The Great

Fir-Tree Forest

R. H. Clark

INTRODUCTION

Previous lecturers in this course have briefly reviewed the history of this Earth and its living systems. Undoubtedly they would argue with my description of their interests in such fields as Astronomy, Geology, Oceanography and Soil Science as being of a historic nature, but from our viewpoint as students of Nature, Science, and Man their contributions to the knowledge of man relate to the physical world which is already in existence. They have presented a picture, blurred at times and with many omissions, but distinct enough for us to appreciate the complexity and interdependence of the physical and living components of this small satellite earth.

Like Jacob Marley's ghost, I now invite you to join me on an exploration of the present and the future with the thought that perhaps by suitably changing our attitudes we might confound the prophets of doom and misery. This exploration will take the remainder of the term. It will lead us to consider not only the status of man and his future but cause us to appraise his behaviour patterns and morality upon which so much depends.

Man is now the dominant species on earth. The biologist, being fully conscious of the implications of this status, has repeatedly warned us of the dangers of conquering nature to permit an uncontrolled expansion of the species. Until recently, these warnings have been unheeded.

Development and growth, accelerated by economic, technological and social incentives, have characterized the 20th Century. Although the unpleasant by-products of this expansion were predictable, Man has only started to recognize them as they have become undeniably visible. In recent years the developed countries have become concerned by resource shortages, social and economic problems and the underdeveloped countries face a daily challenge to feed their populations. These are some of the visible signs of an impending crisis in human affairs.

Garrett Hardin (1969) writes, in explanation of our reluctance to interpret these signs:

> *"The emerging history of population is a story of disaster and denial in our innermost being - disaster foreseen, but disaster psychologically denied in our innermost being. Our reaction to the signals assaulting us is perfectly understandable: they foretell an event that has never happened before. How can one believe in something - particularly an unpleasnat something - that has never happened before?"*

The dedicated unbelievers, supported by either a Micawber-like philosophy that 'something will turn up' or a faith in man's ingenuity, see these signs as only temporary checks to man's progress. They take comfort by referring to the history of mankind, in the spirit of, if not the wording of a *Lagos Sunday Post* news story, which read in part:

> *"Quite too frequently we hear cries from old and young soothsayers, seers, forecasters and even the naivest of Jehovah's Witnesses, putting across to the people in adamant forms, terms and dates when the world will end. Historically, such forecasts or predictions have usually come to nought."*

The debate between the confident optimists and the cautious pessimists has ancient origins, but intensified with the publication in 1798 of *An Essay on the Principal of Population as it Affects the Future Improvement of Society*. The author, Robert Malthus, postulated "that population, when unchecked, increased in a geometrical ratio, and subsistence for man in an arithmetic ratio". The population he foresaw would increase to the limits imposed by the resources since an increase beyond these limits is checked by disease, famine, and war and by the influence of misery and vice. These and other thoughts, expressed in this essay and his further works, were unpalatable and were attacked by spokesmen representing the whole spectrum of public opinion. Marx, for example, saw this as a challenge to his entire system and referred to Malthus as a "shameless sycophant of the ruling class". He viewed the concept of overpopulation as a Capitalist notion invented to justify the poverty of the working classes since he saw the threat of overpopulation as rectifiable by enhanced production and distribution rather than by birth control.

Some authors believe that the dire predictions of Malthus, which were based on observations of an agricultural community, would probably have been fulfilled but for the advent of the Industrial Revolution. Certainly, the consequent development of improved farming techniques, the ability to use resources outside the confines of small communities, and the improvement of health standards did lead to an expansion of the world's population and standard of living. Thus the checks envisaged by Malthus were removed, at least temporarily.

The Malthusian debate, modified by recent events, continues however. The bookstalls abound with books emphasizing the disasters of overpopulation. Paul Ehrlich's book *The Population Bomb* is perhaps the best known to the public. His general thesis in this and his later book *Population, Resources, Environment* is summarized in his opening paragraph to the latter book:

> *"The explosive growth of the human population is the most significant terrestrial event of the past million millenia. Three and a half billion people now inhabit the earth and every year this number increases by 70 million. Armed with weapons as diverse as thermonuclear bombs and DDT this mass of humanity now threatens to destroy most of the life on the planet. Mankind itself may stand on the brink of extinction: in its death throes it could take with it most of the other passengers of Spaceship Earth. No geological event in a billion years - not the emergence of mighty mountain ranges nor the submergence of entire subcontinents, nor the occurrence of periodic glacial ages - has posed a threat to terrestrial life comparable to that of human overpopulation."*

After reading these books you will feel more abject than Scrooge did when presented with the picture of Christmas future. Your first question, like his, will be, "must it be so?".

You might take some small degree of comfort from the fact that in many cases the bleakest picture is presented and that the senastional aspects are often emphasized. You might also choose to regard these writers as the sons and daughters of Malthus and conclude that their views are interesting, but will prove, like his, to be invalid for at least many years to come. Since the publication of *The Limits to Growth* by Donella Meadows *et al* and "A Blueprint for Survival" by *The Ecologist*, there have been a number of articles by confident optimists. Some predict that future technology will permit the population to grow by a million times its current value or that our problems will be solved by shrinking the human being to 6" height by genetic engineering. Others envisage space colonies as an eventual answer to the population problem. However, in 1975 the optimists were in a minority and the newspapers, publications and conferences were filled with contributions describing the problems of Mankind.

In a later essay on population, Malthus added moral restraint as a further positive check on the population increase. It would indeed be for-

tunate if the human race could consciously choose this course of action at the appropriate time based upon consideration of the facts, unclouded by emotion or politics.

POPULATION FACTS

Demographers often choose to show population statistics in terms of 'fir-tree' diagrams. These are bar diagrams with each bar drawn to represent the number of persons in each age bracket. They form a fir-tree-like configuration when the male and female populations are simultaneously plotted. The normal shape of the tree, unaffected by epidemics, wars or insufficient resources, is probably similar to that illustrated in Figure 1 for the U.K. in 1871. It will be noted that in shape it is indeed very similar to a healthy fir tree.

The shapes resulting from overgrowth and temporary checks in population caused by wars, epidemics and economic recessions, are illustrated in Figure 2. Included in this figure is an impression of the general form of the fir tree if the North American dreams of controlling death and maintaining growth are realized. It presumes the elimination of all fatal diseases, accidents and wars and the successful introduction of body transplants for the privileged, while at the same time maintaining a steady population growth to satisfy the demand for economic growth. The shape of the diagram is obviously unnatural and its artificiality might by itself provide a warning that these policies are unsound.

The shape of the fir-tree is also an indication of its growth rate and the demands of the 'tree' for space and resources. Thus, a high percentage of young persons, revealed by overgrown lower branches of the tree, could indicate a high growth rate. As an example of the way a tree grows, the fir trees for Ontario shown in Figure 3 form a very interesting study. In 1951 the effect of of recession is clearly indicated, together with the beginning of the baby boom in the post-war years. These two effects are then reflected back as the age of fertility is achieved to provide first a reduction in births and then an echo of the first baby boom. Thus, the utilization of this simple pictorial form for population statistics is of considerable value in planning for the future. An understanding of its characteristics is essential to determine the future growth rate since data on 'migration', birth and death rates, only provide the net growth rate for the year the data was obtained. The prediction of the future growth and the shape of a fir-tree is by no means simple, and demography has become almost a branch of mathematics. (See *The Growth and Structure of Human Populations* by A.J. Cooke, Princeton University Press, 1972 and the appropriate sections in *Mankind at the Turning Point*, 1974).

The fir-trees for other nations provide examples of healthy,

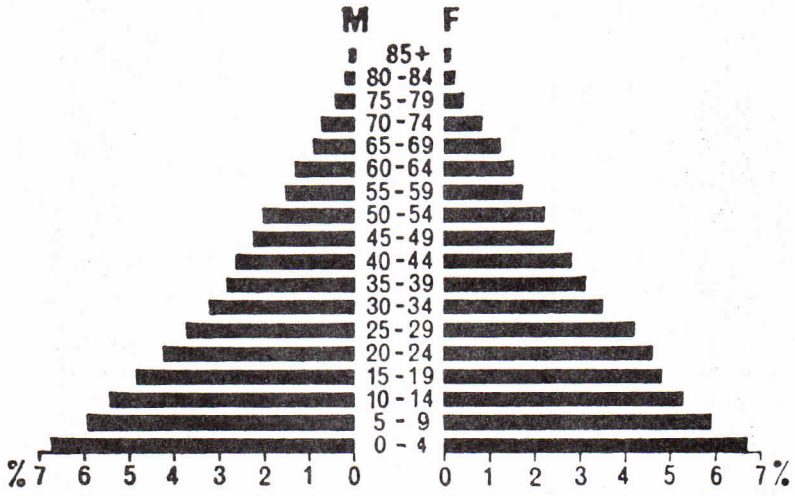


FIGURE 1. A TYPICAL FIR-TREE. THIS ONE IS FOR THE UNITED KINGDOM IN 1871, AND IS AN EXAMPLE OF A HEALTHY POPULATION PROFILE. HERE THE SCALE ALONG THE ABSCISSA IS IN PERCENT OF TOTAL POPULATION, BUT IT IS OFTEN REPRESENTED AS ABSOLUTE NUMBERS. SEE ALSO FIGURE 3. *(Data from U.K. Annual Abstract of Statistics).*

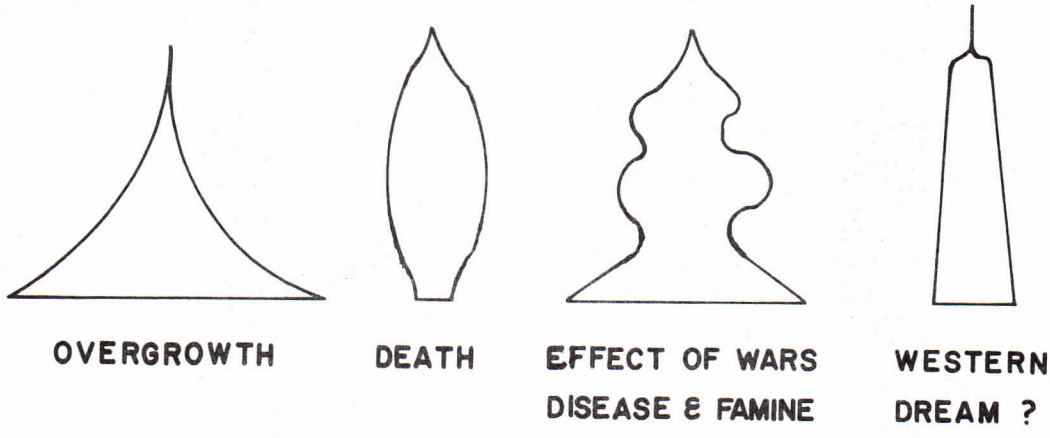


FIGURE 2. FIR-TREE TYPES.

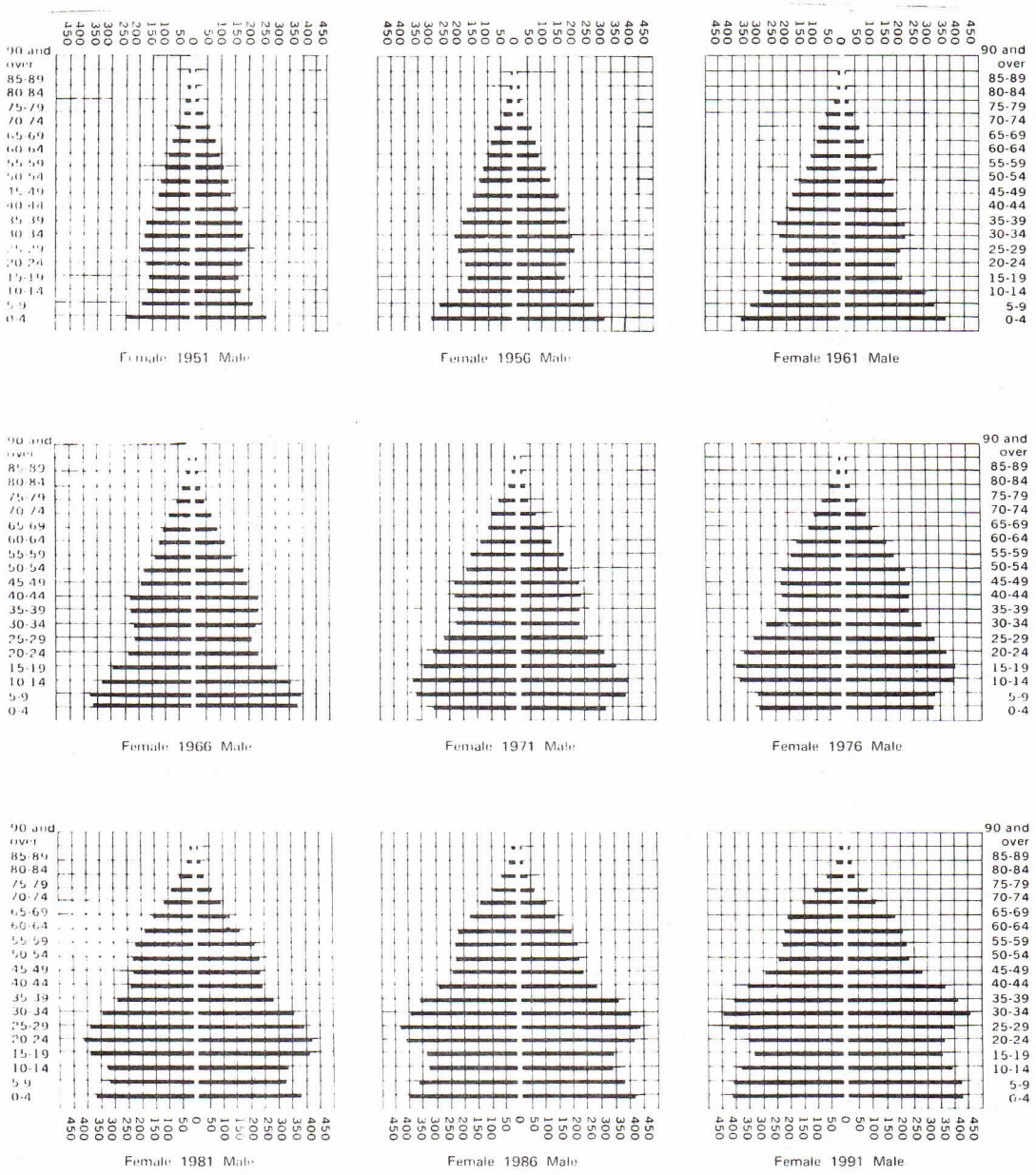


FIGURE 3. FIR-TREES FOR ONTARIO FOR CENSUS YEARS 1951-1966 AND PROJECTIONS TO 1991. NOTE THE GROWTH AND CHANGING SHAPE OF THE TREE. (Figures shown in thousands. Source: *Draft Report of the Commission on Post-Secondary Education in Ontario,* Queen's Printer, Toronto, 1972).

diseased, dying and rapidly expanding forms. If we pursue our analogy it is reasonable to expect that the rapidly growing fir-trees have space and an ample supply of nutrients for their growth. To test this hypothesis the data reported in Table 1 were abstracted from the U.N., 1971, Yearbook of Statistics. This information for a few of the larger and representative countries has been depicted in various ways in Figures 4 and 5.

The apparent relationship between population growth, as a percentage of the population, and the birth rate is shown in Figure 4. It would seem that approximately 10 to 12 births per 1000 of the population are required in order to maintain the population. At this level, the death rate and the net emigration rate are equivalent to the birth rate. East Germany currently would appear to be closest to this 'Z.P.G.' condition.

Between 10 and 30 live births per thousand, the population growth rate increases in an approximately linear fashion with the birth rate. Beyond about 30 births per thousand the population growth is approximately constant at 2.5 percent. This change coincides with a dramatic increase in the death rate. An examination of the list of countries represented reveals that this break point in the relationship also represents the division between the developed and underdeveloped countries, or more bluntly, the rich and the poor.

There are always exceptions to general approximations and a country having one of the highest birth rates also has by far the highest population increase. This distinction is held by the Virgin Islands! The nutritional standards, health care and wealth provided by the U.S. involvement would seem to be responsible for this achievement by these fertile islanders.

To return to our hypothesis it would seem that the birth rate rather than the population growth should be the criterion for testing whether land and food availability are the true growth stimulants for an individual fir tree, since the birth rate should surely indicate the desire to reproduce. Figure 5 shows that there is little correlation between birth rate and population density, and contrary to the hypothesis many highly populated countries exhibit the highest birth rate. The influence of food illustrated in the second graph of Figure 5 even more conclusively underscores the weakness of the hypothesis. As the food consumption of a nation increases, the birth rate declines. In the last graph of Figure 5 the relationship between the birth rate and energy consumption is obtained, but again the weakness of the hypothesis is emphasized: the increasing ability to utilize energy results in a declining birthrate.

Thus the factors which might be expected to stimulate growth appear

TABLE 1: IMPORTANT STATISTICS FOR SELECTED COUNTRIES
(data from *United Nations Statistical Yearbook*, 1974).

Reference No.	REGION AND COUNTRY	POPULATION					FOOD			CONSUMPTION	
		Millions	Density per Km^2	Births	Life Expectancy yrs.	Increase Percent	Calories	Protein g/capita	% Animal Protein	Total Energy kg coal/year	Newspapers per 1000
	AFRICA										
1	Egypt	30.1	33	34.9	52.6	2.2	2770	80	7	294	22
2	Ghana	8.6	38	46.6	46	2.7	2070	43	3	155	46
3	Nigeria	55.7	60	49.6	37	2.7	2290	60	7	67	3
4	South Africa	21.4	16	40.3	49	2.8	2730	77	19	2815	32
5	Liberia	1.0	9	50	45	2.9	2290	41	4	338	4
	N. AMERICA										
	Virgin Is.	0.01	72	45.6	-	4.3	-	-	-	-	-
6	Canada	21.6	2	15.7	52	1.2	3200	97	46	11237	230
7	Cuba	8.6	73	25.4	72	1.7	2500	63	16	1144	95
8	U.S.A.	203.2	22	15.0	71	0.9	3300	99	40	11960	297
	S. AMERICA										
9	Brazil	92.3	11	37.8	61	2.8	2820	67	14	566	37
10	Argentina	23.4	9	21.9	67	1.5	3160	105	35	1908	154
11	Columbia	17.5	19	44.6	45	3.2	2140	50	20	601	109
12	Chile	8.8	13	27.6	63	1.7	2560	66	21	1458	86
	ASIA										
13	China	590.2	61	33.1	50	1.7	2050	55	9	594	-
14	Taiwan	13.1	390	28.1	-	2.6	2620	68	15	-	-
15	Hong Kong	4.0	3829	19.3	70	1.7	2370	65	21	998	485
16	India	548.0	164	42.8	41	2.1	1990	49	5	188	16
17	Indonesia	118.5	80	48.3	47.5	2.8	1920	43	2	146	7
18	Japan	104.7	280	19.4	73	1.3	2470	77	15	3601	519
19	Pakistan	64.9	81	36.0	51	3.6	2410	55	11	149.0	6
20	Viet Nam	15.9	133	37.5	50	2.0	2200	48	7	274.0	67
21	Saudi Arabia	8.44	3.93	50.0	42	2.9	2080	56	8	1023.0	7
	EUROPE										
22	France	49.78	93	16.5	73	0.9	3270	103	41	4389	238
23	Germany, W.	60.70	240	10.2	71	0.7	3180	83	43	5792	294
24	Germany, E.	17.1	150	10.6	71	-0.2	3040	76	37	-	425
25	Portugal	8.7	93.8	20.1	68	-0.4	2920	82	19	898	87
26	Spain	30.1	59.5	19.2	73	1.1	2770	80	21	1993	98
27	Italy	54.0	179	16.8	70	0.8	2950	88	19	2681	127
28	Sweden	8.1	18	13.6	74	0.8	2750	79	41	6311	534
29	U.K.	55.4	228	16.2	71	0.5	3180	88	40	5362	488
	OCEANIA										
30	Australia	12.73	2	20.5	71	2.0	3220	106	41	5425	321
31	New Zealand	2.86	10	22.1	71	1.5	3320	106	51	2649	376
32	U.S.S.R.	241.7	11	17.4	70	1.1	3180	92	21	4445	336

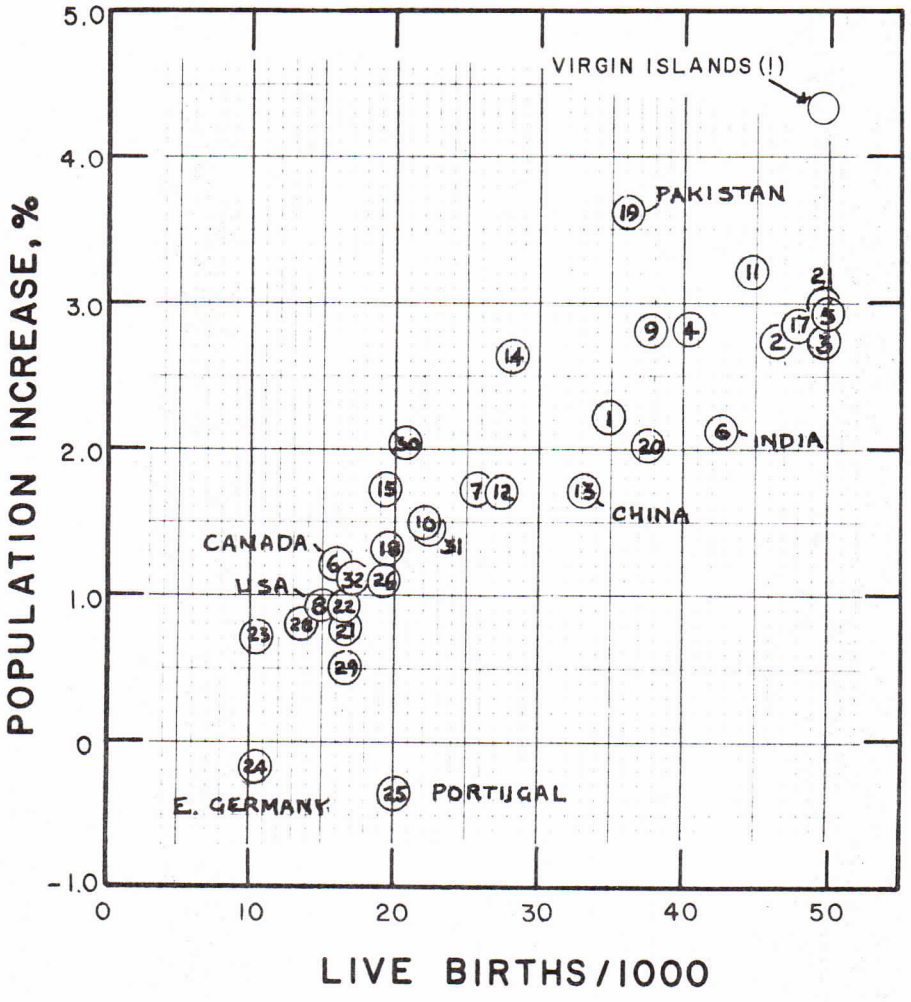
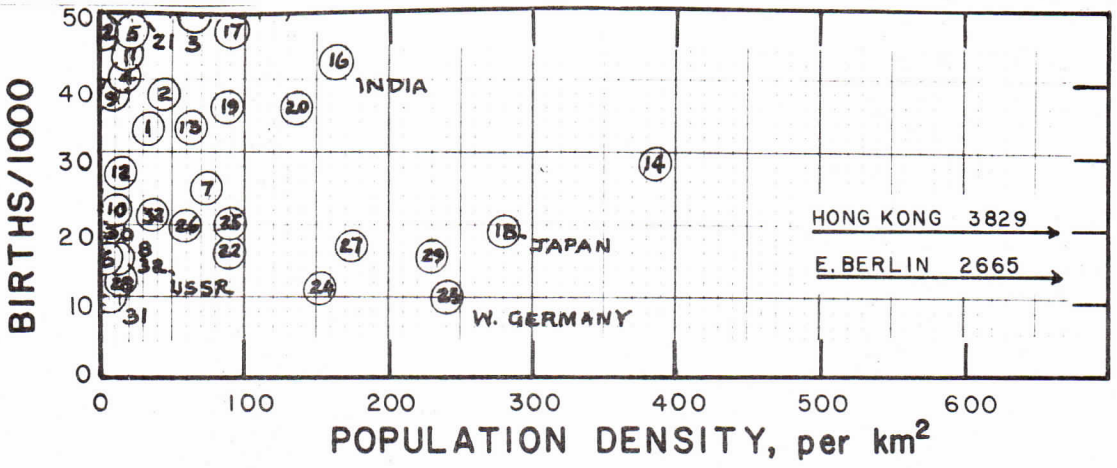
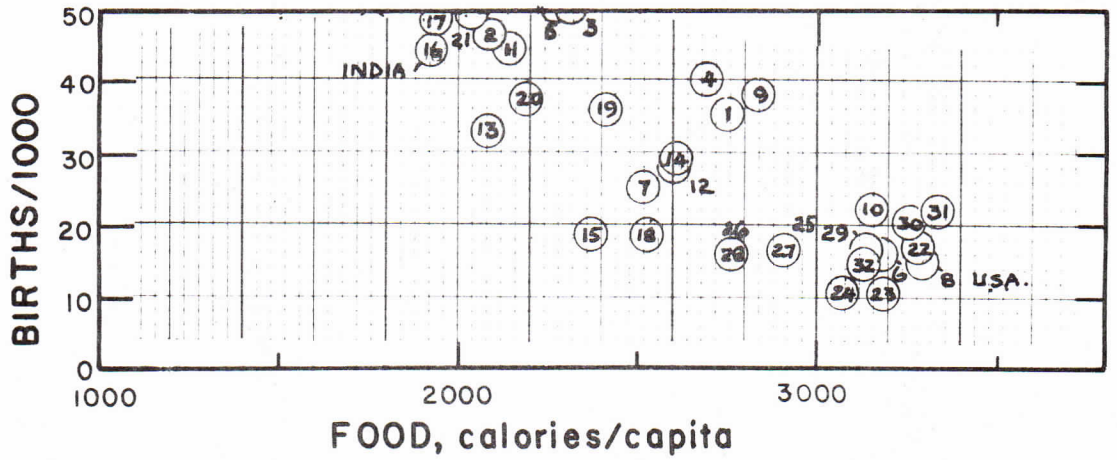


FIGURE 4. THE APPARENT RELATIONSHIP BETWEEN POPULATION GROWTH AND BIRTH RATE.





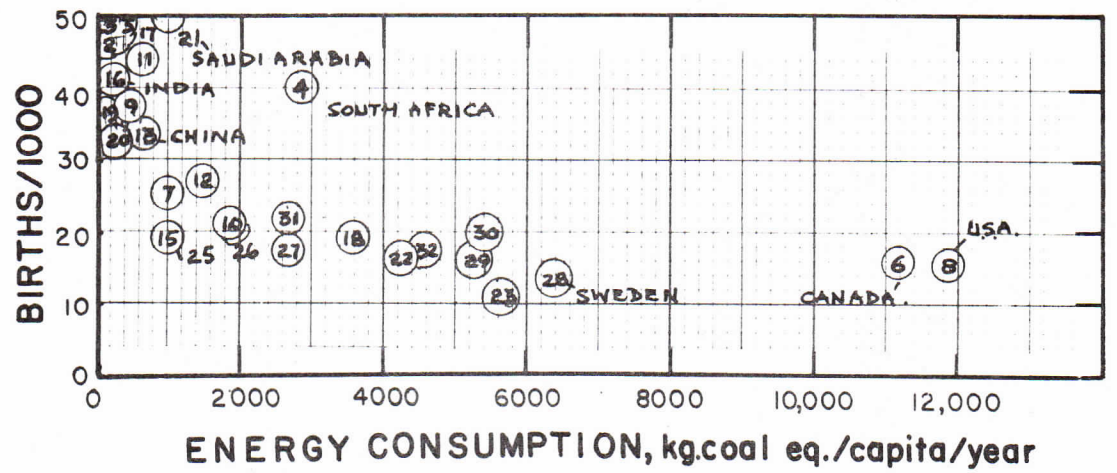


FIGURE 5. THESE GRAPHS INDICATE THE DEGREE OF CORRELATION BETWEEN THE BIRTH RATE AND POPULATION DENSITY, FOOD, AND ENERGY CONSUMPTION.

to have negative effects. The greatest growth is occurring under the most unfavourable conditions. It would appear from this analysis that not only the hypothesis, derived from the fir-tree analogy, is incorrect, but also that the checks envisaged by Malthus are ineffective. The hypothesis fails because important historic, economic, social and political factors have not been considered, whereas, as we shall see, the Malthusian checks are real but, fortunately, largely ineffective at the present.

The Great Fir-Tree Forest

The human species has populated the world. Figures 6a and 6b provide a pictorial representation of the geographic areas, wealth per capita (GNP per capita) and the population distribution for 1975 and the year 2000. The bulk (71%) of the world's population live in underdeveloped countries in which the annual rate of population increase averages 2.5%. By contrast the population of developed countries is only increasing at 0.8% with a number of these populations approaching the zero growth condition.

The growth of the world's population is depicted in Figure 7. It will be noted that the population has risen dramatically in the last century and that with the current growth rate it would seem likely to achieve infinite proportions in an insignifigant interval in terms of the earth's lifetime. All the characteristics of an explosion are present: the interactive ingredients, the detonator and the drama.

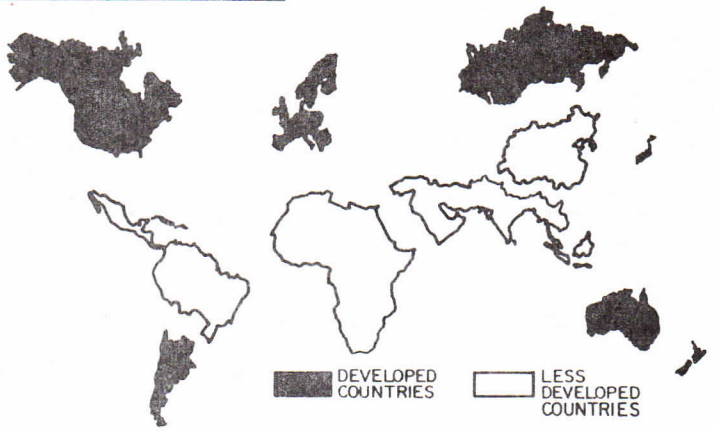
A closer examination of the data employing a logarithmic plot reveals some interesting aspects (see Figure 8). The population has not increased steadily and three phases of development may be defined. Some demographers believe that these correspond to man's development from a fruit gatherer and a hunter, to a food cultivator, and finally to a technologist. The movement of ideas, materials and people, aided by the improving methods of transportation and communication, must have been an important factor in this development. Whatever the reasons, each succeeding period is distinctly shorter and it might suggest that the current period of man's development is almost complete.

There are other reasons for presuming that the present technological period is almost over and that a new period is about to begin. Foremost is the fact that the earth cannot support a greatly increased population, and in this respect we might be humble enough to compare ourselves with other biological systems.

A typical growth period for population of cells contained in a vessel with a limited supply of nutrient is shown in Figure 9. A lag phase corresponding to the early development of man first occurs. This is then followed by an exponential growth phase in which the rate of growth is proportional to the cell population, i.e.

$$\frac{dN}{dt} = \mu N$$

GEOGRAPHIC AREAS OF THE WORLD



AREAS IN PROPORTION TO G.N.P.

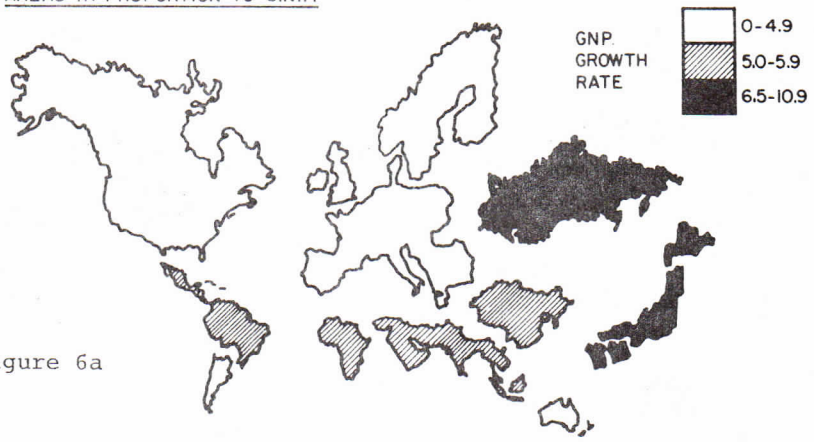


Figure 6a

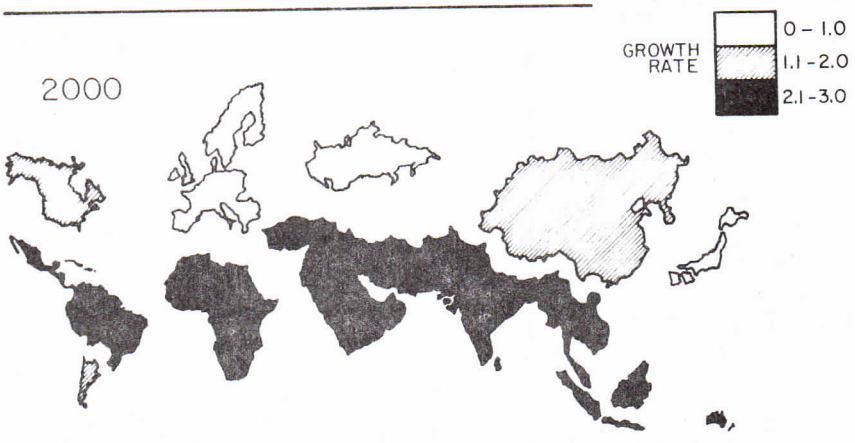
REPRODUCED FROM 1974 BULLETIN OF LABOUR STATISTICS, INTERNATIONAL LABOUR OFFICE, GENEVA

APPROXIMATE WORLD POPULATION DISTRIBUTION

1970

Figure 6b

2000



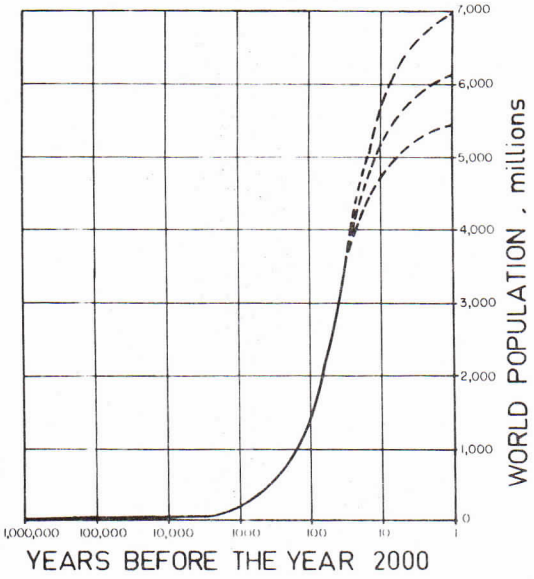


FIGURE 7. SEMI-LOG PLOT OF WORLD POPULATION GROWTH. BROKEN LINES INDICATE HIGH, MEDIUM AND LOW UNITED NATIONS PROJECTIONS. (Based on United Nations data).

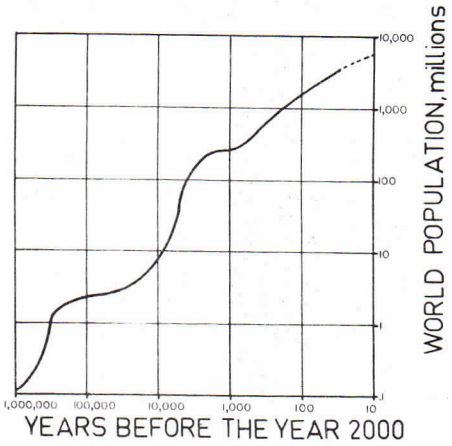


FIGURE 8. LOG-LOG PLOT OF WORLD POPULATION GROWTH, SHOWING THREE APPARENT GROWTH STAGES. BROKEN LINE REPRESENTS UNITED NATIONS MEDIUM PROJECTION. (Based on United Nations data).

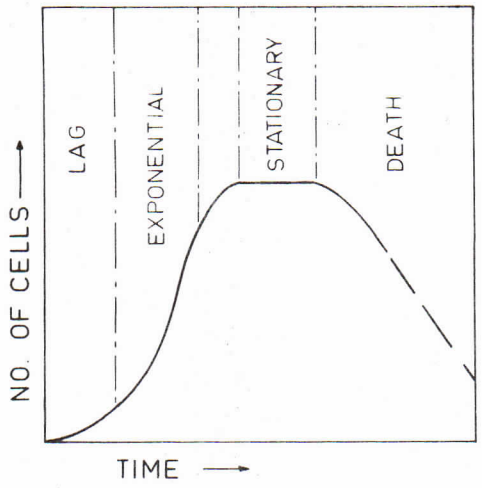


FIGURE 9. TYPICAL GROWTH CURVE FOR BACTERIA IN A CLOSED SYSTEM.

This corresponds to the present growth phase for man where N is the population and μ is a constant for a given environmental situation. Integration of this equation provides:

$$\ln \frac{N}{N_o} = \mu(t-t_o)$$

or by integration of this equation:

$$N = N_o e^{\mu(t-t_o)}$$

This form of relationship, showing an exponential rise in the population, allows one to predict the population N at time t, given the original population N_o at time T_o and the value of the assumed constant μ. For an exponential growth it is often convenient to relate percentage growth to the doubling time, being the time required for the quantity or population to double. Thus, using the

previous equations

$$\text{Percentage Growth Rate} = \left(\frac{dN}{dt}/N\right) \times 100$$

$$= 100\mu$$

$$\text{Doubling Time} = 1/\mu \ln 2$$

$$= \frac{0.693}{\mu} = \frac{69.3}{\text{P.G.R.}}$$

From these relationships it can be seen that the doubling time can be approximately obtained by dividing 70 by the percentage growth rate.

Thus, if we regard the world's population as now being in the exponential phase of development, and it is increasing at the rate of 2% per year, the world population should double in 35 years.

The next phase for cells in a system of predetermined nutrient content is termed the stationary phase. The growth limitation occurs either because the supply of an essential nutrient is exhausted, or because some toxic product of the reproduction process has accumulated to life-inhibiting levels. In the stationary phase, reproduction ceases, but the existing cells remain alive.

The last phase is aptly termed the death phase. Not all but many organisms die and some decay and become no longer recognizable as cells.

The human population has not yet entered these last two phases, but the comparison of our initial growth and conditions with those for other living systems appears to be so similar that the parallel might be tragically appropriate.

Predictions of the World's Population

In order to look into the future it is helpful to review the past. The current population explosion with an overall annual growth rate of 2.0% percent is a phenomenon never before experienced and which will never be experienced again for the reasons already given. Records of human fertility, mortality and population size have only been maintained in the more developed counties during the last 200 years and the information presented earlier results from an analysis of meagre derived data on life expectancy and population size. However, it is certain that earlier populations had a short life expectancy, of the order of 15 to 25 years. From Table 2 it can be seen that this life expectation requires a fertility rate of 8.6 to 5.2 births per woman, respectively, in order to maintain the population at an equilibrium level. Thus, for the entire existance of the human race, with the exception of the last 200 years, all population groups have needed to maintain a high fertility rate in order to survive.

TABLE 2: RELATIONSHIP BETWEEN EXPECTATION OF LIFE AND TOTAL FERTILITY FOR THE MAINTENANCE OF CONSTANT POPULATION

Expectation of Life (from birth - years)	15	17.5	20	25	30	40	50	60	75
Total Fertility (births per woman)	8.6	7.4	6.5	5.2	4.4	3.4	2.8	2.4	2.1

In the last 200 years the mortality rate in the newly termed developed nations decreased dramatically. The life expectancy rose from 35 years to 70 years on the average, but the fertility rates remained at the traditionally high values. The 'developed' countries thus experienced a population explosion with an annual growth rate which increased from 0.4 percent to nearly 1.4 percent in 1910 (representing a decrease in doubling time from 173 years to 53 years). During this period the growth rate for the underdeveloped countries remained substantially constant.

Since 1910 the growth rate for developed nations has oscillated between 0.5 and 1.3 percent and now shows a further tendency to decline. Amongst the reasons given for this decline are the high economic and personal costs of rearing children, the new status of women and the existence of effective birth control and abortion techniques. The underdeveloped nations, on the other hand, are now experiencing their population explosion. The annual growth rate of these underdeveloped nations, representing the majority of the earth's population, has steadily increased from 0.3 percent in the 1920's to the present figure of 2.5 percent as the mortality rate has declined.

One might argue from this historical perspective that, in keeping with the developed countries experience, the fertility rate will decrease in the underdeveloped countries and that the world population eventually will be stabilized. The three obvious questions of importance are: When is this likely to happen?, How will it occur? and What will be the size of the stabilized population? To these questions there are no unconditional answers.

First it should be realized that that demographers have had to be satisfied with accuracies of worse than ± 5% in estimating the existing world population on an annual basis. Even at the 5% level this could mean that 195,000,000 persons are not included in the current estimate of 3.91 billion. Predictions of future population levels and distribution are therefore subject to this inherent uncertainty.

Man has diligently attempted to predict the future from the time of his creation. His success has been limited by his inability to comprehend the combinations of the variables involved, and by his failure to make due allowance for his own ingenuity and stupidity. An example of how inaccurate predictions can be is shown in Table 3, which gives the population predictions for the U.S.A. made on the basis of data available at the time.

With the realization that these predictions were made for a single well-developed country, it is not surprising to find a wide range of estimates for the world population in the year 2000 as exhibited by the 1968 predictions contained in Table 4.

TABLE 3: PREDICTED POPULATION FOR THE U.S. IN MILLIONS
(taken from Figure 3.1, *Resources and Man*)

Prediction Date	Prediction for			
	1970	1980	1990	2000
1920	180	205	225	250
1930	160	170	180	185
1940	150	160	160	165
1950	180	205	225	260
1960	210	250	300	370

TABLE 4: PREDICTED WORLD POPULATION FOR THE YEAR 2000

Basis or Source	Population (Billions)
Constant Fertility, Declining Mortality	7.5
U.N. High	7.0
2% Increase	6.6
U.N. Medium	6.2
U.N. Low	5.4
D.J.Bogue	4.5

At the present time many authorites consider that the population will exceed 7 billion in the year 2000, but even at this late stage this prediction might eventually prove to be hopelessly inaccurate.

There is no reason to believe, however that this lack of precision will provide any pleasant surprises. As William Page notes in *Thinking About the Future*, "the record of population forecasting is not an impressive one, however this century was one in which future populations were underestimated - not overestimated."

The most pessimistic estimate for the future would be based upon the assumption that the current growth rate is maintained at 2% per annum. Under these circumstances Ansley Coale concludes that:

> *"In less than 700 years there would be one person for every square foot on the surface of the earth; in less than 1200 years the human population would outweigh the earth; in less than 6,000 years the mass of humanity would form a sphere expanding at the speed of light."*

Clearly this pessimistic estimate is unreal; Malthusian constraints would prevent such an expansion.

In the population study for the Second Report of the Club of Rome, the effect of introducing an equilibrium policy over a 35 year period is considered for different starting dates; at 1975, 1985, and 1995. It is assumed that the fertility pattern remains unchanged in addition to constant mortality both in terms of pattern and magnitude. The results show that in the year 2,000 the 1975 introduction provides for a population of 6.0 billion as compared to a population of 7.0 billion with constant fertility. The results are, as one would expect more dramatically different over a longer period of time. Stable world populations of approximately 8.0, 9.6 and 12.0 billion are achieved in 2075 by introducing equilibrium policies in 1975, 1985 and 1995 respectively, whereas at constant fertility the world population would be 30.0 billion at this time. There are no signs that an equilibrium policy will be established this year and most authorities concede that the final peak of the world's population will be of the order of 10 to 15 billion.

If a world population of 15.0 billion is achieved and present trends continue, the composition of the world's population will also be fundamentally changed. As North Americans, our percentage of the world's population will decline from approximately 6.0 percent to 2.5 percent. The corresponding percentage for those living in China, India and other South Eastern nations will rise from 54 to 62 percent. Those now living in the developed nations will decrease as a percent of the world's population from 27 percent to 11 percent. This changing balance of the world's population could result in a greater tragedy than the effect of the staggering increase in world population, if national territorial rights are challenged.

REQUIREMENTS FOR LIFE

If we accept that there are no alternatives to life on earth for mankind it is appropriate to consider the limitations of this earth to support human life. They will be the subject of a future study, involving analysis of current thinking, but at this stage it is sufficient to state the obvious: that the world is finite and there is a limit to the total population the world can accommodate, and that as the populations grow, life will become less interesting, less varied and will focus on the basic necessities of life.

Man requires basic protein and vitamin-enriched food providing approximately 2,500 cals/day, a room of prison cell dimensions, water to drink and cleanse his body, and a sink for his wastes. Animals are now raised in this

manner in high density, multi-floored buildings and they appear to be as healthy as their farm-bred predecessors. Only a small fraction of the entire population would be required to provide the necessary services and the remainder would need to be confined to their own housing units for much of their life. Initially, drugs, other artifical stimulants and sensual, visual and audio entertainment might be needed for health reasons, but the population might be expected to eventually adapt to the imposed environment. On this basis with little effort, the earth could confidently be expected to support at least 10 times the predicted population for the year 2000. J.H. Fremlin (1964) suggests that indeed, by exploiting technology, we might increase the world population to 10 million times this population figure.

On the way to this brave new world we would have to utilize every scrap of protein, even that from human excrement and our dead. We would need to completely change the physical face of the earth. The technological achievements required, however, are within our grasp and are probably more comprehensible to us than would be the suggestion of a supersonic jet trip to Malthus.

This is one aspect of the requirements for life. The brave new world concept is repugnant, but valid and demonstratably practical. It is alarming to note, for example, how many persons experience this type of living whether it be on this continent in high density, poorer urban areas or in the underdeveloped, overpopulated areas of the world.

At the other extreme, the requirements for life might be deemed to be those of the North American. These so-called necessities are an abundance of luxury goods, private transportation, individual houses, private land, recreational toys, all-year-round temperature-controlled dwellings, and the right if not the duty to be a waste maker in all senses of the word. At this standard of living the world population has long passed the acceptable level and must be swiftly reduced to at the most 1/10 of the current figure.

It should be obvious that an evaluation of man's requirements for life is meaningless without a prior agreement on the purpose and desirable quality of human life. There is, however, considerable flexibility in determining the optimum population level, provided man is willing to sacrifice both the standard of living and the quality of life in order to accommodate more members of his species.

CONCLUSIONS

The world population is increasing at an exponential rate with a doubling time of approximately 35 years. A further decrease in the doubling time could occur with the decreasing age of puberty and the introduction of better nutritional and health standards in the underdeveloped countries. It has been noted that this exponential increase can be temporarily tolerated if considerable sacrifices are made. However, these will eventually prove to be insufficient. At this stage the Malthusian checks, which currently appear to be inoperative, will probably become effective, and one might anticipate a complete collapse

of the entire structure with little left to enable the survivors to rebuild a human society.

These conclusions relate to what has been termed the population bomb. The bomb is now slowly exploding although in terms of geoloical time this must be viewed as an extremely fast explosive reaction. Madamme Jeanne Sauve said in an opening statement to the 1974 World Population Conference in Romania:

> *"The global problems of food shortages and drought, inflation and disarray in the international monetary system, widespread poverty and intensified pressures on a finite environment seem to have outpaced man's capacity to find solutions."*

She added:

> *"A political conference on population was unthinkable ten years ago, yet hard realities on population trends and prospects have now made political action an imperative."*

It is doubtful whether she realizes how illustrative these phrases are of our incredible reluctance to face reality and take the appropriate actions, particularly at a political level. The first international conference on World Population was held in Rome in 1954 and it also discussed the same global problems. Obviously, its impact upon governments was minimal to the extent that even Madamme Sauve was unaware it had taken place. Thus it is, that we disregard continuing problems until we see them as crises which we then believe might be resolved merely by political action. Julian Huxley[1] in 1956 wrote:

> *"If nothing is done soon world overpopulation will be a fact before the end of the century bringing with it a cargo of misery and selfish struggle, frustration and increasingly desparate problems. It has taken just one decade from Hiroshima for the world to face up resolutely to the implications of atomic war. Can we hope it will take no more than a decade from the 1954 World Population Conference for the world to face up equally resolutely to the implications of world overpopulation?"*

Two decades have now gone by and the precious lead time necessary to defuse the population bomb has been lost.

There is much to be done. Of immediate concern is the plight of the underdeveloped countries. They are the least equipped to support the highest rate of population expansion now occurring. Many authors consider that these nations are beyond help and that the Malthusian constraints of famine and disease should be allowed free reign. On the other hand it is conceivable that before this final stage is reached the gross disparities between the rich and the poor nations could lead to conflict. A nuclear war of global proportions would certainly change the course of the population trend. Other means must be sought, if not for humanitarian reasons, to avoid such catastrophes.

It has been suggested that the best means to check the world population growth is to help the underdeveloped nations to develop to the Western standard. This naive suggestion could have arisen from consideration of Figure 5, but as future lectures will show, this is an impossible dream.

Birth control methods have proven to be effective in influencing family size and consequently population levels in the developed countries, but at the lowest socio-economic levels and in the underdeveloped countries birth control and induced abortion have had little effect. The development of more effective methods, some for the control of whole populations, is still a future hope. Paradoxically these can only be developed by the more affluent nations by sophisticated research and they may not be politically acceptable to the underdeveloped nations, where the need is greatest.

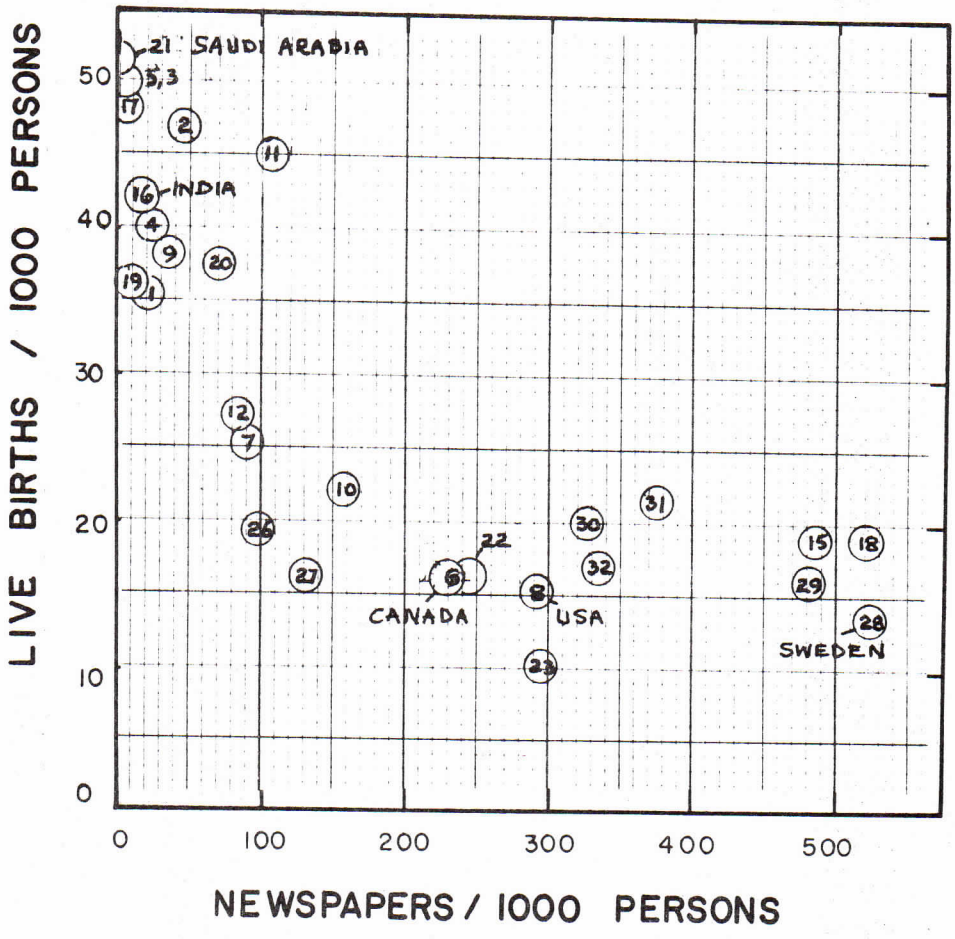


FIGURE 10. BIRTH RATE PLOTTED AGAINST THE NUMBER OF NEWSPAPERS DISTRIBUTED. THIS GRAPH IMPLIES THAT POPULATION CONTROL MAY DEPEND LARGELY UPON EDUCATION OF THE INDIVIDUAL.

So far in our study of population we have neglected the role of the individual. It is well known, for example, that surprise events such as a power failure or an event which wakes a town in the night results in surprise increases in birth rate. Similarly other events such as the Japanese superstition relating to the year of the 'fire horse' cause a marked reduction in the birth rate. These incidents illustrate the indisputable responsibility of the individual and the importance of individual attitudes. Thus the education of the indiviual may be the most effective way to limit the population explosion. An indication of the possible effect may be provided by Figure 10 which relates birth rate to the number of newspapers distributed. If this truly reflects the

influence of education and communication then these factors deserve even more attention than they now receive. The development of radio and television networks in the underdeveloped countries might be the most effective foreign aid the developed nations can provide.

Perhaps, as a final conclusion, we are finding that much maligned Malthus might be vindicated unless his later suggestion of 'moral restraint', encouraged by education, is exercised. It is certain that unless we morally restrain our animal sexual instincts we will need to resign ourselves to an animal-like existence in cages of our own creation to await the day of our eventual extinction.

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