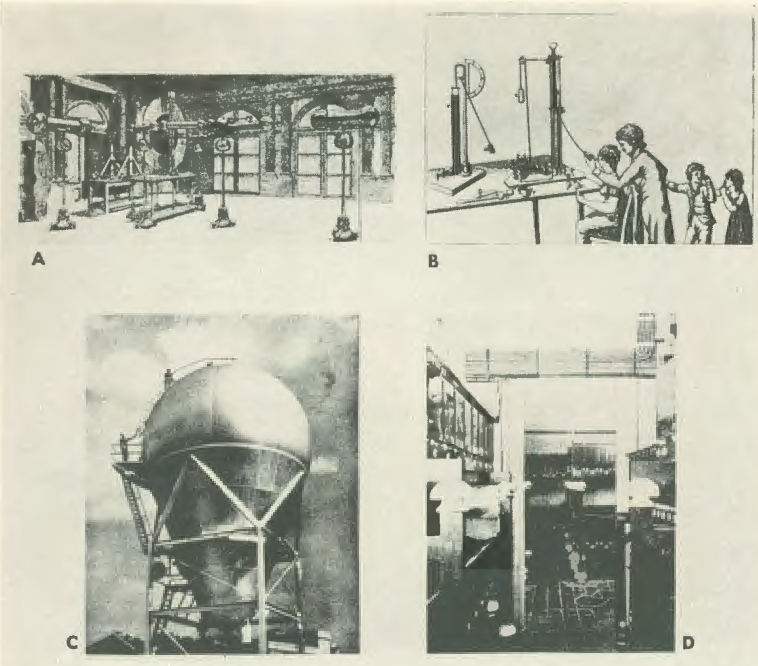

FIGURE 2

A. Van Marum's electrical machine in the Teyler Foundation in Haarlem. With the aid of this apparatus H_2O was decomposed (Paets van Troostwyk and Deiman, 1789).

B. Experiments with the voltaic pile.

C. Van de Graaff's electrostatic generator (Westinghouse Laboratory, Pittsburgh, 1938).

D. Modern storage batteries.

technical invention tends to become smaller and smaller. Let me cite a few examples:

The first experiments with steam as a driving force are mentioned by the Greek philosopher Heron of Alexandria (second century B.C.). Two thousand years passed before Watt's steam engine and Stephenson's locomotive came into existence. (Figure 1.)

In the field of electricity we have the static friction machines of the seventeenth and eighteenth centuries and the galvanic piles of the early nineteenth. Electric generators and motors came into use towards the end of the nineteenth century. Here the interval between scientific experiment and practical application has been reduced to about two hundred years. (Figures 2 and 3.)

If we turn to the third important energy source of today: the internal-combustion engine, we find that the first scientific investigations concerning the conversion of heat into mechanical energy date from the middle of the nineteenth century. With the automobile this engine made its entry into our daily life towards the end of the nineteenth century and the beginning of the twentieth. Its highest perfection so far is reached in the airplane engine. The time interval here is about sixty years. (Figure 4.)

Two more examples. In the eighteen-nineties the inert gases: helium, neon, argon, krypton, and xenon were discovered by Rayleigh and Ramsay; and already in the nineteen-thirties, or only about forty years later, these rare gases found extensive use in incandescent electric lamps and for illumination tubes. The modern fluorescent lamps are founded on experiments dating from the seventeenth century.

In the nineteen-twenties and nineteen-thirties the Russian scientist Kapitza (at that time in Rutherford's laboratory, Cambridge, England) was working on the liquefaction of helium and studying the strange phenomena occurring in this liquid near the absolute zero. During the war it became of vital importance for Russia (where Kapitza in the meantime had returned) to increase steel production speedily, especially by the Bessemer process. For the oxidation of the excess carbon, cheap oxygen was necessary. Kapitza succeeded in working out a better and cheaper method for producing oxygen from air than had previously been possible. The basis of this method is his helium condensation process.

We are now on the threshold of a new era in which atomic energy will probably be dominant. It may be of some interest to recall the general trend of development here. The first artificial nuclear reaction was found by Rutherford twenty-six years ago. He succeeded in converting nitrogen into oxygen and hydrogen by bombardment with swift helium nuclei (α-rays) from natural radioactive substances. Cockcroft and Walton found that swift hydrogen nuclei, accelerated in a high-tension field, could be used as projectiles; Chadwick discovered the neutron, and Fermi found that this particle easily penetrated into the nuclei. All these discoveries provided ample means for starting new nuclear reactions. Enormously energetic projectiles are now produced by means of the cyclotron invented by Lawrence. By the aid of this tool most atoms can be smashed. (Figure 5.)

Twenty years after the first artificial atomic transformation, Hahn discovered a new type of nuclear reaction—the so-called fission. This reaction is accompanied by the release of enormous quantities of energy, and it is this type of nuclear disintegration that is utilized in the atomic bomb. At present we only know of a few atom species which react in this manner and they are exceedingly rare, but it is highly probable that in the future means will be found to release atomic energy from other elements. (Figure 6.)

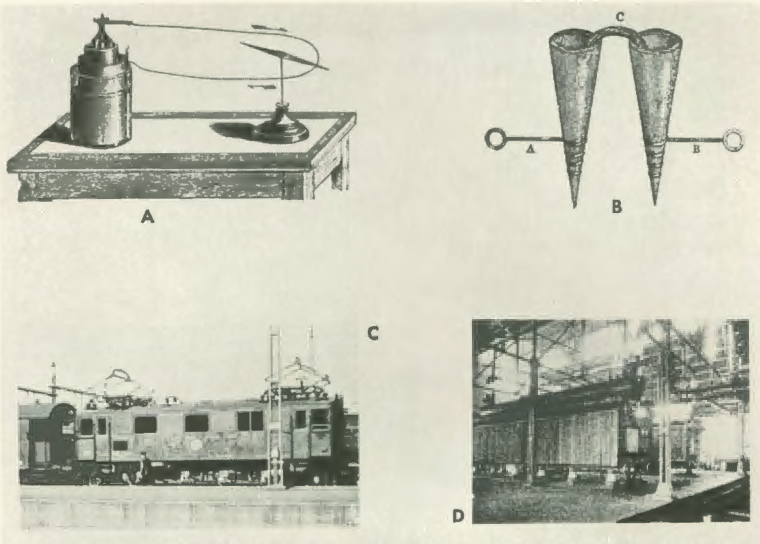

FIGURE 3

A. Oersted's experiment demonstrating the influence of the electric current on the magnetic needle, 1820.

B. Davy's electrolysis apparatus, 1806.

C. Modern electric locomotive.

D. Hydrogen electrolyzer for ammonia production (Ljungaverk, Sweden).

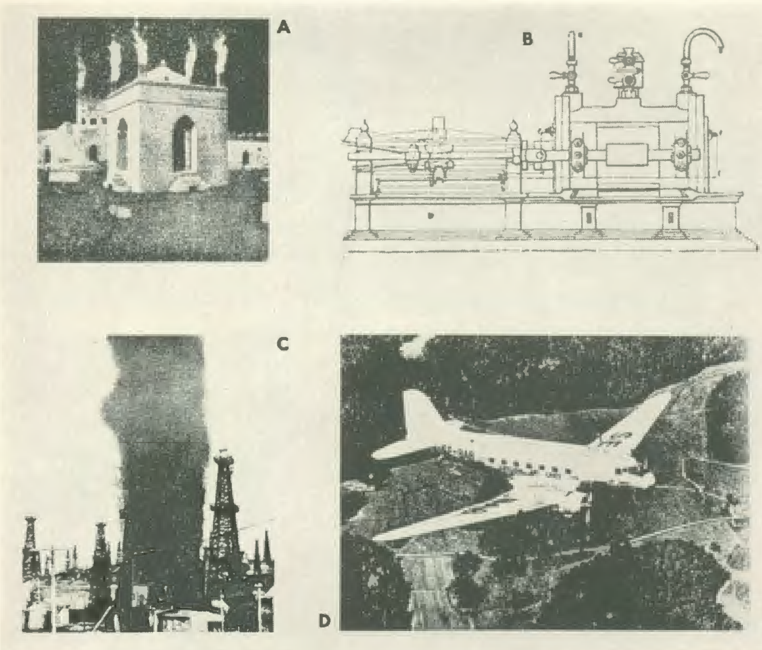

FIGURE 4

A. Fire worship in Baku.
B. Lenoir's gas engine.
C. Modern oil field.
D. Modern airplane with combustion motor.

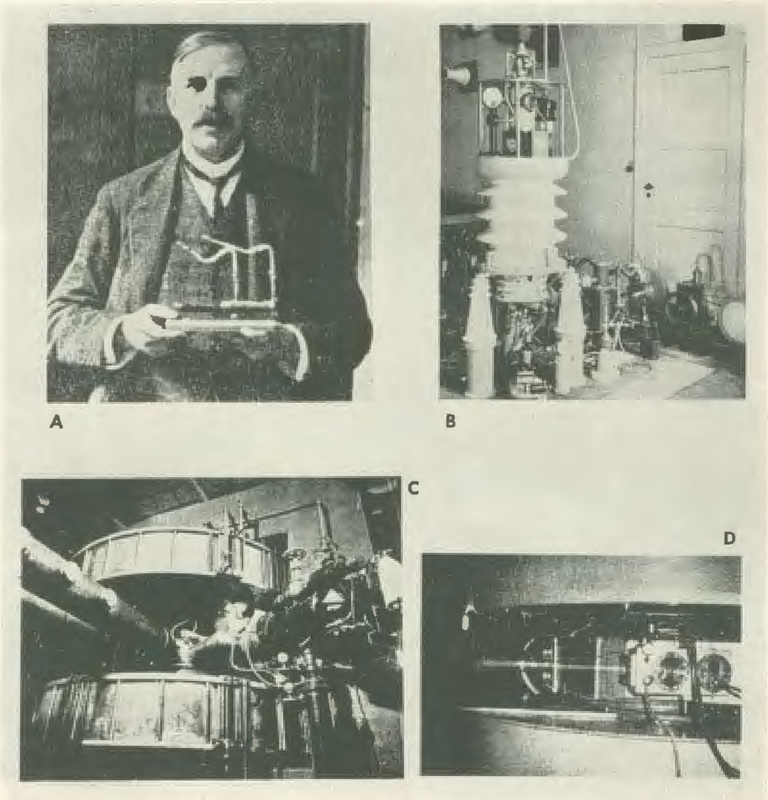

FIGURE 5

A. Rutherford with the first modest apparatus for atom smashing (1919); photo by The Svedberg (1920).

B. Neutron generator in the Institute of Physical Chemistry, Upsala.

C. Modern cyclotron.

D. Ray of atomic nuclei from the cyclotron.

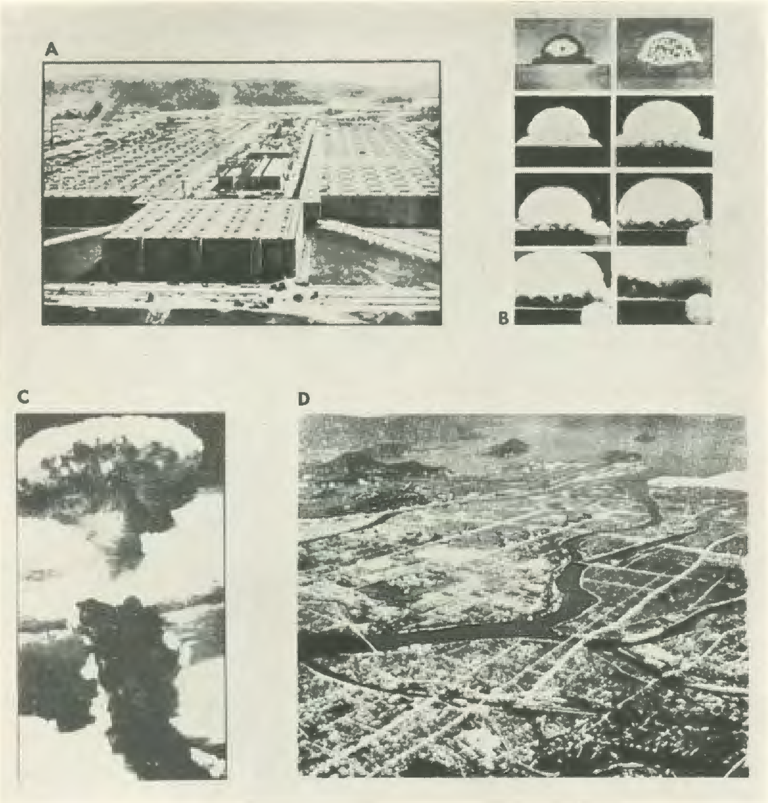

FIGURE 6

A. Plant for producing atomic bombs.
B. Explosion of the experimental atomic bomb (Alamogordo, New Mexico, July 16, 1945).
C. The atomic bomb over Nagasaki (August 9, 1945).
D. Hiroshima after bombardment (August 6, 1945).

In what I have said, I have been trying to indicate the relation between research and material progress. It would now be of interest if one could estimate, on the one hand, the in-

FIGURE 7

Percentage distribution of total population by main occupational groups.

crease in prosperity which is a direct result of the progress in technics; and, on the other hand, the disasters in the shape of social ills and international disputes, with the resulting wars, of which that advance is the direct or indirect cause.

Official statistics furnish some illuminating figures. The great technical advances of the nineteenth century—the util-

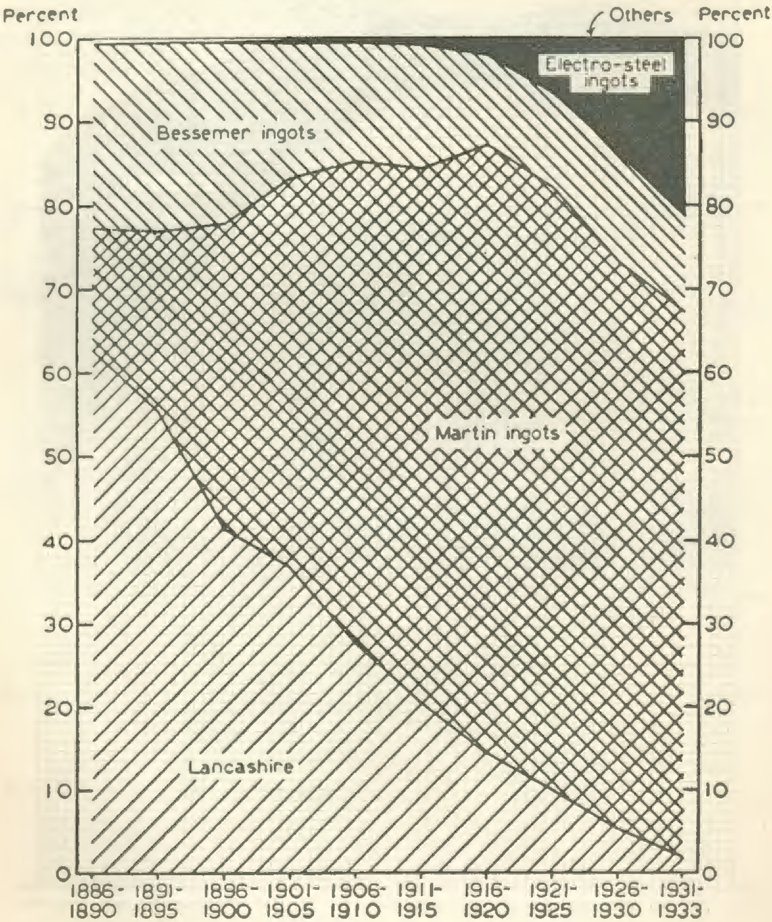

FIGURE 8
Production of iron and steel bars and ingots.

ization of steam, electricity, and oil—have brought about, for instance in Sweden, from the eighteen-fifties and up to our day a very marked relative increase in industrial employment. (Figure 7.)

In the production of iron and steel we can note from 1920 the increased importance of electric energy. (Figure 8.)

FIGURE 9

Index numbers (1913 = 100) of number of industrial workers, volume of production, and effective horsepower of motors installed in industry for direct power, 1913–1933.

Year	Mining and metal industry	Textile and clothing industry
1861	1.0	1.0
1870	1.6	1.0
1880	3.4	1.1
1890	4.5	1.1
1900	21	1.4
1910	26	1.9
1920	55	3.1
1930	45	3.4

FIGURE 10
Value of production per worker.

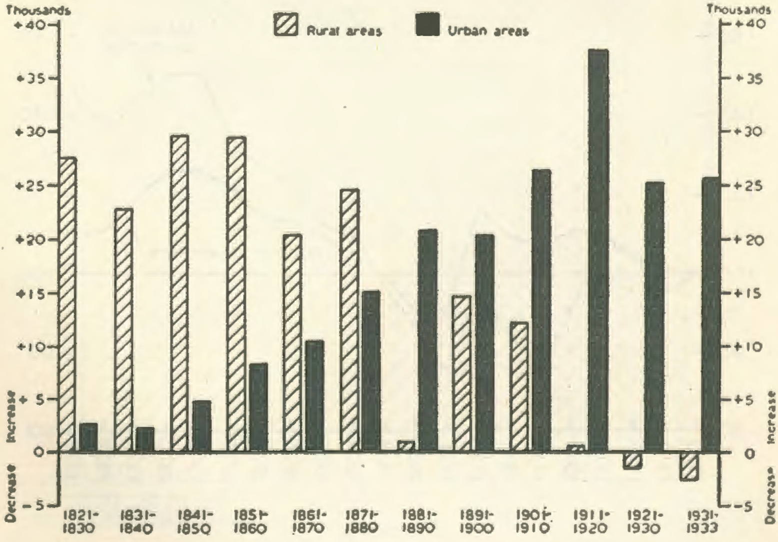

FIGURE 11
Population change in rural and urban areas, 1821–30 to 1931–33.

The effective horsepower of motors installed in industry and the value of production per worker rise quickly during the twentieth century as a result of the mechanization of industry. (Figure 9.) For two branches, mining and the metal industry, and the textile and clothing industry, the relative numbers shown in Figure 10 are found.

The extensive use of machine power has caused a migration of population from rural to urban areas. (Figure 11.) The value of agricultural property has dropped and the value of other property risen. (Figure 12.)

The rise in the production of utilities made possible by the technical advances was accompanied, at the beginning of industrialization, by a certain lowering of hygiene and general

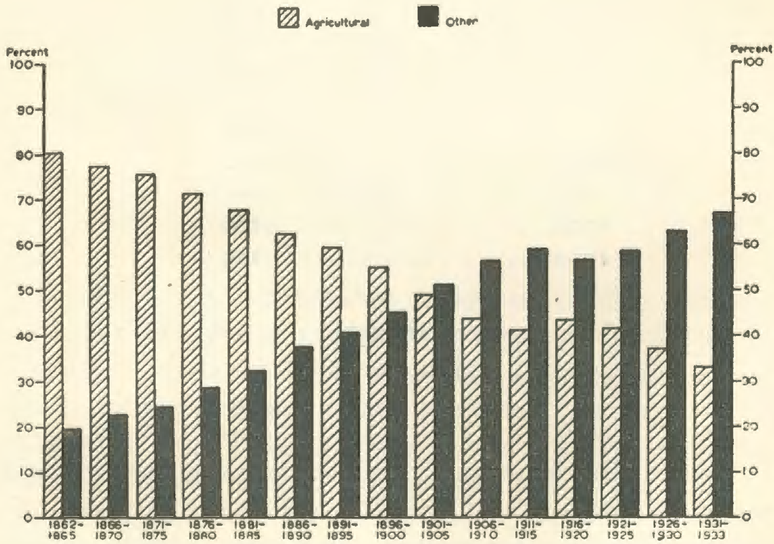

FIGURE 12

Taxation value of agricultural and other property as percent of total, 1862–65 to 1931–33.

welfare in the most densely populated industrial districts. In Sweden this decline is not very noticeable. Infant mortality does not go up during the period of industrialization, but on the contrary decreases uniformly from 205 pro mille between 1751 and 1760 to 29 pro mille in 1942. For industrial cities, e.g., New York, infant mortality at first rises and then decreases. (Figure 13.)

Year	Infant mortality pro mille
	SWEDEN
1751–60	205
1801–10	199
1851–60	146
1901–10	85
1942	29
	NEW YORK CITY
1810	130
1850	180
1860	220
1870	240
—	—
1900	160
1910	129

FIGURE 13
Infant mortality.

These difficulties in which the machine has involved us will probably soon be overcome. Rational house planning, effective protection for workers, and other general welfare measures are being carried through rapidly. More difficult to master are the psychical effects of the altered way of living of mechanical civilization. In proportion as the physical strain is lessened, we may perhaps hope for an increase in psychical health and the building up of new spiritual values whereby the inner life of the individual will be enriched. This in its turn ought to allow us to hope for an improvement in the relations between individuals and nations. Before this is accomplished, however, humanity is threatened, in a higher degree than during earlier—from a material point of view, poorer—periods, by deterioration of our race as a result of war.

Let us look (Figure 14) at the wars of the eighteenth, nineteenth, and twentieth centuries:

	Combatants (millions)	Losses (millions)	War expenses (billion $)	Property destroyed (billion $)
18th century wars	1.8	0.3	—	—
19th century wars	7.3	1.0	—	—
First world war...	56	10 (20)	185	7.5
Second world war.	72	14 (45)	700	150

FIGURE 14
War losses.

These estimates are, needless to say, only roughly approximate, but they give us an idea of the appalling development. The only consolation is, perhaps, that a comparison of the figures for the first and second world wars shows that the value of destroyed property has risen much more than the loss of human lives. This applies especially to the Western allies. On the whole there is a marked tendency to economize with life and sacrifice machines.

If international tension with the ensuing release in the shape of war is permitted to rise in proportion to every new major invention, self-destruction will finally be the fate of man. Just now we have passed a mile-post: the discovery of the atomic engine (the atomic bomb). Now more than ever it is to be expected that the curve of disaster will rise sharply if the forces of preservation are not allowed to take charge. Let us hope that the huge latent risks of today will evoke responsible action both from individuals and nations.

"It is easier for an atom bomb to wipe out a city than a mental complex. The sciences of psychology, sociology and politics must not fall too far behind the physical sciences in their future development, if ultimate disaster is to be avoided." (Dr. William Brown, Oxford, *Nature 156*, 262, 1945.)

THE SVEDBERG.

BIOGRAPHICAL NOTE

Professor Svedberg, who is one of the world's leading authorities on colloid chemistry, is best known for his work on the development of the ultra-centrifuge. It was for his achievement in this field that he was awarded the Nobel Prize in 1926. This ultra-centrifuge has been extremely useful in scientific studies on proteins, carbohydrates, viruses, inorganic material, and other important colloidal substances of special interest in the fields of chemistry, biology, and medicine.