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*Edited by
Gerard Piel*

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**Population Growth in Man
and its Consequences**



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XVI
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Science and Man Symposium

POPULATION GROWTH IN MAN
AND ITS CONSEQUENCES

The Science and Man Symposia were held on three evenings during the Congress. Each was designed to explore an important biological problem that besets man and to show how biological knowledge can assist in the solution of the problem.

The symposium, Population Growth in Man and its Consequences was organized for the Congress by Gerard Piel, who also chaired the session.

POPULATION GROWTH IN MAN
AND ITS CONSEQUENCES

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OPENING REMARKS

Gerard Piel

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The ultimate subject of Zoology -- the "proper study" in the language of Socrates -- is Man. In all humility before the splendor of nature discovered for men's eyes by the manifold specialties of modern Zoology we must yet admit that our expanding knowledge gains meaning principally from its relevance to our understanding of our own presence on this planet. The subject of man comes before us explicitly in this Symposium on Population Growth in Man and its Consequences.

It is perhaps too early in the evolution of Zoology to reach so directly to the heart of the matter. But time has grown short, and time must be reckoned as a diminishing numerator in all human equations.

In this XVI International Congress of Zoology we have taken stock of the impact of physics and chemistry upon the life sciences. The changes wrought in the life of mankind by these disciplines also provide in part the terms of reference of the present Symposium. For the hard sciences, transformed to technology, have given men organized in modern national states a sudden overweening command of the forces of nature and the resources of the earth. Thus far relatively small numbers of men share in the material abundance of industrial civilization. Yet their appetites, expressed by their rate of current consumption, approach the same order of magnitude as the wealth of the earth itself. Nor is the contribution of the life sciences to be discounted in the despoliation of nature now carried forward by the most wealthy and fortunate nations. Some of the issues raised have been dealt with in other Science and Man Symposia of this Congress, under the headings of "Nature, Man and Pesticides" and "The Protection of Vanishing Species". In this Symposium we are called upon to confront the central issue of the survival of our species.

The present acceleration in the increase of the human population, as Kingsley Davis will show, had its beginnings in the scientific-industrial revolution, only 300 years ago. By that time, however, the antecedent agricultural revolution had already carried human settlements out upon all of the most desirable and fruitful landscapes of the earth. In these bountiful niches the great masses of men were already long settled in an equilibrium of insufficiency with want. Only the most fortunate members of society enjoyed what we would today call a human existence, at the summit of the high civilizations of pre-industrial technology. Professor Davis will show how the present "population explosion" has proved to be self-limiting in the industrial societies. In these nations -- comprising a minority of

the world population and an overwhelming command of political power in the modern world -- a human existence has become recognized as the right of all citizens. What is more, the abundance generated by industrial technology has begun to make this novel moral dispensation effective for increasing numbers of these citizens. Professor Davis will further explore the question whether the self-limitation of human population still remains open as a choice to the majority of the human population that has yet to make the transition from agricultural to industrial civilization. To speak to you about "Population" Kingsley Davis is qualified as one of the most distinguished American demographers. Some people may not recognize demography as a branch of Zoology, but surely it plays an integral part in Zoology reunited from its separate specialties.

The other side of the supply-demand equation to which we address ourselves here is "Production". On this topic we are fortunate to have the experience and counsel of another zoologist of equally novel origin. Professor Ritchie Calder is perhaps the only member of this Congress who comes before you robed only in an honorary degree -- the M.A. that had to be conferred upon him so that he could occupy a chair at the University of Edinburgh. He has explored every continent of earth in his searching examination of the question whether the expanding human population can make this earth its home. He has waded in the paddy fields and he has crumbled with his own fingers the sterile laterite soils that have confounded the most advanced techniques of industrial agriculture. Before this Congress, Calder comes as a zoologist who comprehends the special adaptations by which our species has succeeded all others to ultimate stewardship for the earth's resources.

There is still a third term to the supply-demand equation. It is not enough to conclude from examination of the balance sheet that human population growth will or will not over-run the earth's resources, amplified and fructified as these may be by science and technology. We are not talking about lemmings or bacteria. The third term of the equation is man -- the unique, individual man who is any one of us present here and who confronts each of us in the anonymity of the statistics of world population. On the social and ethical issues that here come to the center of Zoology I had hoped, as the organizer of this Symposium, to offer you the wisdom of one or another of the few social scientists who have the necessary knowledge and the insights. Failing as your organizer, I can offer only my own temerity as the speaker on the question of "The Living Generation".

POPULATION

Kingsley Davis
Professor of Sociology
Chairman, International Population and Urban Research
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Just as the nation-state is a modern phenomenon, so is the explosive increase of the human population. For hundreds of millennia Homo sapiens was a sparsely distributed animal. As long as this held true, man could enjoy a low mortality in comparison to other species and could thus breed slowly in relation to his size. Under primitive conditions, however, crowding tended to raise the death rates from famine, disease and warfare. Yet man's fellow mammals even then might well have voted him the animal most likely to succeed. He had certain traits that portended future dominance: a wide global dispersion, a tolerance for a large variety of foods (assisted by his early adoption of cooking), and a reliance on group cooperation and socially transmitted techniques. It was only a matter of time before he and his kind would learn how to live together in communities without paying the penalty of high death rates.

Man remained sparsely distributed during the neolithic revolution, in spite of such advances as the domestication of plants and animals and the invention of textiles and pottery. Epidemics and pillage still held him back, and new kinds of man-made disasters arose from erosion, flooding and crop failure. Indeed, the rate of growth of the world population remained low right up to the sixteenth and seventeenth centuries.

Then came a spectacular quickening of the earth's human increase. Between 1650 and 1850 the annual rate of increase doubled, and by the 1920's it had doubled again. After World War II, in the decade from 1950 to 1960, it took another big jump. The human population is now growing at a rate that is impossible to sustain for more than a moment of geologic time.

Since 1940 the world population has grown from about 2.5 billion to 3.2 billion. This increase, within 23 years, is more than the total estimated population of the earth in 1800. If the human population were to continue to grow at the rate of the past decade, within 100 years it would be multiplied sixfold.

Projections indicate that in the next four decades the growth will be even more rapid. The United Nations' "medium" projections give a rate during the closing decades of this century high enough, if continued, to multiply the world population sevenfold in 100 years. These projections are based on the assumption that the changes in mortality and fertility in regions in various stages of development will be

roughly like those of the recent past. They do not, of course, forecast the actual population, which may turn out to be a billion or two greater than that projected for the year 2000 or to be virtually nil. So far the UN projections, like most others in recent decades, are proving conservative. In 1960 the world population was 75 million greater than the figure given by the UN's "high" projection (published in 1958 and based on data up to 1955).

In order to understand why the revolutionary rise of world population has occurred, we cannot confine ourselves to the global trend, because this trend is a summation of what is happening in regions that are at any one time quite different with respect to their stage of development. For instance, the first step in the demographic evolution of modern nations -- a decline in the death rate -- began in northwestern Europe long before it started elsewhere. As a result, although population growth is now slower in this area than in the rest of the world, it was here that the unprecedented upsurge in human numbers began. Being most advanced in demographic development, northwestern Europe is a good place to start in our analysis of modern population dynamics.

In the late medieval period the average life expectancy in England, according to life tables compiled by the historian J. C. Russell, was about 27 years. At the end of the seventeenth century and during most of the eighteenth it was about 31 in England, France and Sweden, and in the first half of the nineteenth century it advanced to 41.

The old but reliable vital statistics from Denmark, Norway and Sweden show that the death rate declined erratically up to 1790, then steadily and more rapidly. Meanwhile the birth rate remained remarkably stable (until the latter part of the nineteenth century). The result was a marked increase in the excess of births over deaths, or what demographers call natural increase. In the century from about 1815 until World War I the average annual increase in the three Scandinavian countries was 11.8 per 1,000 -- nearly five times what it had been in the middle of the eighteenth century, and sufficient to triple the population in 100 years.

For a long time the population of northwestern Europe showed little reaction to this rapid natural increase. But when it came, the reaction was emphatic; a wide variety of responses occurred, all of which tended to reduce the growth of the population. For example, in the latter part of the nineteenth century people began to emigrate from Europe by the millions, mainly to America, Australia and South Africa. Between 1846 and 1932 an estimated 27 million people emigrated overseas from Europe's ten most advanced countries. The three Scandinavian countries alone sent out 2.4 million, so that in 1915 their combined population was 11.1 million instead of the 14.2 million it would otherwise have been.

In addition to this unprecedented exodus, there were other responses, all of which tended to reduce the birth rate. In spite of opposition from church and state, agitation for birth control began

and induced abortions became common. The age at marriage rose. Childlessness became frequent. The result was a decline in the birth rate that eventually overtook the continuing decline in the death rate. By the 1930's most of the industrial European countries had age-specific fertility rates so low that, if the rates had continued at that level, the population would eventually have ceased to replace itself.

In explaining this vigorous reaction one gets little help from two popular cliches. One of these -- that population growth is good for business -- would hardly explain why Europeans were so bent on stopping population growth. The other -- that numerical limitation comes from the threat of poverty because "population always presses on the means of subsistence" -- is factually untrue. In every one of the industrializing countries of Europe economic growth outpaced population growth. In the United Kingdom, for example, the real per capita income increased 2.3 times between the periods 1855-1859 and 1910-1914. In Denmark from 1770 to 1914 the rise of the net domestic product in constant prices was 2.5 times the natural increase rate; in Norway and Sweden from the 1860's to 1914 it was respectively 1.4 and 2.7 times the natural increase rate. Clearly the strenuous efforts to lessen population growth were due to some stimulus other than poverty.

The stimulus, in my view, arose from the clash between new opportunities on the one hand and larger families on the other. The modernizing society of northwestern Europe necessarily offered new opportunities to people of all classes: new ways of gaining wealth, new means of rising socially, new symbols of status. In order to take advantage of those opportunities, however, the individual and his children required education, special skills, capital and mobility -- none of which was facilitated by an improvident marriage or a large family. Yet because mortality was being reduced (and reduced more successfully in the childhood than in the adult ages) the size of families had become potentially larger than before. In Sweden, for instance, the mortality of the period 1755-1775 allowed only 6.1 out of every 10 children born to reach the age of ten, whereas the mortality of 1901-1910 allowed 8.5 to survive to that age. In order to avoid the threat of a large family to his own and his children's socioeconomic position, the individual tended to postpone or avoid marriage and to limit reproduction within marriage by every means available. Urban residents had to contend particularly with the cost and inconvenience of young children in the city. Rural families had to adjust to the lack of enough land to provide for new marriages when the children reached marriageable age. Land had become less available not only because of the plethora of families with numerous youths but also because, with modernization, more capital was needed per farm and because the old folks, living longer, held on to the property. As a result farm youths postponed marriage, flocked to the cities, or went overseas.

In such terms we can account for the paradox that, as the progressive European nations became richer, their population growth slowed down. The process of economic development itself provided the

motives for curtailment of reproduction, as the British sociologist J. A. Banks has made clear in his book *Prosperity and Parenthood*. We can see now that in all modern nations the long-run trend is one of low mortality, a relatively modest rate of reproduction, and slow population growth. This is an efficient demographic system that allows such countries, in spite of their "maturity", to continue to advance economically at an impressive speed.

Naturally the countries of northwestern Europe did not all follow an identical pattern. Their stages differed somewhat in timing and in the pattern of preference among the various means of population control. France, for example, never attained as high a natural increase as Britain or Scandinavia did. This was due not solely to an earlier decline in the birth rate, as is often assumed, but also to a slower decline in the death rate. If we historically substitute the Swedish death rate for the French, we revise the natural increase upward by almost the same amount as we do by substituting the Swedish birth rate. In accounting for the early and easy drop in French fertility one recalls that France, already crowded in the eighteenth century and in the van of intellectual radicalism and sophistication, was likely to have a low threshold for the adoption of abortion and contraception. The death rate, however, remained comparatively high because France did not keep economic pace with her more rapidly industrializing neighbors. As a result the relatively small gap between births and deaths gave France a slower growth in population and a lesser rate of emigration.

Ireland also has its own demographic history, but like France it differs from the other countries in emphasis rather than in kind. The emphasis in Ireland's escape from human inflation was on emigration, late marriage and permanent celibacy. By 1891 the median age at which Irish girls married was 28 (compared with 22 in the United States at that date); nearly a fourth of the Irish women did not marry at all, and approximately a third of all Irish-born people lived outside of Ireland. These adjustments, begun with the famine of the 1840's and continuing with slight modifications until today, were so drastic that they made Ireland the only modern nation to experience an absolute decline in population. The total of 8.2 million in 1841 was reduced by 1901 to 4.5 million.

The Irish preferences among the means of population limitation seem to come from the island's position as a rural region participating only indirectly in the industrial revolution. For most of the Irish, land remained the basis for respectable matrimony. As land became inaccessible to young people they postponed marriage. In doing so they were not discouraged by their parents, who wished to keep control of the land, or by their religion. Their Catholicism, which they embraced with exceptional vigor both because they were rural and because it was a rallying point for Irish nationalism as against the Protestant English, placed a high value on celibacy. The clergy, furthermore, were powerful enough to exercise strict control over courtship and thus to curtail illicit pregnancy and romance as factors leading to marriage. They were also able to exercise exceptional restraint on abortion and contraception. Although birth control was

practiced to some extent, as evidenced by a decline of fertility within marriage, its influence was so small as to make early marriage synonymous with a large family and therefore to be avoided. Marriage was also discouraged by the ban on divorce and by the lowest participation of married women in the labor force to be found in Europe. The country's failure to industrialize meant that the normal exodus from farms to cities was at the same time an exodus from Ireland itself.

Ireland and France illustrate contrasting variations on a common theme. Throughout northwestern Europe the population upsurge resulting from the fall in death rates brought about a multiphasic reaction that eventually reduced the population growth to a modest pace. The main force behind this response was not poverty or hunger but the desire of the people involved to preserve or improve their social standing by grasping the opportunities offered by the newly emerging industrial society.

Is this an interpretation applicable to the history of any industrialized country, regardless of traditional culture? According to the evidence the answer is yes. We might expect it to be true, as it currently is, of the countries of southern and eastern Europe that are finally industrializing. The crucial test is offered by the only nation outside the European tradition to become industrialized: Japan. How closely does Japan's demographic evolution parallel that of northwestern Europe?

If we superpose Japan's vital-rate curves on those of Scandinavia half a century earlier, we see a basically similar, although more rapid, development. The reported statistics, questionable up to 1920 but good after that, show a rapidly declining death rate as industrialization took hold after World War I. The rate of natural increase during the period from 1900 to 1940 was almost exactly the same as Scandinavia's between 1880 and 1920, averaging 12.1 per 1,000 population per year compared with Scandinavia's 12.3. And Japan's birth rate, like Europe's, began to dip until it was falling faster than the death rate, as it did in Europe. After the usual baby boom following World War II the decline in births was precipitous, amounting to 50 per cent from 1948 to 1960 -- perhaps the swiftest drop in reproduction that has ever occurred in an entire nation. The rates of childbearing for women of various ages are so low that, if they continued indefinitely, they would not enable the Japanese population to replace itself.

In thus slowing their population growth have the Japanese used the same means as the peoples of northwestern Europe did? Again, yes. Taboo-ridden Westerners have given disproportionate attention to two features of the change -- the active role played by the Japanese government and the widespread resort to abortion -- but neither of these disproves the similarity. It is true that since the war the Japanese government has pursued a birth-control policy more energetically than any government ever has before. It is also clear, however, that the Japanese people would have reduced their childbearing of their own accord. A marked decline in the reproduction rate had already set in by 1920, long before there was a government policy favoring this trend.

As for abortion, the Japanese are unusual only in admitting its

extent. Less superstitious than Europeans about this subject, they keep reasonably good records of abortions, whereas most of the other countries have no accurate data. According to the Japanese records, registered abortions rose from 11.8 per 1,000 women of childbearing age in 1949 to a peak of 50.2 per 1,000 in 1955. We have no reliable historical information from Western countries, but we do know from many indirect indications that induced abortion played a tremendous role in the reduction of the birth rate in western Europe from 1900 to 1940 and that it still plays a considerable role. Furthermore, Christopher Tietze, of the National Committee for Maternal Health, has assembled records that show that in five eastern European countries where abortion has been legal for some time the rate has shot up recently in a manner strikingly similar to Japan's experience. In 1906-1961 there were 139 abortions for every 100 births in Hungary, 58 per 100 births in Bulgaria, 54 in Czechoslovakia, and 34 in Poland. The countries of eastern Europe are in a developmental stage comparable to that of northwestern Europe earlier in the century.

Abortion is by no means the sole factor in the decline of Japan's birth rate. Surveys made since 1950 show the use of contraception before that date, and increasing use thereafter. There is also a rising frequency of sterilization. Furthermore, as in Europe earlier, the Japanese are postponing marriage. The proportion of girls under 20 who have ever married fell from 17.7 per cent in 1920 to 1.8 per cent in 1955. In 1959 only about 5 per cent of the Japanese girls marrying for the first time were under 20, whereas in the United States almost half of the new brides (48.5 per cent in the registration area) were that young.

Finally, Japan went through the same experience as western Europe in another respect -- massive emigration. Up until World War II Japan sent millions of emigrants to various regions of Asia, Oceania and the Americas.

In short, in response to a high rate of natural increase brought by declining mortality, Japan reacted in the same ways as the countries of northwestern Europe did at a similar stage. Like the Europeans, the Japanese limited their population growth in their own private interest and that of their children in a developing society, rather than from any fear of absolute privation or any concern with overpopulation in their homeland. The nation's average 5.4 per cent annual growth in industrial output from 1913 to 1958 exceeded the performance of European countries at a similar stage.

As our final class of industrialized countries we must now consider the frontier group -- the United States, Canada, Australia, New Zealand, South Africa and Russia. These countries are distinguished from those of northwestern Europe and Japan by their vast wealth of natural resources in relation to their populations; they are the genuinely affluent nations. They might be expected to show a demographic history somewhat different from that of Europe. In certain particulars they do, yet the general pattern is still much the same.

One of the differences is that the riches offered by their untapped resources invited immigration. All the frontier industrial countries except Russia received massive waves of emigrants from Europe. They

therefore had a more rapid population growth than their industrializing predecessors had experienced. As frontier countries with great room for expansion, however, they were also characterized by considerable internal migration and continuing new opportunities. As a result their birth rates remained comparatively high. In the decade from 1950 to 1960, with continued immigration, these countries grew in population at an average rate of 2.13 per cent a year, compared with 1.76 per cent for the rest of the world. It was the four countries with the sparsest settlement (Canada, Australia, New Zealand and South Africa), however, that accounted for this high rate; in the United States and the U.S.S.R. the growth rate was lower -- 1.67 per cent a year.

Apparently, then, in pioneer industrial countries with an abundance of resources, population growth holds up at a higher level than in Japan or northwestern Europe because the average individual feels it is easier for himself and his children to achieve a respectable place in the social scale. The immigrants attracted by the various opportunities normally begin at a low level and thus make the status of natives relatively better. People marry earlier and have slightly larger families. But this departure from the general pattern for industrial countries seems to be only temporary.

In the advanced frontier nations, as in northwestern Europe, the birth rate began to fall sharply after 1880, and during the depression of the 1930's it was only about 10 per cent higher than in Europe. Although the postwar baby boom has lasted longer than in other advanced countries, it is evidently starting to subside now, and the rate of immigration has diminished. There are factors at work in these affluent nations that will in all likelihood limit their population growth. They are among the most urbanized countries in the world, in spite of their low average population density. Their birth rates are extremely sensitive to business fluctuations and social changes. Furthermore, having in general the world's highest living standards, their demand for resources, already staggering, will become fantastic if both population and per capita consumption continue to rise rapidly, and their privileged position in the world may become less tolerated.

Let us shift now to the other side of the population picture: the nonindustrial, or underdeveloped, countries.

As a class the nonindustrial nations since 1930 have been growing in population about twice as fast as the industrial ones. This fact is so familiar and so taken for granted that its irony tends to escape us. When we think of it, it is astonishing that the world's most impoverished nations, many of them already overcrowded by any standard, should be generating additions to the population at the highest rate.

The underdeveloped countries have about 69 per cent of the earth's adults -- and some 80 per cent of the world's children. Hence the demographic situation itself tends to make the world constantly more underdeveloped, or impoverished, a fact that makes economic growth doubly difficult.

How can we account for the paradox that the world's poorest regions are producing the most people? One is tempted to believe that

the underdeveloped countries are simply repeating history: that they are in the same phase of rapid growth the West experienced when it began to industrialize and its death rates fell. If that is so, then sooner or later the developing areas will limit their population growth as the West did.

It is possible that this may prove to be true in the long run. But before we accept the comforting thought we should take a close look at the facts as they are.

In actuality the demography of the nonindustrial countries today differs in essential respects from the early history of the present industrial nations. Most striking is the fact that their rate of human multiplication is far higher than the West's ever was. The peak of the industrial nations' natural increase rarely rose above 15 per 1,000 population per year; the highest rate in Scandinavia was 13, in England and Wales 14, and even in Japan it was slightly less than 15. True, the United States may have hit a figure of 30 per 1,000 in the early nineteenth century, but if so it was with the help of heavy immigration of young people (who swelled the births but not the deaths) and with the encouragement of an empty continent waiting for exploitation.

In contrast, in the present underdeveloped but often crowded countries the natural increase per 1,000 population is everywhere extreme. In the decade from 1950 to 1960 it averaged 31.4 per year in Taiwan, 26.8 in Ceylon, 32.1 in Malaya, 26.7 in Mauritius, 27.7 in Albania, 31.8 in Mexico, 33.9 in El Salvador and 37.3 in Costa Rica. These are not birth rates; they are the excess of births over deaths! At an annual natural increase of 30 per 1,000 a population will double itself in 23 years.

The population upsurge in the backward nations is apparently taking place at an earlier stage of development -- or perhaps we should say undevelopment -- than it did in the now industrialized nations. In Britain, for instance, the peak of human multiplication came when the country was already highly industrialized and urbanized, with only a fifth of its working males in agriculture. Comparing four industrial countries at the peak of their natural increase in the nineteenth century (14.1 per 1,000 per year) with five nonindustrial countries during their rapid growth in the 1950's (32.2 per 1,000 per year), I find that the industrial countries were 38.5 per cent urbanized and had 27.9 per cent of their labor force in manufacturing, whereas now the nonindustrial countries are 29.4 per cent urbanized and have only 15.1 per cent of their people in manufacturing. In short, today's nonindustrial populations are growing faster and at an earlier stage than was the case in the demographic cycle that accompanied industrialization in the nineteenth century.

As in the industrial nations, the main generator of the population upsurge in the underdeveloped countries has been a fall in the death rate. But their resulting excess of births over deaths has proceeded faster and farther, as a comparison of Ceylon in recent decades with Sweden in the 1800's shows.

In most of the underdeveloped nations the death rate has dropped with record speed. For example, the sugar-growing island of Mauritius in the Indian Ocean within an eight-year period after the war raised its average life expectancy from 33 to 51 -- a gain that took Sweden 100 years to achieve. Taiwan within two decades has increased its life expectancy from 43 to 63; it took the United States some 80 years to make this improvement for its white population. According to the records in 18 underdeveloped countries, the crude death rate has dropped substantially in each decade since 1930; it fell some 6 per cent in the 1930's and nearly 20 per cent in the 1950's, and according to the most recent available figures the decline in deaths is still accelerating.

The reasons for this sharp drop in mortality are in much dispute. There are two opposing theories. Many give the credit to modern medicine and public health measures. On the other hand, the public health spokesmen, rejecting the accusation of complicity in the world's population crisis, belittle their own role and maintain that the chief factor in the improvement of the death rate has been economic progress.

Those in the latter camp point out that the decline in the death rate in northwestern Europe followed a steadily rising standard of living. Improvements in diet, clothing, housing and working conditions raised the population's resistance to disease. As a result many dangerous ailments disappeared or subsided without specific medical attack. The same process, say the public health people, is now at work in the developing countries.

On the other side, most demographers and economists believe that economic conditions are no longer as important as they once were in strengthening a community's health. The development of medical science has provided lifesaving techniques and medicines that can be transported overnight to the most backward areas. A Stone Age people can be endowed with a low twentieth-century death rate within a few years, without waiting for the slow process of economic development or social change. International agencies and the governments of the affluent nations have been delighted to act as good Samaritans and send out public health missionaries to push disease-fighting programs for the less developed countries.

The debate between the two views is hard to settle. Such evidence as we have indicates that there is truth on both sides. Certainly the newly evolving countries have made economic progress. Their economic advance, however, is not nearly rapid enough to account for the very swift decline in their death rates, nor do they show any clear correlation between economic growth and improvement in life expectancy. For example, in Mauritius during the five-year period from 1953 to 1958 the per capita income fell by 13 per cent, yet notwithstanding this there was a 36 per cent drop in the death rate. On the other hand, in the period between 1945 and 1960 Costa Rica had a 64 per cent increase in the per capita gross national product and a 55 per cent decline in the death rate. There seems to be no consistency -- no significant correlation between the two trends when we look at the figures country by country. In fifteen underdeveloped countries

for which such figures are available we find that the decline in death rate in the 1950's was strikingly uniform (about 4 per cent per year), although the nations varied greatly in economic progress -- from no improvement to a 6 per cent annual growth in per capita income.

Our tentative conclusion must be, therefore, that the public health people are more efficient than they admit. The billions of dollars spent in public health work for underdeveloped areas has brought down death rates, irrespective of local economic conditions in these areas. The programs instituted by outsiders to control cholera, malaria, plague and other diseases in these countries have succeeded. This does not mean that death control in underdeveloped countries has become wholly or permanently independent of economic development, but that it has become temporarily so to an amazing degree.

Accordingly the unprecedented population growth in these countries bears little relation to their economic condition. The British economist Colin G. Clark has contended that rapid population growth stimulates economic progress. This idea acquires plausibility from the association between human increase and industrialization in the past and from the fact that in advanced countries today the birth rate (but not the death rate) tends to fluctuate with business conditions. In today's underdeveloped countries, however, there seems to be little or no visible connection between economics and demography.

In these countries neither births nor deaths have been particularly responsive to economic change. Some of the highest rates of population growth ever known are occurring in areas that show no commensurate economic advance. In 34 such countries for which we have data, the correlation between population growth and economic gain during the 1950's was negligible, and the slight edge was on the negative side: -- 0.2. In 20 Latin-American countries during the period from 1954 to 1959, while the annual gain in per capita gross domestic product fell from an average of 2 per cent to 1.3 per cent, the population growth rate rose from 2.5 to 2.7 per cent per year.

All the evidence indicates that the population upsurge in the underdeveloped countries is not helping them to advance economically. On the contrary, it may well be interfering with their economic growth. A surplus of labor on the farms holds back the mechanization of agriculture. A rapid rise in the number of people to be maintained uses up income that might otherwise be utilized for long-term investment in education, equipment and other capital needs. To put it in concrete terms, it is difficult to give a child the basic education he needs to become an engineer when he is one of eight children of an illiterate farmer who must support the family with the produce of two acres of ground.

By definition "economic advance" means an increase in the amount of product per unit of human labor. This calls for investment in technology, in improvement of the skills of the labor force and in administrative organization and planning. An economy that must spend a disproportionate share of its income in supporting the consumption needs of a growing population -- and at a low level of consumption at that --

finds growth difficult because it lacks capital for improvements.

A further complication lies in the process of urbanization. The shifts from villages and farmsteads to cities is seemingly an unavoidable and at best a painful part of economic development. It is most painful when the total population is skyrocketing; then the cities are bursting both from their own multiplication and from the stream of migrants from the villages. The latter do not move to cities because of the opportunities there. The opportunities are few and unemployment is prevalent. The migrants come, rather, because they are impelled by the lack of opportunity in the crowded rural areas. In the cities they hope to get something -- a menial job, government relief, charities of the rich. I have recently estimated that if the population of India increases at the rate projected for it by the UN, the net number of migrants to cities between 1960 and 2000 will be of the order of 99 to 201 million, and in 2000 the largest city will contain between 36 and 66 million inhabitants. One of the greatest problems now facing the governments of underdeveloped countries is what to do with these millions of penniless refugees from the excessively populated countryside.

Economic growth is not easy to achieve. So far, in spite of all the talk and the earnest efforts of underdeveloped nations, only one country outside the northwestern European tradition has done so: Japan. The others are struggling with the handicap of a population growth greater than any industrializing country had to contend with in the past. A number of them now realize that this is a primary problem, and their governments are pursuing or contemplating large-scale programs of birth limitation. They are receiving little help in this matter, however, from the industrial nations, which have so willingly helped them to lower their death rates.

The Christian nations withhold this help because of their official taboos against some of the means of birth limitation (although their own people privately use all these means). The Communist nations withhold it because limitation of population growth conflicts with official Marxist dogma (but Soviet citizens control births just as capitalist citizens do, and China is officially pursuing policies calculated to reduce the birth rate).

The West's preoccupation with the technology of contraception seems unjustified in view of its own history. The peoples of northwestern Europe utilized all the available means of birth limitation once they had strong motives for such limitation. The main question, then, is whether or not the peoples of the present underdeveloped countries are likely to acquire such motivation in the near future. There are signs that they will. Surveys in India, Jamaica and certain other areas give evidence of a growing desire among the people to reduce the size of their families. Furthermore, circumstances in the underdeveloped nations today are working more strongly in this direction than they did in northwestern Europe in the nineteenth century.

As in that earlier day, poverty and deprivation alone are not likely to generate a slowdown of the birth rate. But personal aspira-

tions are. The agrarian peoples of the backward countries now look to the industrialized, affluent fourth of the world. They nourish aspirations that come directly from New York, Paris and Moscow. No more inclined to be satisfied with a bare subsistence than their wealthier fellows would be, they are demanding more goods, education, opportunity and influence. And they are beginning to see that many of their desires are incompatible with the enlarged families that low mortality and customary reproduction are giving them.

They live amid a population density far greater than existed in nineteenth-century Europe. They have no place to which to emigrate, no beckoning continents to colonize. They have rich utopias to look at and industrial models to emulate, whereas the Europeans of the early 1800's did not know where they were going. The peoples of the underdeveloped, overpopulated countries therefore seem likely to start soon a multiphasic limitation of births such as began to sweep through Europe a century ago. Their governments appear ready to help them. Government policy in these countries is not quibbling over means or confining itself to birth-control technology; its primary task is to strengthen and accelerate the peoples' motivation for reproductive restraint.

Meanwhile the industrial countries also seem destined to apply brakes to their population growth. The steadily rising level of living, multiplied by the still growing numbers of people, is engendering a dizzying rate of consumption. It is beginning to produce painful scarcities of space, of clean water, of clean air and of quietness. All of this may prompt more demographic moderation than these countries have already exercised.

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PRODUCTION

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The race is between production and reproduction, or, as H. G. Wells said many years ago, between education and catastrophe. In terms of Homo sapiens that means the same thing.

It has taken mankind 250,000 years to reach the present population figures of 3,000,000,000; it will take less than 40 years to double those figures. The graph of population is like an aircraft taking off. For most of the quarter million years, it just skims along the time-axis. Then, about 1600, we raise the undercarriage and begin to soar. Today, it is like a rocket rising from the launching pad.

That is what human reproduction can do. What about human production? At this moment, there are 57 man-made satellites in orbit -- apart from hundreds of pieces of rocket debris. In addition, there are seven in heliocentric orbit, round the sun. Man has surmounted the gravitational fences of the earth. We can regard that either as the vainglory of Man's achievement -- throwing the pyramids of our civilization into Space -- or as a salutary reminder that ours is a minor planet round which those pieces of hardware travel sixteen times a day. For the multimillions of mankind who will remain earthbound, the perspective of the world as seen from Space is a reminder that, on its relatively limited surface, 3,000 million today, 4,000 million by 1980 and possibly 7,000 million by 2,000 AD have to contrive to live and work together, sharing its resources.

An eye, human or electronic, in an artificial satellite in orbit sees only the geographical realities of a globe of which seven-tenths is covered by water and only three-tenths by land. Of that land-fraction, it sees forests covering one-third and the hot deserts, cold deserts and mountains covering two-fifths. It sees one-fifth which comprises the permanent pastures and meadows and the one-tenth which cultivated land. It might convey the sobering truth that, at present, the human race depends for the food for its survival on the twelfth part of the earth's surface which is arable or pastoral, since the hydrosphere still produces only a small fraction, 41 million metric tons of fish per annum, of human sustenance.

That satellite's eye-view shows the limits of Man's family estate of which, so far, we have been the reckless and improvident stewards. The fertility of the earth depends on nine inches of soil, product of countless centuries. In a paper at UNCSAT, the United Nations Conference on Science and Technology, for the benefit of the Less Developed Areas, held in Geneva, February 1963, Academicians Gerosimov and

Fedorov pointed out that the total land area subject to erosion is reckoned to be 600 million to 700 millions hectares -- 1,500 million to 1,750 million acres -- throughout the world. This sick soil constitutes almost half the cultivated areas and a considerable part of it is sick unto death.

It is not just the soil which has been impaired. The lithosphere, the atmosphere, the hydrosphere and the biosphere are integrated natural resources. The atmosphere is not only the air which humans, animals and plants breathe; it is also the envelope which protects living things from harmful radiations from the sun and outer space; it is also the medium of climate, winds and rains. Those are inseparable from the hydrosphere, including the oceans with their currents and evaporation; and the biosphere, the trees and their transpiration and in terms of human activities the minerals mined from the lithosphere. The hydrocarbons, the fossil-fuels, coal, oil and natural gas, extracted by Man, go back into the atmosphere from the chimney stacks and the exhaust pipes. During the past century, in the process of industrialization with the release of carbon by the burning of fossil-fuels, more than 400,000 million tons of carbon dioxide have been artificially introduced into the atmosphere. The concentration in the air we breathe has been increased by about 10 per cent and, if all the known reserves of coal and oil are burned, the concentration will be ten times greater -- we will have doubled the carbon dioxide. This artificial excess is already disturbing the heat balance of the earth, because the carbon dioxide acts like a greenhouse, a transparent diffusion which keeps the heat at the surface of the earth. It is estimated that at the present rate of increase of carbon dioxide, the mean annual temperature all over the world will increase by 3.6 per cent in the next 40 to 50 years. This represents a drastic modification, not only in terms of melting glaciers and icecaps which increase the flow of rivers originating in snowfields and raise the level of the seas but of changing the pattern of rainfall, with the possibility of increase of precipitation and of aridity in now fertile regions.

Man's interference with the atmosphere accelerates the natural phenomena of the climatic cycles. The clearing of forests which absorb and transpire moisture, affects localities. Upper atmosphere explosions and absorbing layers created by rocket exhausts or the deliberate introduction of particles or artificial disturbance of the natural layers, are factors which, in knowledge and not in ignorance, have to be taken into account. With the release of nuclear energy has come the injection of man-made elements into the environment. Like their natural counterparts, they chemically combine in all the processes. As fall-out from nuclear explosions, they pervade the atmosphere and are carried by climatic currents and are deposited in rain. Their disposal as atomic wastes, in gaseous, liquid or solid form from atomic installations are a major public health concern. In the hydrosphere, they can be the ionising contaminants of rivers, lakes or oceans. In the biosphere, they enter into the biochemical and genetic processes of plants, microorganisms, insects, animals and humans.

Human activities are interfering with the hydrosphere in other ways as well. Notoriously, there is the case of discharge of oil

wastes from tankers into the sea, which apart from effects on sea-creatures, has wreaked havoc among bird life. This example can be extended in many forms of pollution, from industrial wastes, from domestic detergents, frothing in mineral profusion in our rivers and streams and from the sewage of civilization. It is estimated that the sewage drained into water courses and reservoirs total 600 to 700 cubic kilometers a year. To correct this by natural dilution would require 4,000 cubic kilometers, or an eighth of the world's total runoff.

One does not need to elaborate on the subject of the Silent Spring and how we have used pesticides and insecticides with reckless disregard to the balance of nature. Or how in manifold ways through human activities -- including the age-old story of the locust and the present story of the bilharzia snail, spreading disease through artificial irrigation systems -- insects harmless in a state of nature can become the plagues of advancing civilization.

One recalls the Arusha Conference, called in Tanganyika by the International Union for the Conservation of Nature and sponsored by UNESCO and FAO in 1961, which reminded all who care to harken that wild animals are neither the enemies nor the trophies of mankind. In the precarious balance of the savannah lands of East Africa, for example, they can, and must, coexist to the advantage of human populations. Whereas Man's flocks and herds eat only surface herbage, the wild animals in the parsimony of the plains, discriminately share what is available. They consist of animals which root, animals which selectively graze, animals which browse off the shrubs and the elephants and giraffes which can eat tree foliage -- a sort of self-service restaurant on four floors. Culled, for their own conservation, they can provide a substantial source of protein.

As was pointed out, however, at the Conference by Sir Julian Huxley, himself a wild life enthusiast, wild life enthusiasts might sometimes include human beings in the natural ecology.

There is another example of wasted natural resources which we will ignore at our peril and that is the use of water. Civilizations, in the past, have died of thirst. And when one considers the water-budget of some areas of the United States one might wonder whether the American Eagle should not now be changed to the Albatross -- the curse of Coleridge's Ancient Mariner -- "water, water everywhere but not drop to drink". When Southern California uses 1,000 times more water a year than precipitation provides, then this is deficit water-banking on an alarming scale; the ghost towns of exhausted gold and exhausted oil may be repeated in the ghost towns of exhausted geological water-supplies.

Or to take another cautionary tale which alarmed me when I encountered it at first hand and alarmed me even more when I heard the report of President Kennedy's scientific mission to Pakistan, headed by Dr. Jerome Wiesner and Dr. Roger Revelle. This concerns the irrigation damage in the Indus Valley. Here the population is increasing at the rate of ten-more-mouths-to-be-fed every five minutes and every five minutes an acre of land is lost through waterclogging and salina-

tion. The Indus, with its tributaries, the Jhelum, the Chenab, the Ravi, the Beas and the Sutlej created the soils of the Punjab and the Sind. In the alluvial plains which they deposited, one of our earliest civilizations flourished, with the relics of Harappa and Mohenjodaro still remaining after 5,000 years. In the 19th Century, the British began a great farm program in lands which were fertile but low in rainfall. Barrages and distribution canals were constructed. Since Pakistan became independent, those engineering works have been massively extended and the irrigation systems intensively expanded. The 23 million acres of water by canals is the largest single irrigated area in the world. Today the system and the livelihoods of 30,000,000 people are threatened. Over 40,000 miles of canals have been dug in the surface of the Indus plain. Apart from the water which is spread by irrigation methods some 40 per cent of the water in the unlined distribution canals seeps underground and does not find its way back into the river, to be drained into the sea. The water-table has risen. Low-lying areas have become waterlogged, drowning the crops and in other parts the water seeps continuously upwards from the water-table to the surface where it evaporated leaving its dissolved salts in the top-layers, poisoning the crops. At the same time the irrigation economy itself spreads water too thinly. It is not sufficient to leach the salts from the top-soil and, with its own dissolved salts, evaporates leaving a crust of salt. So serious is the situation that President Ayub appealed in person to President Kennedy. A panel of 20 specialists from many disciplines in the natural agricultural, engineering and soil sciences was sent out. The specialists did the studies and the complex calculations were referred back to the Harvard computer teams. The proposals which they made to repair the damage, involving vertical pump-drainage and capital schemes for increased agricultural productivity, will cost \$2,000 million and will take over 25 years.

This illustrates the dangers of specializations in isolation. The barrage engineers did an excellent job according to their knowledge and their lights; so did the irrigation engineers and the soil scientists but there was no real grasp of the hydrology and the archaeologists were never consulted. Why archaeologists? Because they might have reminded the modern engineers how Babylon and Sumaria lived with an inland delta drainage system and salt-accretion for at least 700 years. So did the Aral civilization -- they used a system of plant-drainage, alternating economic crops with deep-rooting, water-glutton weeds, which dried out a barrier in the soil, between the water-table and the surface, so that the farmers were coping only with the salt of the surface-water.

Attention has been drawn to the debit balance, the behavior of Homo insapiens because a fairly intimate and widespread, geographical experience of this over the past 16 years, has made me realize that technology is liable to write such mistakes on a much larger, multi-billion dollar scale, if we do not realize our historical mistakes.

Consider the realities of the present. The population is increas-

ing at the rate of 160,000 a day. Every time the clock ticks there is another mouth to be fed. If one thinks of that as a daily influx of refugees, the picture is an intimidating one. Imagine a food distribution point which they are passing in single file -- 160,000 would mean a column 40 miles long. Give them a meager survival ration of a glass of milk, a hunk of bread and a handful of fish. In the course of a year that glass of milk would represent the product of 4,380,000 additional cows, that loaf of bread would mean the grain-product of 20,000,000 more acres, an area as big as Ireland and that half-pound of fish would represent ten times the total catch of all the fishermen along the 3,000 mile coast of India.

We all know that demography is an inexact science and that all kinds of social, economic and psychological factors operate to modify the figures. Indeed the demographers modify them all the time but, unfortunately, at present, they are modifying them upwards as countries improve their censuses. One figure we must accept and that is, short of a man-made cataclysm such as a nuclear war, the figure will not be, cannot be, less than 4,000 million. It may be more but it cannot be less. If, in all the countries where the survival rate is rising most, we had family-planning, responsible parenthood or birth-control measures as effective as they have had in Japan where the birth-rate has been halved since 1955, that global figure for 1980 would not be radically reduced. It is a biologically committed figure. As one recognizes, the population increase is not due to an orgy of procreation. On the average, couples are not having more children. More couples are having children who do not die as frequently. Mothers survive the perils of childbirth to have other children. Infants survive and grow up to marry and multiply. The increase is due to death-control, to the breakthrough of medical science which began with sulfa drugs in the mid-1930's followed by antibiotics and insecticides, which have attacked the germs and the vectors of disease. The expectation of life at birth, the span of life has increased; so has survival in the reproductive years. We are considering the potentially reproductive who already exist and who, with their progeny, will give us at least another 1,000,000,000 additional mouths to be fed by 1980.

Not only to be fed but to be clothed and housed, educated and given a life more consistent with human dignity than that tolerated by more than half the world's population today.

So I take as my reference date 1980. I burke the further projections. I do not here consider how many people the world could eventually sustain -- figures which have been set as 10 to 12 times the present world population. We can battery-feed chickens by the thousand million. Presumably we can battery-feed people and house them in a Megalopolis-Hilton. In the long-term all things are possible. At the United Nations Science and Technology Conference, Academician Fedorov, arguing free demographic expansion, suggested that, beyond the dimensions of Planet Earth, space research holds out possibilities of an unlimited expansion of the sphere of human inhabitancy. Possibly we shall have emigration space-ships, so that, just as the New World, in the 19th Century, redressed the balance of the

Old, new worlds in space will redress the balance of the global community. But it is as well to remember that all the immigrants who settled the wide open space of North and South America, Africa and Australasia, during the 19th and the first half of the 20th Century, totalled less than the annual increment of world-population now. And while fares will no doubt become cheaper than the \$50,000 per pound weight which is the present cost of rocket-shipping, even stearage space-ships are likely to be costly.

Setting the target as 1980, just 16 years away, what are the prospects? For one thing we shall have to double food production, not only to provide adequate and better standards for the newcomers but to remedy the shortcomings of present diet. This is not only a nutritional requirement; it is a socio-political one. We have seen the onrush of independence and the revolution of rising expectations. When the United Nations was founded there were 52 members; today there are 111 -- most of the new members being countries which have emerged from colonial status. But freedom is not enough. Peoples want the fulfillment of expectations and governments will balk them at their peril. The first fulfillment is enough food. Nor will that be met from the surpluses of the farm-technologies of the highly advanced countries. All the embarrassing stockpiles in the Western Hemisphere, accumulated, through farm-subsidies and farm-efficiency, over the past 15 years, would, if they were the right kind of foods, feed the population of India for less than a year. The only sensible way in which the food situation can be met is by increasing supplies in the regions and localities themselves.

It can be done, providing that, in our technological enthusiasms, we do not make irreversible mistakes. It is gradually being borne upon experts that know-how, valid for one region, has to be adapted, with great humility, to the natural and traditional conditions of another. I repeat "traditional" because experience is, or should be, the moderator of experiment. Much traditional agriculture is primitive and reactionary but, built into it, are reservations which must be studied and respected. A wooden plough drawn by a camel or a water-buffalo may look pathetic but a tractor-drawn steel plough can, and has, killed tropical soils. There has to be a compromise not with the primitive artifact but with Nature itself.

Experts have a lot to give -- provided that they are ready to learn before they try to teach and to recognize that ignorance and stupidity are not synonymous. People cannot respond if they do not understand and the worst kind of technical assistance is when, with the best intentions, we try to do things for people instead of with people. In every technical advance, it is a question of the transfer and adaptation of skills -- not the imposition of techniques or of obsolescent machinery. All over the developing countries, I have seen machinery being cannibalized or abandoned for the simple reason that, like giving a jalopy to a youngster to learn on, we have given obsolete machines, ignoring the fact that spare parts are not being made, and that people in the developing countries have not been taught to improvise them. In the North of India, tractors were provided to draw agricultural equipment. Until, in the process of years, the machine shops and the trained mechanics had been provided, those trac-

tors could not be repaired. So they devised elephant harness to draw the equipment. Elephants do not need spare parts and elephant-power is a perfectly good substitute for h.p.

What is needed in the first instance is training -- a shorter cut than people think. They need better seeds, better fertilizers, better tools, agricultural and fish-culture stations. Where the average income of a peasant is less than \$100 a year, those, even in the most modest proportions, are beyond their means. So they need the priming of international aid. We need, in terms of science and technology, far more imagination and insight. We may not be able to increase acreages fast enough but we can increase the yields from existing acreages. For example, the japonica rice of the higher latitudes yields, in Japan itself three times the rice of the indica variety in India. Indica is the rice of the whole of the tropical region of S.E. Asia, so if a hybrid can be successfully established and adapted, the yield might be doubled. This is an existing project. So is clonal propagation. So is pedigree seed-farming. In Java, for example, in the three growing seasons of a year, one ton of fundamental seed from a state seed farm can become 80,000 tons of edible rice, from the peasant farms.

Protein can be increased by encouragement of inland fish-farming. And here, traditionalism has played a remarkable part. Through the centuries, the Asian peasants have cultivated fish. In Java, they planted the fish with the rice, putting in the fingerlings when the paddy fields were flooded and harvesting the fish when the fields were drained. When FAO wanted to extend the cultivation of tilapia throughout the world, they sent the biologists to study under the illiterate Javanese fish-farmers. It happens that the Javanese like their fish small and while the fields are flooded the tilapia grows to about the size of a pilchard. The Thais like their fish big, so they made a sump in the paddy fields and when the fields were drained the fish retreated into the pond. Then the fields were flooded again and they foraged among the paddy and so on, successively, until the fish were big enough for the Thai table.

One can multiply, by the hundred, examples where with proper understanding, a modicum of material aid, and scientific knowledge adapted and applied, peasants respond and help themselves. They are naturally suspicious of change; that is the nature of farmers everywhere but equally they recognize a good thing when they have it demonstrated to them.

There are other ways. One of the gravest deficiencies in the nutrition of most developing countries is protein. It is no good trying to override tradition, or taboos, by telling vegetarians that they should eat meat or fish, but if, as in India, science and the food-technologists can produce a high-protein food from ground-nuts and grain and pulses and calcium and vitamin supplements, this can be added to the familiar diets, to the curries or the chappatis, without affronting susceptibilities. And even without regard to susceptibilities, this, like INCAP, the protein-rich food evolved in the Caribbean, is a sensible approach, using indigenous plants where animal

products cannot be produced or multiplied fast enough.

There are wider challenges which Homo sapiens in his corporate wisdom must tackle. We can sweeten the seas and harvest the deserts. As the late Dr. Karl Compton of M.I.T. pointed out years ago, if one-tenth of what was spent on developing the atom bomb had been spent on desalination it would now be a practical proposition even for irrigation. For that \$200 million, we could have cut the albatross from the neck of the Ancient Mariner -- or Uncle Sam.

We can harvest the deserts. The Israelis in the Hegov have proved it. In the Sahara, 12 years ago, hydrologists were derided by the desert Old Hands for maintaining that under the Sahara there was a fresh water sea, the Albiene Happo. Today there are fresh-water swimming pools in the Sahara and man-made oases supplied from that nodular sandstone aquifer. It is now known to extend under the Sahara at least as far south as the Tanozrouft, westwards under Mauretania, and eastwards under Tunisia and Libya. Further east there is a similar underground water supply in the Bubian sandstone layer, including an underground tributary of the Nile and aquifers extend to the Red Sea, across it to Arabia and to the Persian gulf islands. A Hungarian-Mongolian expedition has established vast underground resources under the Gobi Deserts. Indeed, the present estimates by the hydrologists show that nine-tenths of the non-Oceanic waters, i.e. the waters of the land surface are not in the great lakes and rivers but underground. The deserts have their own built-in reservoirs.

Similarly, modern plant genetics could unquestionably extend the climatic frontiers of crops far into the North.

But the greatest opportunities which I commend to this conference are in that seven-tenths of our planet which is drowned beneath the oceans. As far as the seas are concerned, we are still at the cave-man stage, hunting our food instead of husbanding it. Sea-ranches, sea-pastures, sea-stud farms are not absurdities. We ought to be able to domesticate the sea-creatures. At least in this generation of zoologists we ought to catch up with our Neolithic ancestors who provided us -- as far as I am aware and correct me if I am wrong -- with every domesticated animal we have. We have bred them out of all recognition but we inherited them. What about starting afresh with the sea-creatures. I can see us employing that highly intelligent and apparently loquacious creature the dolphin as the sheep-dogs, or even the farm-managers of our submarine ranches. And let me commend to you the possibilities of the manatee and the dugong. Those sea-cows are a pretty substantial hunk of mammalian protein but they have another important quality. They eat the water-hyacinth and those of you who know what the water-hyacinth means as the pestiferous plant-plague of the rivers of Africa and Asia will realize that you can be great benefactors if you could adapt the estuarine manatees or dugongs to go up the rivers and get rid of the water-hyacinth while at the same time providing high protein diets themselves.

There are many ways in which we could cultivate the seas. As

Sir Alister Hardy has pointed out we do not even have to introduce artificial fertilizers (which has been done on some sea-inlets) because the bottom of the sea is the greatest compost heap we have and if we could regurgitate the organic and mineral materials back into the fish-feeding layers -- by submarine ploughing or by putting down glorified bicycle pumps and blowing it up, we could greatly increase the yield of fish. He has also declared war on the starfish which he rates as the pests of sea-farming. He wants to harrow them and use them as poultry food, to leave the sea-nutrients for the edible fish.

We could fence off great arms of the sea, turn them into oceanic Texas by putting mild electric shock-waves across the entrances to discourage the fish from migrating just as strands of electric wire remind farm animals.

The sea has immense possibilities and if we could only give to Inner Space that adventurous, finance-propagating publicity we give to Outer Space, we might, with much less than \$6,000,000,000 a year -- which I reckon is the investment of the main promoters of Space Research -- find an answer to that inescapable problem of feeding our multiplying millions.

And for a great deal less than the \$120,000,000,000 which the world now spends on defense of peace we could be giving material meaning to the peace we are supposed to be defending and avert the wars that can be fomented by the frustration of the revolution of rising expectations.

There is no doubt that in terms of technology, resources and production we could, **even in the very short term between now and 1980** meet the needs of our growing population, but only if we start now and direct human resourcefulness to the needs of human resources.

THE LIVING GENERATION

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In 20th century man Zoology confronts an entirely new order of life. With infinite adaptability, as Ritchie Calder has shown, he stands now upon the verge of the world ocean, ready to secure his survival in the last and the first of all niches -- that from which life itself first came teeming upon the earth 2,000 million years, or so, ago. For almost one-third of mankind the problem of sustenance has already been solved. In the industrial nations, poverty remains as a social and political issue, but scarcely as a challenge to technology. Existing technology, multiplying the yield of the earth's resources, offers more than adequate capacity to meet the needs of a much larger world population than that which now lives in want.

The population question may equally be reckoned as settled. Kingsley Davis has shown that the human population is not fated, as is a bacterial culture, to increase until it saturates its food supply. In those nations that have entered into industrial civilization, deliberate and rational control of human fertility has brought population growth into an unstable but approximate equilibrium with increase in production. Increase in individual well-being has thus far supplied the motive for population control. It is not impossible to imagine that more generous social motivation, at work in a peaceful and abundant world, may yet bring the total human population into stable equilibrium with the yield of the earth's resources.

The question that remains is the question of economic development. The two-thirds of mankind who live today outside the pale of industrial civilization live much as most men have lived since the beginning of agricultural civilization 10,000 years ago. Their condition satisfies the baleful forecast of Thomas Malthus. In perpetual equilibrium with want, life for the great masses of mankind remains not only short but nasty and brutish as well. Now, the task of economic development is not an exercise in statistics. It is easy enough to project the world population and production curve forward and to show that they can be made to intersect within some finite time in the future and at a reasonable level of total demand upon the earth's resources. But development transcends technology and demography. It is a social and political process that engages the ambition, cupidity, daring, enterprise and imagination of men.

The question of development brings this symposium to the third term of the equation with which we are here concerned: "the living generation".

The phrase comes from Thomas Jefferson. It recurs again and again in his writings. From Paris in 1789, Jefferson wrote to James Madison:

"I set out on this ground which I take to be self-evident, that the earth belongs to the living, that the dead have no power nor rights over it".

Jefferson, the American revolutionist disengaged the dead hand of the past, the hand of the feudal social order, from the future-dwelling aspirations of the new order that was coming into being in America. Jeffersonian ethics has its roots in Zoology. It looks for sanction not to some brooding omnipresence, some absolute, some abstraction -- but to the living individual man, clothed in all the singularity of his mortal life. Jefferson declares that the living generation is the end of political action, never the means to some other end.

Jefferson is seconded by another revolutionist, a member of the generation that came after him -- Alexander Herzen. A refugee from his native Russia in 1847, at the age of 35 years, Herzen lived in exile until his death in Paris in the fateful year of 1870. Herzen was a declared enemy of the collective noun. "Submission of the individual to Society", he said, "to the People, to Humanity, to the Idea is merely a continuation of human sacrifice .. the individual who is the true, real monad of society, has always been sacrificed to some concept, some collective noun, some banner or other".

Herzen stated more plainly than most economists have the true cost of economic development: "Slavery is the first step toward civilization. In order to develop, it is necessary that things should be much better for some and much worse for others; then those who are better off can develop at the expense of the others".

The record shows that for 5,000 years, the institution of slavery -- appearing nakedly as such in some cultures and in others disguised, as in the caste system of India or the feudal system of mediaeval Europe -- provided the underpinning of agricultural civilization. Slavery was the primary device by which this technological order secured a sufficiently inequitable distribution of its chronically insufficient product to build high civilization. By the coerced deprivation of the overwhelming majority of their populations, all of the ancient civilizations managed to sustain the ostentation and adornment, the military and political adventure and the more enduring accomplishments of man's history through the first 5,000 recorded years. History rested until the most recent times upon the enslavement of 80 per cent of the people. The very existence of the slaves goes largely unremarked in the annals; for those annals were invariably written by the beneficiaries of the institution of slavery. Americans, who called it their "peculiar institution", can testify that slavery at last became immoral and finally illegal in their land only after the steam engine had made slavery technologically obsolete.

Some time in the 18th century, the surplus secured by the inequitable distribution of the insufficient product of agricultural technology found a new function. The surplus became the "wealth of the nations", to be devoted to increase of the productive capacity of society.

In a recently renewed concern with development, economists have been re-examining the development of the industrial order. They have been finding that the dynamics of the process eludes the simplistic axioms of classical economics. This, the first of the social sciences, has its roots in the ethos of Protestantism: it holds that the accumulation of capital is accomplished by the individual personal sacrifice called "savings". In the classical model, the capitalist abstains from the present enjoyment of consumption in order to secure future increase in his wealth. The interest rate is his reward for sacrifice; profit, his return on his risk. The virtue of thrift, that so distinguishes him, sets him apart especially from the aristocrat whose ostentation adorned the summit of agricultural civilization.

B. S. Keirstead of the University of Toronto has consulted the early history of development. He states his conclusion in blunt language: "If interest is the reward for abstinence, it [has been] paid to the wrong people".

"When society, taken as a whole abstains", Keirstead writes, "the per caput consumption of its members is less ... than it would have been if the new net saving had not taken place ... The individual members who abstain, however, may be divided into those who do so voluntarily and those who do so involuntarily ... Historically most social abstinence has been imposed and enforced".

Now, Great Britain before its industrial revolution boasted a modest agricultural civilization amplified by a power on the oceans that preyed upon other agricultural civilizations. The largest number of its people, however, lived by subsistence agriculture. Something new entered the life of England at the revolutionary turning point marked by the birth of modern physics in the latter half of the 17th century. The process called capital accumulation got under way, and the record shows that it had a more vivid social reality than is suggested by the economic textbooks. Capital accumulation called for a sharpening of the inequity in the distribution of goods.

As Keirstead says, "It is not possible to get people on the margin of subsistence to abstain voluntarily". England was governed throughout the 18th and early 19th centuries with great severity. A whole new body of law asserted the rights of property at the expense of the hitherto recognized sanctity of life; the catalog of capital crimes numbered crimes against property in the hundreds and came to include the most petty thefts.

For those who abstained involuntarily, the accumulation of capital for the British industrial revolution was prolonged over a century and a half. We have the contemporary journalism of Charles Dickens to tell us explicitly about the situation of the nation's poor at mid-19th century. The bitter words of William Blake deny that Jerusalem could have been "builded here among these dark Satanic mills".

The same may be said of the history of the industrial revolutions that have succeeded Britain's. It is true even of the American industrial revolution. There is all too little sense of history in the official economic literature, and what little history there was is now

being rewritten. The Populist Movement, the direct-action protest of the Wobblies, the violence at the Homestead Works, the Chinese coolies buried under the ties of the Western railroads, the squalid history of the slums of the Atlantic seaboard cities occupied by successive waves of scorned minorities and now being bulldozed out of sight and memory -- all insistently declare that the wealth of a virgin continent did not obviate the need for involuntary abstinence coerced for the purpose of accumulating capital. Compared with the archetype of the British industrial revolution, however, the American industrial revolution was of shorter duration, and it carried further as well as faster.

The record of the briefer and more recent industrial revolutions of Germany and Japan is the same. Industrialization in these two nations was promoted by the authority of the state, which imposed on their severely disciplined populations the abstinence necessary to insure the supply of capital.

With each industrial revolution, however, the path grows shorter. The nation next in line is able to draw upon an already existing and expanding stock of technology. Its leaders, planners, designers and engineers do not have to promote the evolution of Watt's steam engine into Parson's steam turbine all over again. Yet, somehow, the quotient of human sacrifice has not been reduced.

The nation that has most lately joined the circle of the rich nations now looks back in dismay upon the cruel human cost of the first 40 years of its industrial revolution. Its moralists, ideologists and economists deny that such costs must be exacted as the inexorable price of development and the attendant transformation of society. They declare that the acknowledged excesses are not inherent in the dictatorship of the proletariat, that they are the price paid to counter-revolution, to foreign invasion, to the cult of personality.

Today some 70 or 80 nations are poised at the start of the task of economic development on the far side of the transition from agricultural to industrial civilization. Some of these nations -- notably India -- begin with a heritage of ancient civilization; some -- notably the new states of Africa -- must make the leap from the neolithic to the industrial revolution; some -- notably the nations of Latin America -- take their start from a rapidly obsolescing feudal-agricultural order installed in the Americas by their European colonists.

Poverty ties all of these lands in the same common bond to the industrial West. The underdeveloped countries present an economic mirror-image to the industrial nations. Each exports one or two major commodities, mineral or agricultural, in exchange for a diverse shopping list of industrial goods. The imports of a typical underdeveloped country are consumed, in the main, by a tiny fraction of the population -- the tiny fraction that is engaged in the nation's monetary economy. In country after country, the monetary economy is more closely tied to the developed nation that takes its exports than to the indigenous subsistence agriculture in which 60 to 80 per cent of the population is immured. Development implies, therefore, not only change in the terms of the relations of the poor nations to the rich, but a thorough recon-

struction of the social systems that bind the poor nations to their present increasingly unfavorable relations to the rich.

If the precedents of the past history of development must be followed, then the next few years must see the developing nations, one after another, come under authoritarian leadership. Admittedly, ad hoc regimes are more common than not among the poor nations, regardless of their rate of development or degree of stagnation. The nations that are moving, however, are those that are most harshly governed, and the rate of development seems to correlate directly with the disposition to apply and submit to the coercion necessary to secure the accumulation of capital.

If the grim cycle must go on as before, the rich nations cannot hope to remain as spectators. Those in particular that hold stakes in the one-crop and mineral-extracting economies of the pre-industrial poor nations must anticipate that the fervor of the new nationalisms will be turned against them. Given the instability and disorder in the relations of the rich nations, the proliferation of authoritarian regimes among the poor must constantly increase the danger of war. That danger must ultimately become intolerable as thermonuclear weapons find their way into the armament of the "nth country".

Throughout the lifetime of the living generation, therefore, the survival of mankind must be reckoned as in doubt. Economic development is too important to be left to economists and politicians. It lays claim upon the conscience of all morally responsible men. It has found its way on to the agenda of this XVI International Congress of Zoology because those who know the biography of our species best have their unique role to play in the next great adaptation in our evolution.

It can be shown, in the first place, that history need not go on repeating itself. In the plans for development thus far projected by those few developing nations that have laid plans, domestic resources supply 70 to 80 per cent of the necessary capital. For this major share in the effort, the developing nations possess the necessary resources in abundance -- in the form of unemployed geological wealth and underemployed manpower. The missing 20 per cent is technology -- in the form of skills, engineering, tools and plant equipment. These assets the poor nations do not yet possess in the self-regenerating abundance of the rich nations. Supplied from abroad they will affect the junction of men and physical resources and produce 100 per cent where the values are now negative or zero.

This is the nature of the so-called aid that the developing nations seek from abroad. The function of this aid is equally decisive. Aid is the offset to involuntary abstinence and the coercion necessary to secure it. Without aid, the leaders of the next round of industrial revolution must be compelled to extract the last ounce of surplus from insufficiency by coercive deprivation.

External aid is the catalyst of development. It supplies the technology that brings manpower into reaction with resources at lower social pressures and temperatures. With external aid, it becomes possible to dream of carrying development forward without sacrifice of

the living generation to the promised welfare of the next.

Aid, thus defined, is a misnomer. The word is as misleading, in view of the relation it implies between the poor and the rich nations, as the terms "particle" and "wave" in 20th century physics. The call for aid is not an appeal to the benevolence of the world. It is a rightful demand of mankind upon the assets of industrial civilization.

The first among these assets is scientific knowledge and the power this gives man over nature; these are the heritage of all men because they constitute the accumulated experience of our species. Science and technology are not diminished by the sharing of them. It is the information -- the accumulative human experience -- embodied in the tools and machines that the developing nations require. It is this stored-up treasure of history that gives technology its fructifying power, not the gross materials of which the artifacts of technology are made. The materials represent the least of the values and the smallest of the cost as well. The rich nations can respond to the demand for aid without perceptible cost to their well being.

The rendering of external aid can, in fact, relieve the rich nations of peculiar temporary embarrassments that arise from the mismatching of the progress of their technology and the evolution of their social and economic institutions. What I shall have to say under this heading applies to a greater or lesser degree to all of the industrial countries. I shall call, however, upon the example of my own country, because I know it best and because it represents industrialization in its presently most fully realized form. If my analysis leads into paradox from point to point, this flows from the no less incredible nature of the facts and figures of the U. S. industrial system. The logic of its abundance necessarily inverts values and habits of thought predicated upon the more familiar experience of scarcity.

America's success in production has confounded and subverted the institutions through which it secures the distribution of its abundance. The distribution system requires that the would-be consumer hold a job in order that he may bring his need into the market place as effective demand. But technology has severed the connection between people and production. In contrast to the poor nations of the world, where 70 per cent of the people are bound to the soil, not more than 7 per cent of the U. S. labor force is engaged in farming. Besides our farmers, not much more than 30 per cent of the U. S. labor force can now be classified as "producers of goods". Since 1950, this category has not only declined as a percentage of a growing labor force, but even in absolute numbers. What is more, employment in distribution -- which recently helped so mightily to secure the distribution of goods by qualifying its own workers as consumers -- has begun to yield to technological disemployment. The same is true of the white-collar clerical work force.

In U. S. society the most significant trend, from the ideological standpoint, is the rising ratio of employment in the public as contrasted to the private sectors of the economy. More than half of the

new jobs created since 1950 are in the public sector. The biggest expansion in jobs -- more than a million new jobs in the decade -- has come in teaching, a function which is characteristically public and which, in the U. S., is the responsibility of local, municipal and state governments. In percentage terms, scientific research and engineering have been the most rapidly growing professions. Since the end of World War II the substantial growth -- totalling perhaps 3,000,000 jobs -- in these elite functions has been financed almost entirely by the public sector.

The economic surplus of America today arises not from the classical process of coercive deprivation but consists in a true physical excess of product and of capacity to produce. In the first place, the American economy is able to conduct the continuous expansion and modernization of its industrial plant without any perceptible cost to the current high rate of consumption. Profit has become a tax, taken in advance on the sales price of goods, to be used for expansion and modernization of the productive system. This, not the speculative return to the entrepreneur, has become the moral rationale of the profit motive. Significantly, as industrialization proceeds in the Soviet Union, the economic literature of that country has begun to carry treatises in praise of profit as an institution serving precisely the same social function.

The most stunning index of America's surplus capacity, however, is to be found in its gigantic war economy. In every modern state armaments have practically unquestioned command of the public treasury; for armaments carry the absolute sanction of national survival. In the United States, since 1939, the steady stream of funds pumped into the economic sink of armament has directly and indirectly subsidized from at least 10 to as much as 20 per cent of the nation's total economic activity. Space, the Atom and Big Science have held their catch-basins under the overflow from Defense and provided employment for many of the highly trained people that U. S. society has been producing in such large numbers. It is a measure of the distance already traveled toward abundance that the American industrial economy can sponsor so much non-productive and even purely wasteful activity not only without visible sacrifice but even as a covertly acknowledged means for maintaining consumer demand. The military budget has carried an additional ideological sanction, in that it re-diverts something more than 5 per cent of the gross national product from the public directly back into the private sector.

The advance of technology has now, however, overtaken this makeshift arrangement. With the acquisition of overkill, armaments have lost their absolute claim on the treasury. Plainly the U. S. economy must soon find other ways to sustain its activity at the present high rate. Since it will necessarily continue to produce surpluses beyond its own effective demand, the U. S. must invent new methods for disposing of its surpluses.

The most convenient alternative to armaments would seem to be offered by foreign aid. As significant elements in the leadership of industry already realize, 80 cents out of each foreign-aid dollar is

spent within the borders of the U. S. In the prospective American collaboration on the building of the Bokaro steel mill in India, for example, "...what has to be financed is rolling mills, presses and other equipment that has to be imported into India to construct this mill ... Those things ... cannot be bought with Indian rupees. They have to be bought -- they will be bought entirely -- in the United States if we finance this mill". Moreover, just as in the case of military expenditures, foreign aid takes the goods it buys out of the domestic market -- thereby maintaining the scarcities that still keep the economic mechanism ticking.

Foreign aid in the U. S. economy thus calls upon the same institutional relations between government and business as armaments and provides an equally direct channel for diverting funds from the public back into the private sector. A substantial foreign-aid program would generate demand for the products of neglected and vital sectors of industry, including the heavy machinery builders and the machine-tool industry, whose domestic business proceeds in cycles of "chickens today and feathers tomorrow". What is more, the installation of U. S. machine tools in the new industrial systems would establish beachheads for future dollar markets. A radical expansion in foreign aid would also provide the most convenient way to soak up the surplus of engineering and research talent that will accumulate with the imminent cut-back in national defense and prestige expenditures.

During the period of 15 to 20 years which will be required, at a minimum, for the U. S. to bring its economic, social and value systems into adjustment with the advent of automatic production, foreign aid can relieve many of the nation's internal stresses and strains. The same considerations commend foreign aid to other "developed" nations caught up in the same revolutionary process of industrialization. By the end of this period, given a sufficiently massive flow of aid, many of the "developing" countries will have acquired the capacity for self-sustaining growth.

If foreign aid has not yet rallied the support of significant numbers of interested parties in the rich countries, this is only because it has been conducted on such a pitifully inadequate scale. The rich nations variously inflate their claims as to the size of their foreign aid programs. A dispassionate estimate is provided by the 1962 report on the economic and social consequences of disarmament to the Secretary General of the United Nations, prepared by an international group of expert consultants. The report indicates that the net flow of aid from rich to poor nations does not exceed \$3,500 to \$4,000 million per year. This squares with independent estimates that the total rate of investment in the underdeveloped countries does not exceed \$20,000 million -- or less than 20 per cent of the armaments outlays of the rich nations. To the present flow of \$3,500 to \$4,000 million, the U. S. contributes about 40 per cent, or something under \$2,000 million, a figure that agrees well with the official U. S. governmental figures less the funds laid out for military purposes.

Since the U. S. economy must soon find conveniently large open sluices for its surpluses -- other than armaments -- its foreign aid

outlay could easily double. With disarmament, it might easily double again. If the U. S. were thus to take the lead in expanding the scale of external aid to the development of the poor countries, as it already leads in the rationing of the current trickle of aid, the total flow might mount up to \$15,000 million per year. With external aid on such a scale, the total investment programs of the poor nations might be boosted to as much as \$100,000 million per year and might begin to approach the world's outlay for armaments. An increasing number of taxpayers in the U. S. and in other countries are ready to agree that foreign aid is a better buy.

There is another aspect to the relations of the rich and the poor nations, however, that presents considerable hazard to the generation of a significantly large flow of foreign aid. Development in some countries can come only with social and political as well as industrial revolution. In almost every country, it implies the revision or abrogation of the last thread of the colonial bonds that tie the developing country to its "home" country.

No matter what the leitmotif or the bloody detail of each cycle as it gets under way, however, the extension of external aid can facilitate the underlying process of capital formation and soften its demands upon the people. It is important to know that foreign aid on an adequate scale is technologically feasible and that it promises as much economic benefit to the rich as to the poor. The ground is cleared for confrontation of the moral issue. In the case of my own country, I am sure, external aid will begin to flow in significant volume just as soon as my fellow citizens understand that their surplus can life the burden of history off the backs of the living generation.