



Hunt Institute for Botanical Documentation
5th Floor, Hunt Library
Carnegie Mellon University
4909 Frew Street
Pittsburgh, PA 15213-3890
Telephone: 412-268-2434
Email: huntinst@andrew.cmu.edu
Web site: www.huntbotanical.org

The Hunt Institute is committed to making its collections accessible for research. We are pleased to offer this digitized item.

Usage guidelines

We have provided this low-resolution, digitized version for research purposes. To inquire about publishing any images from this item, please contact the Institute.

Statement on harmful and offensive content

The Hunt Institute Archives contains hundreds of thousands of pages of historical content, writing and images, created by thousands of individuals connected to the botanical sciences. Due to the wide range of time and social context in which these materials were created, some of the collections contain material that reflect outdated, biased, offensive and possibly violent views, opinions and actions. The Hunt Institute for Botanical Documentation does not endorse the views expressed in these materials, which are inconsistent with our dedication to creating an inclusive, accessible and anti-discriminatory research environment. Archival records are historical documents, and the Hunt Institute keeps such records unaltered to maintain their integrity and to foster accountability for the actions and views of the collections' creators.

Many of the historical collections in the Hunt Institute Archives contain personal correspondence, notes, recollections and opinions, which may contain language, ideas or stereotypes that are offensive or harmful to others. These collections are maintained as records of the individuals involved and do not reflect the views or values of the Hunt Institute for Botanical Documentation or those of Carnegie Mellon University.

About the Institute

The Hunt Institute for Botanical Documentation, a research division of Carnegie Mellon University, specializes in the history of botany and all aspects of plant science and serves the international scientific community through research and documentation. To this end, the Institute acquires and maintains authoritative collections of books, plant images, manuscripts, portraits and data files, and provides publications and other modes of information service. The Institute meets the reference needs of botanists, biologists, historians, conservationists, librarians, bibliographers and the public at large, especially those concerned with any aspect of the North American flora.

Hunt Institute was dedicated in 1961 as the Rachel McMasters Miller Hunt Botanical Library, an international center for bibliographical research and service in the interests of botany and horticulture, as well as a center for the study of all aspects of the history of the plant sciences. By 1971 the Library's activities had so diversified that the name was changed to Hunt Institute for Botanical Documentation. Growth in collections and research projects led to the establishment of four programmatic departments: Archives, Art, Bibliography and the Library.

WORLD FOOD AND POPULATION CRISIS SEMINAR

Reading Assignments for February 11

1. Chapter 20 of Plants, Man and Life by Edgar Anderson - "Rubbish Piles and the Origin of Agriculture"
2. "Tropical Agriculture: A Key to the World Food Crises" BioScience, 19 : 1. Article by H. David Thurston, pp. 29-34.
3. The World Food Problem: A Report of the President's Science Advisory Committee, Vol. 1, pp. 11-24. "Principal Findings and Conclusions"
4. "Population" by Roger Revelle, Science Journal Reprint, October 1967.
5. Population, Evolution, Birth Control, edited by Garrett Hardin, Freeman & Co. First 34 pages.
6. "World Population" by Sir Julian Huxley, Scientific American 194 : 3 reprint, 1956.
7. Williams, George C. (1966) Adaptation and Natural Selection: Chapter 6, Reproductive Physiology and Behavior; Chapter 7, Social Adaptations. Princeton University Press.
8. Harrison, G. A. et al. (1954) Human Biology: Chapter 29, Population Stability. Oxford.
9. Irven De Vore, ed. 1965. Primate Behavior: Chapter 14, The Annual Reproductive Cycle in Monkeys and Apes, by Jane B. Lancaster and Richard B. Lee. Holt, Rinehart and Winston.
10. Eaton, J. W. and A. J. Mayer (1954) Man's Capacity to Reproduce. Human Biology, Vol. 25, No. 3, reprinted by The Free Press, Glencoe, Ill.

11. Geertz, Clifford Agricultural Innovation

12. McNauland; world Food Statement

by Time 1 Oct 1968

15. Megfite, Nathan,
"Ecology of Londonian cities"
Journal of Sociology

16. Stout, Percy. "Power: The Key to
Food Sufficiency in India"
Bull of Atom Sci.
Nov 68

Odell

An Address by Arthur D. Odell, Manager, Isolated Protein Program,
General Mills, Inc., before the General Mills' College Professors
Seminar, Wayzata Country Club, August 16, 1966

In attempting to arrive at a title for this address to you, it occurred to me that perhaps the most apt one would be "Food for Thought". I am particularly pleased to have this opportunity to discuss with your special disciplines the increasingly obvious fact that the length of the food chain between sunlight, oxygen, dissolved nutrients and man's table must be shortened and that this shortening process had better begin with all possible speed. There seems hardly any need to reiterate to this group that an appalling shortage of food already exists in the world and that this situation can only worsen under the present ground rules. Although the total caloric food deficit is bad enough, that of high quality protein is worse by several orders of magnitude. Adequate supplies of high quality dietary protein for the existing world population are either not available at this moment, or cannot be distributed or, paradoxically, are being wasted in wholly unbelievable amounts in those very areas of the world which can least afford to permit this to happen.

Obviously, your disciplines have much to contribute to attempts to solve all three aspects of this problem. It is equally obvious that, if it took man a million years to reach its present population level and if this number is to more than double in the next 35 years, then the shape of this curve is the exponential one which is familiar to all of our guests. I used the expression "more than double" advisedly, since the United Nations has just

recently revised upward the expected world population increase from its current 3.3 billion level to 7.4 billion by the year 2000. Certainly this curve is exponential. At this moment we are well around the upward bend of the curve and approaching the 90° slope. Since an exponential curve means that the system which it is measuring will, unless firm restraining forces are applied, go completely out of control and destroy itself, then the term "population explosion" is justified.

While it is true that some arresting forces are already being applied to population increase, these are not of the controlled, humane type which we should be intelligent enough to impose by ourselves. In everywhere except the most affluent nations, these braking forces are the direct result of the application of those implacable laws of survival which sooner or later apply to all living things. There is no escape, for the lower forms of life, from the rigid requirement that total numbers of population must equate with the available supply of food. For these forms of life, famine, disease and predators are constantly in action and interaction, and are maintaining the required balance. There is no escape for man either, even though up to this point he has been able to delay matters somewhat. Until now, there have always been escape routes for man from high population density. New continents to be opened up, tilled and harvested offered escape from famine by migration to these new lands or by importing foods from them. These escape routes

are now slamming shut with rather sickening thuds. There are very few nations left who have any exportable food surpluses, and one cannot help but wonder if there will be any at all by the year 2000.

There can be no escaping the conclusion that the present and future food supply situation is a very real, very urgent and very present threat to mankind's survival over a large portion of the globe. Man must now face the stark realization that a stable fertility and declining mortality cannot co-exist permanently in a finite universe such as ours. The plain, unvarnished truth is that many people now living are doomed to die prematurely, either directly or indirectly, from the lack of adequate amounts of proper foods. A far greater number, yet to be born, will suffer the same fate. If you question this, pause for a moment and reflect that there are 30,000 new babies every day in India alone and that India now has more children than there are people in the United States. This vast sub-continent, with a total population greater than that of the United States and Soviet Russia combined, has 80% of her people employed in agriculture and yet is literally, as the Wall Street Journal put it last year, living from ship to mouth on imported grains.

It is possible, I suppose, to be callous about this situation and to conclude that, although this is a great pity, at least if they are dead, they will not have to be fed. No one, least of all a group such as this, aware as we are of some of the things which might be done if it were possible, likes to

contemplate such ground rules. Quite simply, the world population is increasing faster than any present or predictable increase in total food supply. However much the layman may like to think so, food science or engineering is not going to find a way out of this mess without the intervention of the controlling action of the natural laws which will inevitably regulate our total numbers.

One could go on in this vein for a long time, but it would serve very little purpose. Before turning to the main theme of this evening, let's take just one last look at the most frightening aspect of the effects of the current world food supply problem, which is only just beginning to receive the degree of attention which it most certainly deserves. The generation which will tip the nutritional scales towards disaster is already here. Avert your faces, if you will, from those children being weaned at this moment who will not survive, and consider those in the emerging nations who will, in enormous numbers, manage to be the young adults of the 1980's. As all of you are aware, the rapidly growing body represented by that of the pre-school child has a very high demand for high quality protein represented by meat, fish, eggs, milk and animal products. The supply of these, and the absolutely essential amino acids which they represent and which are required for adequate physical and mental development are in their very shortest supply in those very countries where the population density of pre-school children is at its greatest.

Even though infant mortality rates in these areas range

from 40-70 times higher than those in the affluent nations, huge numbers of these mal-nourished children will survive, somehow, but will be physically stunted and irrevocably damaged mentally. These survivors will be those who represent a very large segment of the world population by 1985. The political and socio-economic consequences represent a terrifying aspect of future life in this world of ours. No explosion does a great deal of damage unless it is confined. These people are and will be confined by political, ethnic and geographic boundaries. Because of their nutritional history, they can be expected to be ready converts to Marxism or any other ism, however fraudulent it may be, which can be so presented to them as to offer even a partial anodyne to their anguish.

It serves no purpose at all to consider this prospect as one of either academic or humanitarian interest from our current affluent vantage point. Even the most affluent nations will be in deep trouble by the year 2000. Consider for a moment that, left unchecked, the population of the United States will be well over 400 million as opposed to its current 190-odd, and that an entirely new United States will have to be superimposed on the same real estate. Consider also the enormous appetite which freeways, airports, suburban sprawl and all of the other parameters of expansion will have for arable land in this country. Let's remember also that our potable water usage has shot up from 6% of the total available amount in 1900 to 65% at this moment, will approximate 85% by 1980 and that all of the avail-

able above and below ground supply will be under full demand by the year 2000. Drought even now plagues thirteen states on the Eastern seaboard, Lake Erie is now the world's largest open cesspool, which will take at least four billion dollars to begin to correct, and last year the Western Inter-state Water Conference warned that five of the seven great drainage areas of the western states will be developed as far as they can possibly be within the next fifteen years. We may be affluent, but we had better not be complacent.

What are the things which can be done, both immediately and on a longer range basis? Obviously, better fertilization, conservation measures, elimination of wastage and losses are all approaches to which the engineer can make a most worthwhile contribution. In the overall picture, however, no significant progress can or will be made in the newly independent nations until there is an adequate industrial base established which, as you well know, is an enormously complicated task and which will take far more years to accomplish than there are available before a major crisis situation will have developed.

One approach which offers workable relief is that of shortening the food chain. One of the many reasons why there is not enough high quality protein available is the gross inefficiency which is represented by the traditional method of growing animals from vegetable materials and then eventually consuming the animal. A 1,000 pound steer, for example, consumes a lot of forage in 24 hours but gains only one pound in edible protein.

??

recent figure for
chickens +
turkeys:
 $\frac{1}{3} - \frac{1}{2}$ lb food
per lb feed.

This is an efficiency of about 7%. Fowl and hogs do somewhat better, efficiency-wise, but it is still a poor performance. Show an engineer or a chemist a multi-step process with an overall low efficiency and he immediately begins to consider methods of eliminating steps and improving the efficiency. It is such an approach, that of shortening the food chain to man's table, which offers at least a partial solution to future food supplies.

As most of you know, defatted soy meal contains about 50% protein, and this protein is of rather high quality. The soy meal as such is, however, beany, bitter, contains crude fiber and indigestible polysaccharides and is not too attractive for direct consumption by man. By some rather simple process engineering, this 50% protein can be upgraded to over 95% purity, and the resultant isolated soy protein is bland in flavor and totally digestible. The efficiency in such a process is better than 70%, or ten times better than the steer. Attractive, palatable and highly nourishing foods can be made from isolated protein. If it is desired to reproduce the texture, flavor and appearance of familiar foods, this is also possible. The canapes which were served to you before dinner were made directly from soy meal and other ingredients with our friend, the steer, fish and hogs excluded from the process. The ham was not ham, the chicken was not chicken, the seafood never saw the ocean and the beef-like components never saw a cow, unless it was from the other side of the fence around the soybean field.

What we in General Mills and other companies are doing,

as represented by these examples, is to use the 95% soy protein as the basic textural material, after spinning it into edible fibrils by a wet spinning process reminiscent of that used for rayon or nylon, for example. These fine, edible, pure protein fibrils have been combined with other edible materials such as wheat protein, carbohydrates, vegetable fats, food dyes and flavors to produce the products which my colleagues hope that you found acceptable. Since the basic material is vegetable protein and since the manufacturer is in complete charge of the final composition, these foods can, and indeed are being manufactured to meet any ethnic, religious or dietary requirement. All such foods are cooked during manufacture and there are no subsequent losses during preparation for the table. They can be made available in fresh, refrigerated, frozen or dehydrated form. When dehydrated, they need no refrigeration, they can be eaten directly or reconstituted to familiar textures after ten minutes in hot water. The convenience and non-spoiling aspects are obvious. Engineers and chemists have played key roles in this development. Practically all of this technology and the associated hardware is of the new, never-before variety.

Edible fibril production is not limited to soy proteins. The same procedures can be applied to sunflower, safflower, cottonseed, peanut or any other spinnable, edible protein. With further research and subsequent engineering simplification, there are distinct downstream possibilities for production of these foods by local industries in the less favored nations, based on their

indigenous raw materials and flavored to suit the local palate. Here then, is an example of a long stride away from convention, with perhaps a ten-fold increase in efficiency. The economics are very favorable as well, and there is no technical reason why these foods cannot be made to excel animal foods in nutritional quality. Please note that the adjectives, synthetic or imitation, should not be applied to these items. There is nothing synthetic about them! They are totally new textured foods compounded with greater efficiency from classical food materials currently being used in a very inefficient manner. Is bread synthetic, or cake, or corn flakes?

Perhaps the greatest engineering challenge of all in the field of foods for the future is in that enormous, relatively untapped reservoir of high quality protein represented by the oceans that make up 71% of the surface of the globe. I say relatively untapped, since only a pitifully small amount of engineering thought has gone into any type of ocean harvest, and even less engineering thought has been given to the real possibilities for a controlled harvest of the oceans. In this area, a tiny fraction of our defense budget would have miraculous results.

It has been demonstrated in Italy, for example, that one acre of the bottom of a screened off estuary can yield 100,000 pounds of shellfish per year. Compare this with our friend the steer. The food chain in the ocean is long and inefficient also, but at least the total potential is enormous. All fish depend,

ultimately, on the microscopic plankton which undergo population explosions on the surface of the ocean whenever the dissolved nutrients in the lower depths happen to well up to the surface. A pound of halibut on the table represents 1,000 pounds of total input from the food chain of the sea, and a pound of tuna represents closer to 10,000 pounds by the time it reaches our table. Nevertheless, or so it seems to me, inspired engineers, by what I can only describe as minor meddling, could induce the lower strata of nutrients to well up to the ocean surface in carefully mapped areas. Harvesting of the resultant fish in such areas would be relatively easy and predictable. I leave to your imaginations whether this could be achieved by relatively simple heat pumps or some form of the harnessing of atomic energy. For every pound of edible fish harvested today, at least two pounds of so-called trash fish are discarded. This is absurd. Properly processed, either in shore-based installations or on far ranging floating mills, such fish can be converted, economically, into edible, fat-free concentrates of proteins, vitamins and minerals of very high quality indeed. In this case it is necessary, in order to meet the economic requirements, to process the entire fish. This processing can be of such a nature that the product is entirely wholesome. Such an approach also greatly shortens the food chain of the ocean since tiny fish such as the anchovy can be used as the raw material rather than having them climb the inefficient predatory ladder to the tuna. Peru has now built a sizeable industry on this technology, taking

advantage of the Humboldt current which is just off her shores and which is practically a semi-solid river of protein created by the availability of nutrients as a result of natural ocean current. The Peruvian product is designed for animal feeding, but there is no reason why a slightly different approach would not produce an edible product. Reproducing the proper conditions for nutrient availability in the sea is a challenge which engineering can and should meet. Even present day fishing techniques are a wide open field for engineering ingenuity. Until now, commercial fishing has been almost entirely limited to surface nets or bottom trawls. This is also absurd, but no gear has been available to harvest the enormous schools of hake, for example, which inhabit the middle depths. It is encouraging to note that the Bureau of Commercial Fisheries has just developed a mid-water trawl, which is no more than a great sack-like net, which can be trawled at controlled mid-depths. A recent test of this engineering innovation produced 60,000 pounds of hake in one hour.

The subject of the role of the engineer and the chemist in foods of the future is almost inexhaustible. Algae or yeasts grown on commercial wastes have been bandied about quite a bit, radiation preservation of foods and new canning techniques could be discussed, but there is an even greater engineering challenge in the fact that proteins can be produced directly from crude oil, by a process that improves the oil. This is now under development. This approach should prove of great interest to countries with little arable land, no coast lines, but who do have crude

oil. How is this done? Growing and multiplying in the mud around oil wells, or, for that matter, on the sides of asphalt roads, are yeasts and bacteria which use the highly undesirable waxes, or straight chain hydrocarbons, as their energy source. Some of you may have met up with these yeasts and bacteria as producers of the troublesome sediments in refineries and in jet fuel tanks. They can be put usefully to work, and very efficiently. Pilot plant tests have shown that 1,000 pounds of these organisms, placed in a fermentor tank with water and crude oil stock, sparged with air and supplied with ammonium salts, will multiply to 5,000 pounds in 24 hours. This will, at the same time, dewax the crude oil and, when the organisms are harvested and dried, they give rise to a light colored, bland powder consisting of 60-70% of high quality protein with an impressive vitamin content. I have grown tired of referring to these as proteins from petroleum and have invented a name for them - the petro-proteins -- I predict that more will be heard from them before too long.

Finally, I would like to thank you for your attention and express the hope that some of these ideas will set off chain reactions in your minds which will eventually contribute to partial solutions to this extremely grave problem.



PERRY STOUT

Power: The Key to Food Sufficiency in India?

If India's uneasy position as a food-short country is ever to be brought into a permanent status of food sufficiency, and rapid, large-scale improvements in agricultural productivity will have to be effected.

Professor Stout is director of the Kearney Foundation of Soil Science and chairman of the department of soils and plant nutrition, University of California at Davis. He suggests that nuclear energy appears to be the quickest and cheapest means of solving the near-famine situations on the Indo-Gangetic Plain. It points the way toward raising additional grain at a lower cost than the bill for transporting even free wheat from the United States and Canada.

Food sufficiency can be achieved and maintained in India if adequate sources of low-cost energy can be established quickly. But power must be made available to pump water out of the ground for irrigation and to manufacture nitrogen fertilizer. These energy-consuming farm inputs would enable Indian farmers on the populous Indo-Gangetic Plain to grow high-yield cereal grains during the winter dry season, when good lands now lie idle.

With sufficient cheap energy, it is not unreasonable to think of the eventual conversion of 30 million acres of the Gangetic Plain from single to double cropping. The simple facts of plant nutrition, however, dictate that any shift into modern intensive cultivation and high agricultural productivity must be supported by non-farm energy in large amounts. The energy is required principally for the manufacture of fertilizers. In developed countries such as our own, plentiful resources of cheap natural gas, petroleum, and coal supply the energy to mineralize atmospheric nitrogen, process rock phosphate, move water, and provide a multitude of non-farm energy inputs which have been incorporated in our food-producing operations. We in the developed countries are in effect ingesting calories which are made cheaply available to us through the liberal use of fossil fuels by our agricultural industries.

Energy-poor India's industrial sector is still a long way from being able to supply the fertilizers which will be needed to support a greatly expanded agricultural production required for assured food sufficiency. Yet, an examination of the problem on the scene of the Gangetic Plain suggests that our agricultural and power technologies can provide a solution for this indispensable need.

The land is there, and in an all-year growing climate it can be made fertile. But in the winter, it is dry; without irrigation, it can yield only during the monsoon season. Yet, not far below the surface is a high water table, fed by the monsoon and by the snows of the Himalayas. The problem then is to bring power technology into this basic setting in order to achieve intensive cultivation of cereal grains.

First, consider the breakthrough in the development of short-stemmed, rust-resistant, lodging-resistant wheat varieties in Mexico by the Rockefeller Foundation. These strains are tolerant of short days and can be managed so that they will flourish in Indian winter climates.

Their main advantage over local wheat strains is in the mechanical strength of their shorter stems, provided by a gene originating in Japan. Local strains have weak stems which cannot support the grain heads when growth is forced to higher levels through irrigation and fertilization. Consequently, the indigenous varieties are said to be unresponsive to methods of intensive cultivation because of heavy losses which occur from lodging—that is, mechanical failure of their tall, thin stems. But the new short-stemmed wheats keep the grain

head off the ground so that it is inaccessible to rodents.

Although a great many wheat varieties can be successfully cultivated to provide analogous amounts of grain per acre in localities other than those where they originate, the Mexican varieties happen to be the ones which have proved adaptable to India's winter, with its short days and warm weather. While Indian varieties are disease-resistant and adapted to low soil fertility, the consequences of their stem weakness make the Mexican varieties a better choice. Their use is expanding rapidly and may reach 20 million acres planted by next year.

FERTILIZER AND WATER

The high yields of the Mexican wheat can be realized, however, only with high rates of fertilization, particularly with nitrogen, and with a water supply that can be timed to the critical growth stages of seeding, tillering, and heading. Under these conditions, production rewards can be very great. Controlled field test plots on the Gangetic Plain have demonstrated ten-fold increases in yield over unfertilized, indigenous varieties. But without special care, fertilization, and irrigation, these new varieties may not yield as well as the long-established, indigenous ones. These facts dictate plainly that new energy sources must be created so that water and fertilizer can be provided to meet the requirements of the new, "high-yield" varieties.

Nuclear energy appears to be the quickest and cheapest means of providing electrical power for the manufacture of nitrogen and pumping of ground water. Power levels would have to approach the energy inputs required by intensive cultivation practices in the world's food-sufficient, industrialized nations.

Advances in nuclear reactor engineering and lower costs of uranium fuel are dropping the cost of electrical power to levels where it becomes economical for making nitrogen fertilizers in regions that are short of fossil fuels.

Cheaper power also opens the way for electro-furnace reduction of low-grade, phosphate rock. Subsequent processing to phosphatic fertilizer can also produce some hydrogen, which integrates well with ammonia manufacture. To achieve a feasible power cost level, however, the energy has to come from very large generating units of 10^6 kilowatts. This puts a lower limit on the size of the area to be served by even a single, large reactor. Power requirements for intensive cultivation on the Gangetic Plain, however, are large enough to absorb the full reactor output effectively and profitably. Moreover, the general level of education and industrial activity in the region allows for the orderly establishment and expansion of agro-industrial enterprise. Here we find a bonus in the early emphasis India has placed on encouraging the development of small industry.

In the Gangetic Plain, power from a single 10^6 kilowatt nuclear reactor applied to food production can make the difference between nothing and the full food

needs of approximately 40 million people. At the same time, it can provide the additional energy for agriculturally-related industries required to produce and maintain farm implements, manufacture pumps and motors, process the food, and serve transportation and communication.

THE REQUIREMENTS

Some idea of energy needs can be arrived at directly from basic knowledge of plant nutrition. The extra amount of mineralized nitrogen that an additional crop increment requires is approximately three per cent of the weight of the grain to be harvested. The energy required to manufacture the nitrogen is nearly 10 per cent of the caloric energy contained in the harvestable grain.

Where phosphorous and sulfur are needed, the inputs can increase to 20 per cent or more of the caloric energy the grain furnishes as food.

In considering the conversion of croplands on the Gangetic Plain from single to double cropping, it is reasonable to figure on a fertilization rate of 100 pounds of nitrogen per acre. It takes about five kilowatt hours of energy equivalent to make a pound of nitrogen fixed as ammonia. Thus, for the 30 million acres which might be irrigated by pumps for a second crop, the annual energy requirement to make the fertilizer is 15 billion kilowatt hours (1.5×10^{10}). In 1964-65, India's electric power consumption was 24 billion kilowatt hours.

Here we can see an underlying reason why developing countries are generally short of food. Their basic energy resources are often concentrated on industrial development at the expense of agricultural needs. Consequently, as in India today, cherished plans for building industrial strength are postponed by periodic crises, frequently food crises. Then food imports suddenly take priority over ball bearings and other hardware which are critical to the expanding industrial complex.

As a result, neither agriculture nor industry moves forward as well as they might if food production problems were solved. In developing countries, if agriculture does not receive a priority, it often declines to lower per capita levels of production.

In 1965-67, the famine conditions in India centered in the Gangetic Plain. How could famine stalk a region so similar in climate and geophysical aspects to the productive San Joaquin Valley in California? A principal reason, of course, in India's desperate lack of power resources. Bullock or human muscle power are not enough to lift drainage water or to irrigate from wells. Nor could the fields have been fertilized even if water had been made available.

ELECTRICITY PREFERRED

The Indian farmer is receptive to rural electrification. He is quick to buy electricity when he can get it to operate his well. It is the preferred form of energy

because electric motors are easier to build, operate, maintain, and repair than diesel or gasoline engines.

It is apparent that cultivators would be eager to tap a large block of new power on the Plain. The one million kilowatt reactor would make it possible to pump enough water out of the ground and make sufficient fertilizer to grow an extra crop on 4.7 million acres in the state of Uttar Pradesh alone. This acreage would be under "assured irrigation." This means it would get water when needed and in the required amounts. In India, the term "irrigated land" does not carry this guarantee; it may refer to areas that receive too much or too little water.

The effect of applying nuclear power technology to this acreage would be analogous to adding the same number of acres to the nation's agricultural economy. The 4.7 million acres suggested for intensive cultivation and second cropping from the power of a million kilowatt reactor represent but one-fourth of the 19 million sown acres in Uttar Pradesh which lie in the 30-to-45-inch rainfall belt. It is estimated that the extra winter wheat crop would yield 50 bushels or 3,000 pounds per acre. Eventually, as cultivators gained experience, that yield could be increased. Indeed, this past year some individual cultivators obtained yields of 5,000 and 6,000 pounds.

At the more conservative 3,000 pounds per acre, the total yield of the extra crop would be 14 billion pounds (1.4×10^{10}). It would provide an extra 152 pounds of grain per person for 92.4 million people, the estimated population of Uttar Pradesh in 1971. It would be enough to make the difference between near starvation and a full stomach.

If that amount of grain had to be purchased from other Indian states, it would cost \$741 million at wholesale wheat prices of 5.3 cents a pound. Even if the wheat were donated by the United States, the shipping costs would be \$69.5 million in foreign exchange. Famines are expensive.

The energy required for pumping water for the 4.7 million acres and for manufacturing the fertilizer the extra crop would require would use up to 70 per cent of the reactor's annual capacity of 8.76 billion kilowatt hours (8.76×10^9). The projected cost of energy from a million kilowatt nuclear reactor is 3.31 mills per kilowatt hour. On this basis, the reactor cost for water and nitrogen would amount to \$20.4 million a year.

In this light, the reactor as a famine relief measure would be cheap, since the cost of its operation for agriculture would be only 28 per cent of shipping charges on the same amount of donated wheat from the United States.

The production of nitrogen fertilizer would be based on the electrolytic reduction of water to obtain hydrogen for fixing nitrogen. In developed countries, this process is considered archaic because supplies of fossil fuels and hydrocarbons are plentiful and cheap. But

they are neither plentiful nor cheap on the upper Gangetic Plain.

In India, the cost of fixed nitrogen is relatively high, as much as 16 cents a pound. The power cost for the hydrogen needed to fix one pound of nitrogen begins at 1.7 cents, if nuclear power costs 3.3 mills per kilowatt hour. However, when the fertilizer plant takes off-peak loads from the reactor, the power cost would drop to less than one cent a pound.

POWER SHORTAGE

Since there are no nearby sources of fossil fuels on the Gangetic Plain, nuclear power appears to be the cheapest, quickest way of producing nitrogen fertilizers at a reasonable cost in sufficient quantity. But adverse views are already established regarding nitrogen fixation by the electrolytic method as a result of the experience with the Bhakra Dam on the Sutlej River. Some of the power from this project is being used to produce electrolytic hydrogen of a fertilizer plant. Competing demands for the power have made the plant a bone of contention. The critics contend that the plant is running at a loss and the government is making it up to maintain fertilizer production.

This conflict is a natural outgrowth of the general power shortage which has reached the point where newly dug wells which are wired for electricity cannot function. In Uttar Pradesh, 215 of 4,021 state tube wells drilled during successive five-year plans have not been energized.

Abundant nuclear electric energy would solve the power problem and its limitation on intensive cultivation. One reactor, providing power for irrigation and for the manufacture of 352,000 tons of fixed nitrogen, makes it possible to grow an additional 12.3 million tons of food grain. Two such units serving the alluvial Gangetic soils would be sufficient to fill India's estimated 1973 gap in food grain of 23 million tons. A third unit, added by 1978, a fourth in 1983, and a fifth in 1988 would be required to keep the gap closed. A sixth unit by 1990 would fill the minimum shortage, predicted for that time, of 72 million tons.

The proposal for a power unit of one million kilowatts to raise an extra wheat crop of 4.7 million acres is only a beginning. In Uttar Pradesh, there are 41.7 million acres in crop production, of which 30 million might be double cropped. In the climate of this land, it is possible to grow not only two but three and four crops in a single year—if power is available.

India's prospect for food sufficiency is entirely visible at this time. This could not have been said with confidence as little as two years ago. But now 20 years of prior research in agriculture and nuclear power can be intermeshed in such a way that prior expressions of hopelessness give way to optimism. The question remains: can sufficient power generators be brought into action fast enough?

Proteins From Petroleum

The microbial approach to the synthesis of proteins from hydrocarbons is being intensely studied by many companies throughout the world.

Process economics will be improved when current engineering problems are solved.

DANIEL I. C. WANG, *Massachusetts Institute of Technology*

In his search for food, modern man is now looking beyond agriculture and beyond animal breeding and fish harvesting. His next meal, if he has his way, will probably come from natural gas, normal paraffins, or gas-oil or other petroleum fractions. His idea is not too far-fetched:

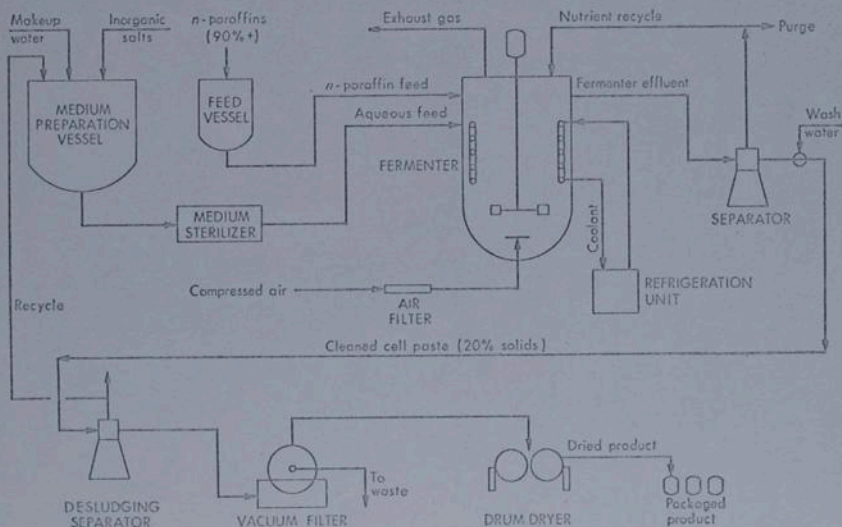
The possible commercial production of proteins from petroleum is based in principle on the same microbial or bacterial approach that the yeast industry has been following for years in making protein-rich single-cell products such as baker's yeast and animal feed supplements. In fact, the current research effort is focused on replacing carbohydrates (e.g., beet and cane

molasses) with hydrocarbons that can act as substrates for single-cell growth.*

There are many reasons that make the protein-from-petroleum scheme so attractive. A production facility, for example, would be independent of such factors as geographic location, climate, and labor availability. Thus, a large-scale protein-production plant could operate even in a desert, and could be run by a small staff of trained personnel.

The scheme also makes sense if one considers that the rate of single-cell reproduction is far greater than that of most animals and plants. Indeed, bacteria and

*Bacteria and yeasts are both single-cell organisms. The main difference between bacteria and yeasts is in the classification scheme as proposed in determinative bacteriology. For further information, see "Clearing the Scene," p. 158 of this issue.



SCHEMATIC REPRESENTATION of a continuous, single-cell, protein-production process from petroleum.

yeasts that feed on hydrocarbons are capable of doubling their weight in 3 to 5 hours, whereas plants like soybeans require as much as 1 to 2 weeks, and animals such as chickens 2 to 4 weeks—not to speak of cattle, which require 2 to 4 months to double their weight. Aside from the rate of weight increase, the total land requirement for single-cell protein production would be a small fraction of that needed for agricultural or animal farming.

Before large-scale commercialization becomes a reality, however, many engineering problems will have to be solved. Some progress has already been made and, in reviewing the current state of the art, I shall begin by considering the basic nutritional, microbiological and engineering factors involved in producing

single-cell proteins from petroleum substrates. In the latter part of this article, the engineering aspects will be explored in more detail.

Single-Cell Composition

The protein content of single cells should be quantitatively high—so that their bulk will be suitable for human consumption or animal-feed supplements—and it should be of good quality in terms of the amino acid distribution. The index that indicates protein quality is often expressed in terms of the essential amino acid content of the protein; Table I shows, for example, that the over-all composition of single cells cultivated on hydrocarbon substrates is not very

Commercial and Research Activities

The worldwide "protein gap"—estimated at a minimum of 2.34 million tons of animal protein and 1.45 million tons of legume-type proteins by 1970*—has spurred an intense interest into the possibility of producing proteins from petroleum. And many organizations are already active in this field.

HERBERT FINEBERG, *Director of Project Analysis, Ashland Chemical Co., division of Ashland Oil & Refining Co.*

Patents on proteins from petroleum have been issued to a number of European groups such as Technische Hochschule, in Switzerland, Farbenfabriken Bayer AG in Germany, and Czechoslovakia Akad. Ved. (Academy of Science); and studies have been published by the National University of Korea; the Ernst-Moritz-Arndt University in Germany, and organizations in East Germany, Holland and Austria. (The U.S.S.R. already claims to have at least one 15-ton/day plant in operation.)

Of all the firms engaged in this type of work, British Petroleum Corp. (BP)—which has carried out extensive animal-feeding studies for several years—may probably be the first to reach large-scale production of "petroproteins" in the Free World. In fact, at its large pilot plant in Scotland, BP has been producing proteins from *n*-paraffins and yeasts, and is now building a 1-ton/day pilot plant in India—where Institut Français des Pétroles (IFP) is already operating a 1-ton/day pilot unit. Initial production plans of BP and IFP are apparently aimed at animal-feed supplements; but both companies, along with Gulf Oil, Chevron, Esso, Nestlé, Chinese Petroleum Corp., and others, are also investigating the nutritional potential of petroproteins for human consumption.

The Competitive Picture

It is still too early to detect which of the two grades (50% or 70% protein content) now being produced will be more acceptable on a commercial basis. As animal-feed supplements, the products seem satisfactory. For human consumption, however, petroproteins may need further amino acid supplements (i.e., methionine, tryptophane, cysteine and isoleucine); and im-

provements in protein-efficiency ratios, compositions and digestibility have yet to be worked out. If the past is any judge, these could be major time holdups, particularly in view of the fact that certainly one of the prime requirements is the acceptance by governments and health authorities.

The petroprotein market does not look promising for many years to come in the U. S., where soybean meal (animal feed grade) at \$76/ton already competes against the \$100/ton price of yeast protein (50% protein). On a contained protein basis, soybean meal is under 9¢/lb., and yeast protein over 11¢/lb. Quite possibly, the current average U.S. soy yield per acre—already equivalent to a respectable 1,200 lb. of 44% protein—could be doubled by better cultivation in this country, thus tending to depress soybean prices even further as well as boost supplies very quickly. From a cost viewpoint, therefore, it seems that petroproteins have some way to go before being competitive in animal feed, and a long way before being a factor in human foods.

Under some conditions, animal-feed usage may not be more than ten years away in some areas of the world. But it is conceivable that before that time some of the oil-rich, dollar-short, controlled-economy countries might be tempted to install the sophisticated and expensive chemical complexes needed to make the nutrients as well as the petroproteins; and then, they might still need a large agriculture to maintain and process the animals to be fed.

If all the arable land in the world were as productive as U.S. land, it would yield 95 billion lb. of animal proteins and 270 billion lb. of vegetable and cereal proteins—just about enough to feed the world in the year 2,000. However, as it is generally believed that the biggest problems of increasing land output will be cost

* Quentin M. West, *World Food Needs*, Agricultural Research Institute Proceedings, Oct. 18-19, 1966.

different from that obtained with carbohydrate substrates, and is comparable to that of vegetable proteins.

From Table I, which compiles the amino acid distribution in single cells produced from various hydrocarbons, it can be seen that proteins from hydrocarbon-grown single cells are comparable to proteins from cottonseed and soybean oil-meals—as well as to the 1957 Food and Agricultural Organization (FAO) standard-reference protein. Thus, from nutritional considerations, single-cell proteins have definite potential as food or feed supplements.

Whether the substrate chosen is a gaseous hydrocarbon such as methane, or a liquid such as gas-oil or *n*-paraffins, depends on many factors—e.g., the

ability of a single-cell organism to consume the substrate, the product yield per unit weight of substrate, the oxygen requirement of the substrate; as well as heat production, ease of purification, and cost of the substrate.

Methane Substrate

As the sole carbon source for growing single-cell organisms, methane has a number of advantages—not only because of its relatively low cost, but also because of the easiness of purification of the single cells once the fermentation is completed. (Purification is more of a problem with liquid hydrocarbon substrates.)

(i.e., capital) and timing; and the worldwide rate of adoption of sophisticated cultivation methods and processing technology will not be high enough.

Thus, although the protein-from-petroleum concept entails many uncertainties about raw materials, technology, economics and competitive factors, it seems to be going in favorable directions. There is certainly a great deal of optimism and a vast amount of competitive R&D activity among the oil and process companies.

By 1970, over 70% of the world's population is expected to be living in the major diet-deficient areas—Central and South America, Africa, Asia, India and Communist China. Since many of these areas have the lowest-cost gas and oil supplies, and the labor is cheap, various governments will have to spend to find out if they can narrow the "protein gap" in time.

The whole field is exciting and deserves to be researched in greater depth.

United States	Type of Activity	Foreign Countries	Type of Activity
Esso Research & Engineering (Standard Oil of New Jersey)	Laboratory and pilot plant—joint venture with Nestlé; purified normal alkanes (C ₁₀ -C ₂₀) substrate, bacteria and yeasts.	British Petroleum (France, England, India, Nigeria)	Pilot plant and plant—yeasts mainly, gas-oil substrate, probably furthest advanced of all—some work with methane and C ₂ hydrocarbons.
Gulf Oil	Laboratory and pilot plant—liquid hydrocarbons, yeasts mainly, product-development phase.	Institut Francais des Petroles (France, India, Nigeria)	Pilot plant—paraffins and crude oils, yeasts and bacteria.
Shell Oil (U.S. & England)	Laboratory—methane substrate, bacteria and yeasts.	Shell Research Ltd. (England)	Laboratory—methane, bacteria.
Mobil Oil	Laboratory—liquid normal paraffins up to C ₂₀ ; bacteria.	Regional Research Laboratory (India)	Pilot plant—gas-oil, yeasts.
Phillips Petroleum	Laboratory — solid -paraffins yeasts.	Imperial Chemical Industries (England)	Laboratory—natural gas, oil.
Chevron Research (Standard Oil of California)	Laboratory—liquid normal paraffins (C ₁₀ -C ₂₀), bacteria.	U.S.S.R.	Pilot plants and plants—crude oil, natural gas, <i>n</i> -paraffins, yeasts.
Standard Oil of Indiana	Laboratory.	Japan—Kyowa Hakko Kogyo Dainippon Ink Kanegafuchi	Pilot plant and laboratory—yeasts, bacteria, <i>n</i> -paraffins, crude-oil plant scheduled.
Sun Oil	Laboratory.	Chinese Petroleum Corp. (Taiwan)	Laboratory—crude oil, yeasts.
The Institute of Gas Technology	Laboratory—methane, yeasts and bacteria.		
Massachusetts Institute of Technology	Laboratory and pilot plant—processing methods and use in human foods.		
U.S. Bureau of Mines, Coal Research Laboratory	Laboratory — Fischer-Tropsch synthetic liquids from coal, yeasts.		

Microorganisms capable of oxidizing methane to produce cellular matter are bacteria such as *Pseudomonas methanotrophica*,¹² *Methylococcus capsulatus*,¹³ *Pseudomonas methanica*,¹⁴ as well as some unidentified organisms.^{4, 15, 16}

Chemical requirements for growing single cells on methane are straightforward: a typical medium for supporting growth would contain NH_4^+ , K^+ , Mg^{+2} , PO_4^{-3} , SO_4^{-2} , Cl^- and other trace mineral salts, with a gas mixture of methane and oxygen fed through mechanical agitation into the fermenter. The partial pressures of oxygen and methane would be sufficiently high so that the dissolved liquid concentrations in the broths do not limit growth.

In mixtures such as just mentioned above, precautionary measures should obviously be taken to maintain the composition of the mixture below the explosion and flammability limits.

Pertinent microbiological data are the growth temperature (which must be controlled because bacterial growth is exothermic in nature), the growth rate, and

—what is very important to the economics of the process—the efficiency of conversion expressed in terms of cell yields.

From Table III, it can be seen that methane-oxidizing bacteria can grow in a 25 to 50 C. temperature range; and growth rates, in terms of the doubling-time of bacteria, are sufficiently rapid to permit a technically feasible large-scale process.

The yield of cellular material produced per unit weight of substrate is the most important microbiological feature: an ideal organism would be one that could convert 100% of the substrate carbon to cellular carbon; but in practice, a large fraction of the substrate is converted to CO_2 , and over-all yields are lower, as shown in Table III.

Although much has been published on the use of methane with microorganisms, yield data are scarce. The recently reported cell-yields, defined as the grams of cells produced per gram of methane consumed, are in the 0.50 to 1.07 range^{15, 16}—though the latter figure is probably in error because the investigators¹⁵ re-

Over-all composition of single-cell proteins and other vegetable proteins—Table I

Type of Protein	Substrate	Protein %	Fat %	Carbohydrate %	Ash %	Cube Fiber %	Reference
Bacteria	Carbohydrate	40-80	1-30	10-30	1-4	—	3
Bacteria	Methane	59.2	6	—	—	—	4
Bacteria	n-paraffin	62-73	10-15	10	6-12	—	5
Bacteria	n-paraffin	65	8.1	—	6	—	6
Bacteria	Gas-oil	70.5	0.45	—	7.9	—	6
Bacteria	Carbohydrate	40-50	1-2	32-40	6-10	up to 10	3
Baker's yeast	Sulfite liquor	47	4.8	32	9.1	0.82	7
Torula yeast	n-paraffin	54	10	26	10	—	—
Yeast	n-paraffin	43.6	18.5	21.9	4.43	—	8
Yeast	n-paraffin	40-50	1-2	12-20	6-12	—	9
Yeast	Gas-oil	37-53	15-23	3-12	4-6	4-7	10
Soybean meal	—	39-50	3.5-9.9	23.4-34.5	5.1-8.8	7.3-15.5	11
Cottonseed meal	—	—	—	—	—	—	—

Amino acid distribution in various types of proteins^c—Table II

Source of Protein	Substrate	Cystine	Isoleucine	Leucine	Lysine	Methionine	Phenylalanine	Threonine	Tryptophane	Valine	Ref.
Bacteria	Methane	—	—	9.1	5.3	3.4	6.2	4.5	—	8.5	4
Bacteria	n-paraffin	0.6	3.6	5.6	6.5	2.0	2.9	4.0	0.9	3.5	5
Bacteria	n-paraffin	1.1	4.5	7.0	7.0	1.8	7.4	4.9	1.4	5.4	6
Bacteria	Gas-oil	0.9	5.3	7.8	7.8	1.6	4.8	5.4	1.3	5.8	6
Yeast	n-paraffin	—	3.6	5.9	7.0	1.2	3.7	3.9	0.5	4.0	5
Yeast	Gas-oil	—	5.1	7.0	6.8	1.3	5.1	5.6	2.3	5.0	9
Soybean meal	—	1.2	5.8	7.6	6.6	1.1	4.8	3.9	1.2	5.2	10
Cottonseed meal	—	—	4.0	6.2	4.2	1.5	5.2	3.5	1.6	5.0	11
FAO	—	2.0	4.2	4.8	4.2	2.2	2.8	2.8	1.4	4.2	—

^a Amino acids are expressed as % of crude protein

Microbiological characteristics of single cells from methane—Table III

Organisms	Cultivation Temperature (C.)	Doubling* Time, T_D (hr.)	Cell Yield on Substrate ($\frac{\text{g. cell}}{\text{g. CH}_4}$)	Cell Yield on Oxygen ($\frac{\text{g. cell}}{\text{g. O}_2}$)	Reference
Mixed culture (2-bacterial species)	25	3.5	0.6	0.2	4
Methanomonas	28	6.28	—	—	17
Unidentified	—	—	0.5	—	15
Methylococcus	30	13	—	—	13
Methylococcus copiosus	37	3.5-5.0	1.07†	0.92†	13
	50	6.5	—	—	13

* Doubling time, T_D , defined as the time required for the organism to double in cell mass.
† Data may be in error, see text.

ported more carbon produced than was available in the substrate. Actually, a cell yield of about 0.60 is a more realistic number to use for process calculations.

The use of cellular yield alone, however, is not completely justified as a comparative economic index because a carbohydrate—which is already partially oxidized (its sub-unit is $[\text{CH}_2\text{O}]_n$)—does not require as much oxygen as methane substrates. In fact, the cell-yield with a carbohydrate substrate ranges from 0.8 to 1.0 g. of cell/g. of oxygen consumed, whereas with a methane substrate the cell-yield is about 0.2 g. cell/g. O_2 —which indicates an oxygen consumption nearly four to five times greater than that of carbohydrates. This greater demand requires the expense of mechanical agitation, which ultimately reflects in the capital investment that is necessary and in the increased operating costs.

Thus, although a methane substrate is an inexpensive material for the production of single-cell proteins having a good amino acid distribution, other considerations such as oxygen requirements and heat-disposal problems may offset the advantages of methane. But we shall say more about this later in the sections ahead.

n-Paraffin or Gas-Oil Substrates

Straight-chain hydrocarbons (*n*-alkanes), usually obtained from petroleum distillates, contain a high fraction of C_{10} through C_{30} *n*-paraffins (90%+) and a small fraction (less than 10%) of isoparaffins, cyclic paraffins and naphthenes. This small fraction cannot be assimilated by microorganisms. Even if a 90%+ *n*-alkane fraction were to be used, the cost of single-cell protein production would increase significantly because of the requirement of an initial separation process.

The other liquid petroleum fraction that has been proposed as a potential substrate is gas-oil, often defined as the component that distills between diesel fuel and lubricating oil. It contains a high fraction

of paraffinic materials that, as waxes, adversely affect the pour point and cloud point of the fraction; usually, a separate unit process, such as solvent-dewaxing or low-temperature crystallization, is necessary to get rid of these waxy paraffins.

It has been found, however, that microorganisms capable of using pure normal paraffins can also attack these waxy compounds in gas-oil fractions. It is thus possible to obtain dewaxed gas-oil and single-cell proteins by the use of this versatile microbiological approach.

Many different microorganisms have been reported to be able to grow on liquid hydrocarbon substrates. (Unlike methane, *n*-paraffins can be attacked by molds, yeasts and bacteria, though most of the studies reported in the literature have been devoted to the production of yeasts.) The other major chemical nutrients necessary for cell reproduction include: NH_4^+ , K^+ , Mg^{+2} , Cl^- , SO_4^{-2} , PO_4^{-3} , and trace salts. Oxygen must also be supplied to the cells, both by direct sparging and, indirectly, through some adequate mechanical means.

Table IV summarizes some of the pertinent microbiological characteristics of single cells grown on various hydrocarbons. It can be seen that yeast cultivated on *n*-paraffins will yield from 0.8 to 1.1 g. of dry cell/g. of substrate. This efficiency of conversion is somewhat higher than for organisms grown on methane or carbohydrates. (But the temperature for yeast cultivation is usually near 30 C., which is somewhat discouraging for heat-transfer efficiency; even at such a temperature as 30 C., mechanical refrigeration may be necessary to remove the heat evolved during fermentation.) The growth rates of single-cell organisms on *n*-paraffins are sufficiently high for large-scale operations; and doubling times are of the same magnitude as those encountered in present commercial yeast manufacturing.

Again, the oxygen requirement for yeast grown on *n*-paraffins is much higher than that for yeast on carbohydrate. This 2.5 to 3-fold increase in oxygen demand will inevitably be a problem in terms of the

Microbiological characteristics of single cells produced from normal paraffin (NP) and gas-oils—Table IV

Organism	Substrate Used	Cultivation Temperature (C.)	Doubling Time (hr.)	Cell Yield on Substrate (g. cell/g. substrate)	Cell Yield on Oxygen (g. cell/g. O ₂)	Reference
<i>Torulopsis</i> sp.	NP (C ₁₄ -C ₁₈)	30	7	0.72	0.29	18
<i>Candida intermedia</i>	NP (C ₁₄ -C ₁₈)	30	4.5-6.5	0.81	0.35	19
<i>Candida intermedia</i>	NP	32-38	4.3	0.87	0.36-0.39	9
<i>Candida lipolytica</i>	NP	32-38	3.85	1.02	0.36-0.39	9
Yeast	NP (C ₁₄ -C ₁₈)	32-38	—	0.94-1.08	0.36-0.39	9
<i>Pseudomonas</i> sp.	NP (C ₁₄)	—	—	1.03	0.5	20
<i>Micrococcus cerificans</i>	C ₁₈	30	1.4	1.30	1.12	21
<i>Micrococcus cerificans</i>	C ₁₈	30	2.6	1.13	0.78	21
Yeast	Gas-oil (32% NP)	30	—	0.8	—	9
<i>Candida</i> sp.	Gas-oil (12.7-18.1% NP)	30	4.0-9.3	0.73-0.96	—	22

Oxygen transfer rates for single-cell production—Table V

Substrate	Doubling Time (hr.)	Cell Concentration (g. cell/liter)	Oxygen Required (g. O ₂ /g. cell)	Oxygen Transfer (g. Mole O ₂ /liter-hr.)
Carbohydrate	3	15	1.0	108
Methane	3	15	5.0	540
n-Alkane	3	15	3.3	356
Gas-oil				

mass-transfer (O₂) ability of the fermentation equipment.

From a nutritional, microbiological or engineering point of view, there is no real advantage in selecting a yeast over a bacterium for producing single-cell proteins. In certain respects, bacteria may have some inherent advantages over yeast. For example, it has already been shown that the protein content of bacterial cells is, as a rule, higher than that of the yeast cells.

In addition, as the data in Table IV show, several species of bacteria (*Pseudomonas* and *Micrococcus*) have extremely favorable yield based on the substrate consumed and the oxygen required. Both of these facts would be economically important since higher substrate yield and lower oxygen demand would decrease both raw-material and operating costs. (Table IV also presents data on the use of gas-oil as substrate.)

It should be mentioned, that in general, there seems to be no detrimental effect of gas-oil on the growth rate of the organism. In many instances, however, the fat content of the cells grown on gas-oils have been found to be higher than with purified n-alkane substrates.

What the Process Looks Like

At this point, a brief description of a typical process scheme for continuous production of a single-cell

protein (see figure, p. 99) will serve as introduction to some of the engineering aspects that will be discussed subsequently.

An aqueous feed containing the necessary inorganic nutrient such as nitrogen, potassium, sulfur, phosphorus and other trace mineral salts is mixed in a medium-preparation vessel. A portion of the water for this feed comes from the effluent of the second dedusting stage. The feed is then metered either directly, or after sterilization, to the cell-production fermenter.

It would certainly be economically desirable to eliminate the medium sterilization step because this would reduce the capital investment cost of the sterilization equipment as well as utility and operating costs. But there are various factors to consider, such as the type and number of the natural microbial flora in the process water, operating conditions within the fermenter, and over-all plant sanitation.

The other major liquid feed to the cell-production fermenter is the paraffinic feedstock, which is metered at an absolute value dictated by the growth rate of the organism and the desired cell concentration in the fermenter. (It is assumed that a purified 90%+ normal paraffin will be used.)

Compressed air, sterilized by depth filtration through fibrous filters, serves as a reliable and economical supply of oxygen to the growing cells; it also serves as a sink for heat removal via evaporative cooling. (Spent

air containing gaseous CO_2 , a product of cell growth, is then exhausted from the fermenter.)

The heart of the entire process is the fermenter. The productivity of any fermenter is defined as dry weight of cell produced per unit fermenter volume per unit time. Generally, for the production of cell mass, maximum cell productivity is desired. It has been shown theoretically and experimentally that a continuous fermenter has a far greater productivity than a batch fermenter, that it is easier to control, and that it produces single-cell proteins of more uniform composition.

The growth of single cells is an autolytic process. Therefore, the exponential growth rate can be maintained—provided the concentrations of all nutrients are kept above their respective critical values in the fermenting brew. Actually, a continuous fermentation is analogous to a perfectly mixed continuous-flow reactor performing a first-order autolytic chemical reaction. The residence time, generally expressed as the reciprocal of the growth rate, has a typical range of 3 to 6 hr. This would correspond to growth rates of 0.33 to 0.16 reciprocal hr. and doubling times of 2.1 to 4.3 hr., respectively. Here, the doubling time is defined as the time required for an organism to double in its cell mass.

The ratio of the paraffin to aqueous feedrates should be maintained as high as possible; assuming that all other nutrients, including oxygen, are in excess, this ratio at a given growth rate will dictate the concentration of the single-cell protein in the fermentation unit. The productivity defined previously is obviously the product of the exit cell concentration multiplied by the total feedrate and divided by the reactor volume. Since the maximum growth rate (feedrate divided by fermenter volume) for an organism is governed by the physiological makeup of the cell, one can only increase the cell concentration in order to maximize productivity. Typical cell concentrations that can be expected are in a range of 10 to 35 g. of dry cell per liter of fermenting brew (1 to 3.5% dry weight).

The temperature during fermentation must be kept constant by continuously removing the heat evolved from paraffin oxidation. What this temperature is depends on the organism being cultivated. For example, yeasts on *n*-paraffin substrates usually have an optimum growth temperature of about 30 C., whereas some strains of thermophilic alkane-oxidizing bacteria are capable of growth at temperatures as high as 70 C. Thus, the choice of a coolant—e.g., an expensive mechanical refrigerant or merely ordinary cooling water—depends on the absolute temperature level necessary during fermentation.

At steady state, the product stream is continuously withdrawn from the fermenter at a rate equal to the feed. The product stream, whose cell-concentration usually ranges from 10 to 35 g. dry weight per liter of solution, is continuously concentrated by the desludging separator to a paste of 20 to 30% dry solids. This paste is then washed with warm water containing a small amount of surface-active agent that re-

moves trace amounts of unassimilated hydrocarbons adsorbed or absorbed by the cell. A second concentration in a desludging separator produces a cleaned cell-paste (of about 20% dry solid content) that is further dehydrated in a rotary vacuum filter to about 30-40% dry solids. A final drying step in an atmospheric drum dryer, where the cells are "killed," reduces the moisture content to less than 10%, and the powdered product is ready for packaging and shipment.

Continuous, Non-Aseptic Processing

From the capital investment and labor requirements data that are available for large-scale manufacturing of baker's yeast,²⁵ it can be shown that continuous fermentation for single-cell production is far more advantageous than batch fermentation. Moreover, a continuous fermenter can be more readily controlled and operated, and it produces a uniform and consistent product.

Ideally, commercial single-cell production should be made capable of operating in non-septic conditions. (This is not the same as saying that no precautions should be taken for plant sanitation.) For any desired organism, its proper growth conditions—selected so as to prevent contamination by other organisms—include such factors as high growth-temperature, low pH, and good practices of plant sanitation.

As far as plant location is concerned, the usual site-finding considerations still apply—e.g., the plant should be near the refinery or gas field, provided that transportation costs of the final product to the market are not out of line, and that process utilities are available at the site.

Mass Transfer: One Key to Economics

The chemical composition of single-cell protein produced from any substrate is relatively constant. Representative cellular composition is 47% carbon, 7% hydrogen, 31% oxygen, 7 to 10% nitrogen, and the remainder ash.

Unlike the carbohydrates, hydrocarbon substrates have no oxygen in the molecular backbone. A physical supply of molecular oxygen, therefore, must be pro-

Relationship of mass-transfer coefficient to impeller power as a function of fermenter size^a—Table VI

Scale of Operation	Fermenter Volume (Gal)	Mass-Transfer Coefficient Dependency on $(P/V)^b$
Laboratory	2.0	$\alpha = 0.95$
Pilot Plant	110	$\alpha = 0.67$
Production	6,000–12,000	$\alpha = 0.5$

^a The general correlation of the mass-transfer coefficient ($k_L a$) to power per unit volume of fermentation broth (P/V) is assumed to be: $k_L a = K(P/V)^\alpha$

Agitation and substrate cost at different scaleup indexes—Table VII

Scaleup Index (n)	0.5				0.75				1.0			
	Molasses	CH ₄	n-Paraffin	Gas-oil	Mol.	CH ₄	NP	Gas-oil	Mol.	CH ₄	NP	Gas-oil
Agitation Cost (\$/lb.)	0.2	5.0	2.18	2.18	0.2	1.71	0.98	0.98	0.2	1.0	0.66	0.66
Substrate Cost (\$/lb.)	3.5	0.42	2.0	1.0	3.5	0.42	2.0	1.0	3.5	0.42	2.0	1.0
Subtotal (\$/lb.)	3.7	5.42	4.18	3.18	3.7	2.13	2.98	1.98	3.7	1.42	2.66	1.66

Substrate Cost Basis: Molasses = 1.75¢/lb.; CH₄ = 0.35¢/lb.; purified n-paraffin = 2¢/lb.; gas-oil = 1.0¢/lb.; substrate consumed; electric power = 1¢/kwh.

vided in order for bacterial cells to grow on hydrocarbons. Not surprisingly, as Table V indicates, the oxygen transfer rates on hydrocarbon substrates are much higher than for carbohydrates, even though cell productivity is the same.* This is an unfortunate situation, further complicated by the relationship of the mass-transfer coefficient to the power requirement in vessels where fermentations in large scales are carried out.

It has been reported that dependence of the mass-transfer coefficient on the agitator power is highly influenced by the size of the equipment,²³ as indicated by the data in Table VI. Using these scaleup indexes, single-cell protein production on petroleum fractions would require a much higher power input to the fermenter than would be involved when considering only the increase of oxygen demand. Such a power increase would be reflected especially in operating costs, which in turn could offset the economic gain of a lower substrate cost.

The economic analyses, considering both the increase of oxygen for hydrocarbons as well as different indexes for scaleup, are presented in Table VII.²⁴ It can be seen that if the scaleup index on power per unit volume is below 0.75, the production of single-cell protein from methane or purified n-paraffins will probably be more costly than from molasses. On the other hand, if the scaleup index could be made more favorable (e.g., $n \geq 0.75$)—through R&D and better mass transfer in a redesigned reactor—the decrease in costs for protein-from-petroleum would be of extreme economic importance.

*The oxygen transfer rates were calculated assuming a constant productivity of about 3.5 g. of cell per liter of fermenter broth per hour. This number is derived from assuming a reasonable doubling time of 3 hr. and a reasonable cell concentration of 15 g./l.

**The basis for the power cost was obtained by examining the present day industrial-scale yeast fermentations, where the requirement is approximately 0.2 kwh. per pound of yeast produced.

Coping With Heat of Fermentation

Fermentation generates considerable heat that must be disposed of to maintain the optimum temperature for growth, and mechanical refrigeration may be required also at fermentation temperatures such as 30 C.; this expense can considerably increase the operating costs.

From existing data of cell yields on various substrates, heat-production rates for single-cell proteins have been calculated (see Table VIII); the costs presented in the table are only the operating costs (not investment costs), and they indicate where potential savings in cooling can be possible if cell yields on petroleum could be increased—an extremely optimistic hope. Cost-cutting on mechanical refrigeration could be achieved if single-cell organisms were capable of growth at 60 deg. C.; then, heat removal could be accomplished without the assistance of any mechanical refrigerants.

Actually, there has been some degree of success in isolating or adapting a particular organism to temperatures high enough to simplify heat-transfer problems and to facilitate the maintenance of aseptic conditions; as a matter of fact, a thermophilic bacterium that is capable of growing at temperatures ranging up to 70 C. on n-paraffin compounds has already been isolated.²⁶

Cell Separation and Purification

The microbial cells recovered from the fermentation broth must be cleaned and dried to a final product that can be used directly in different formulations. But cell concentration from the fermenter is rather low (about 1.5% on dry basis), and before any additional processing can be performed, cell concentration must be increased. Usually this is done by centrifugation or filtration. The cell size of the organism

important in selecting a separation method. Bacterial cells, for instance, are usually three to five times smaller than yeast cells; since the efficiency of centrifugal separation is proportional to the square of particle size, the recovery of yeast cells will be far easier, certainly, than will be the recovery of bacterial cells.

In addition to physical recovery, cell purification may be necessary, depending on the type of substrate. The advantage in using methane is that relatively few cells can be produced. But if purified normal raffinose are used, the unassimilated hydrocarbons associated with the cells must be removed by successive centrifugation and washing with hot water, as indicated in the figure.

Gas-oil substrates involve the most difficult recovery and purification procedures. For example, assuming a substrate that contains about 30% usable normal paraffins, for every 100 lb. of effluent there will be 1.5 lb. of cells, 3.5 lb. of unassimilated hydrocarbon, and 1 lb. of aqueous medium. The presence of the unused hydrocarbon will make cell recovery by centrifugation extremely difficult because some of the cells are in the hydrocarbon phase and some are in the aqueous phase. In addition, due to the presence of the large amount

of unassimilated hydrocarbon, the degree of contamination of these cells will be very much greater than for cells grown on purified paraffins. Since the gas-oil fraction is known to contain aromatics, these compounds must be completely removed in order to ensure a wholesome and safe product for use either in animal or human food supplements.

Purification procedures for cells grown on gas-oil are usually based on differential solvent extraction. For example, it has been reported²⁴ that microbial cells grown on gas-oil can be effectively purified using sequential polar and nonpolar solvent extractions—which, unfortunately, increase over-all costs because of additional processing equipment, solvents requirements and operating expenses. It is not possible at this time to state in exact manner the optimal method for purifying cells from the latter substrates. However, there is room for improvement. The centrifugal separator, although efficient and easy to operate, is expensive from capital investment and operating cost considerations. R&D efforts in increasing the efficiency of centrifugal separation will undoubtedly yield lower over-all cost for cell production. Quantitatively, the approximate operating costs for cell recovery by centrifugal separators are illustrated in Table IX. It

Heat evolution for single-cell production on various substrates—Table VIII

Substrate	Yield on Substrate (g. cell/g. substr.)	Heat of Fermentation (K cal./100 g. cell)	Rate of Heat Evolution ^a $\left(\frac{\text{Kcal.}}{\text{Ltr.}} \right)$		Power Cost for Refrigeration (¢/lb. cells)
	From Existing Data			(Btu./gal.-hr.)	
polyhydrate	0.5	380	13.2	198	0.54
paraffin	1.0	780	27.0	405	1.03
gas oil	0.6	1,660	64.3	965	2.52
	With Improvement				
gas oil	0.8	1,300	45.0	675	1.75
paraffin	1.0	970	33.6	505	1.31
polyhydrate	1.2	590	20.4	306	0.79
paraffin	1.4	453	15.7	236	0.61

^a Doubling time = 3 hr.; cell conc. = 15 g./l.; refrigeration = 1.2 hp./12,000 Btu./hr.; 1 Kwh. = 1¢

Operating cost for cell recovery by centrifugal separation—Table IX

Size of Cells	Cell Concentration in Fermenter (g./l.)	Washing Requirements ^a (Vol./Vol.)	Operating Cost ^b (¢/lb. cell)
	10	2.0	0.32
5-5 microns	15	2.0	0.24
10 microns	15	2.0	0.91
2 microns			

^a Washing requirement based on volume of wash water per volume of fermenter broth.
^b Operating cost based on 1¢/kwh. for centrifuge.

Cost estimate of protein from petroleum—Table X

Basis: 100,000 tons/yr. (50% protein)		Cost per lb.	(\$/lb.)
Raw Materials			
Normal paraffin		1.5 to 3.5	
Others		0.5 to 0.5	
Subtotal			(2 to 4)
Operating and Utilities			
Aeration & agitation		1.25 to 2.0	
Cooling		1.0 to 1.0	
Recovery		0.25 to 0.5	
Drying		0.4 to 0.6	
Others		0.2 to 0.4	
Subtotal			(3.1 to 4.5)
Capital Investment			
Fermentation		0.35 to 0.7	
Recovery		0.36 to 0.5	
Drying		0.05 to 0.05	
Cooling		0.22 to 0.44	
Others		0.2 to 0.4	
Subtotal			(1.18 to 2.09)
Total Cost			(6.3 to 10.6)

can be seen that improvement in cell recovery must be obtained when using bacteria.

Possible methods for upgrading recovery efficiencies could also involve flocculating and coagulating agents. Or, by physiological manipulations, cell-surface characteristics could conceivably be changed to induce flocculation.

Over-All Economics

If single-cell proteins are to be used either as animal or human feed-supplements, the cost of production must be competitive with such products as oil-seed meals and fishmeals that are priced from \$120 to \$140/ton, or about 6 to 7¢/lb.

Based on the cost presented last year by Esso Research & Engineering Co., the price of a 50% protein single-cell was estimated at about 17.5¢/lb.⁵ More recently, for the single cells from *n*-paraffins process, British Petroleum Co. estimated that raw materials accounted for 30% of the total product cost, aeration and agitation 15%, recovery 15%, and labor and depreciation 40%.⁶ Assuming that the total raw-materials (*n*-paraffins plus other nutrients) cost is on the order of 2 to 4¢, this would correspond to a production cost of 6.7 to 13.3¢/lb. of single cells containing 50% protein.

I have prepared an independent estimate of production costs for single-cell protein from purified *n*-paraffins (see Table X). At 6 to 8¢/lb., single cells could be competitive as a potential animal-feed supplement. Above 8¢/lb., it would be difficult to gain a share of the animal-feed market.

For human consumption, the protein could command a price in the range of 30 to 40¢/lb. But additional processing, such as cell purification through selective solvent extraction, or manipulations of cell properties

for food formulations, or reduction of the nucleic acid content of the cells, would undoubtedly add to the production cost. While there presently is no way of knowing exactly how much this additional processing would cost, all these uncertainties will be resolved at some near-future date.

The last big hurdle will probably be that of acceptance, which depends on such factors as flavor, color, appearance, personal and cultural idiosyncrasies of consumers.

References

1. Bunker, H. J., Microbial Food, in "Biochemistry of Industrial Microorganisms," A. H. Rose and C. Hainbow, Eds., Academic Press, 1962.
2. Pepper, H. J., Yeast Technology, in "Microbial Technology," H. J. Pepper, Ed., Reinhold, 1967.
3. Stokke, J. L., Microbial Proteins, in "Processed Plant Protein Foodstuffs," A. M. Altschul, Ed., Academic Press, 1958.
4. Vary, P. S. and Johnson, M. J., "Cell Yields of Bacteria Grown on Microbial," *Appl. Microbiol.*, 15: 1473, Nov., 1967.
5. Anon., "Proteins Grown on High-Purity Alkanes," *Chem. & Eng. News*, Jan. 9, 1967.
6. Llewellyn, D. A. R., "The Production of Protein Concentrate Biomass from Hydrocarbons," Presented at the Symposium on Microbiology, London, England, Sept. 19-20, 1967.
7. Inskeep, G. C., others, "Food Yeast from Sulfite Liquor," *Ind. Eng. Chem.*, 49: 1792, Aug., 1957.
8. Champagnat, A., others, "Biosynthesis of Protein Vitamin Concentrates from Petroleum," *Nature*, 197, 15, Jan. 1962.
9. Chopin, S. V., others, "The Production & Utilization of Fodder Yeasts Grown on Petroleum Hydrocarbon," presented at the 7th World Petroleum Congress, Mexico City, Mexico, 1963.
10. Craven, W. W. and Sirois, E., Soybean Oil Meal, in "Processed Plant Protein Foodstuffs," A. M. Altschul, Ed., Academic Press, 1958.
11. Altschul, A. M., others, Cottonseed Meal, in "Processed Plant Protein Foodstuffs," A. M. Altschul, Ed., Academic Press, 1958.
12. Davis, J. R., others, "Atmospheric Nitrogen Fixation by Methane-Oxidizing Bacteria," *J. Bacteriol.*, 88(2), 468, Aug., 1964.
13. Foster, J. W. and Davis, R. H., "A Methane-Dependent Coculture," *J. Bacteriol.*, 82(5), 1924, May, 1966.
14. Dworkin, M. and Foster, J. W., "Studies on *Pseudomonas Methanica*," *J. Bacteriol.*, 72(4) 646, Oct., 1956.
15. Anon., "Bacteria Metabolize Methane," *Chem. & Eng. News*, June, 1966.
16. Wolke, B., others, "Fermentation of Methane," *Biotech. & Bioeng.*, 9(11), 57, Jan., 1967.
17. Hauser, G. and Heden, C.-G., "Methane as a Carbon Source for the Production of Microbial Cells," *Biotech. & Bioeng.*, 9(4), 499, Nov., 1967.
18. Takeda, L., others, "Production of Microbial Cells From Hydrocarbons," *Appl. Biol. Chem.*, 29(9), 756, Sept., 1965.
19. Miller, T. L. and Johnson, M. J., "Utilization of Normal Alkanes by Yeasts," *Biotech. & Bioeng.*, 8(4), 549, Nov., 1966.
20. Johnson, M. J., "Growth of Microbial Cells on Hydrocarbons," *Science*, 153, 1515, Mar. 24, 1967.
21. Esso Research and Engineering Co., "Process of Producing High Protein Feed Supplements from Hydrocarbons," British Patent 1,062,816, Mar. 22, 1967.
22. Miller, T. L. and Johnson, M. J., "Utilization of Gas Oil by a Yeast Culture," *Biotech. & Bioeng.*, 8(11), 567, Nov., 1966.
23. Bartholomew, W. H., Scale-up of Submerged Fermentations, in "Advances in Applied Microbiology," Vol. 2, 283, Academic Press, 1959.
24. Champagnat, A. and Laine, R., "Process of Rupturing Microorganism Cell Grown on Hydrocarbon Feed Stock," U.S. 3,268,412, Aug. 2, 1966.
25. Olsen, A. J. C., Manufacture of Baker's Yeast by Continuous Fermentation, I. Plant and Process, in "Continuous Culture of Microorganisms," Society of Chemistry and Industry Monograph No. 18, London, 1961.
26. Maties, R. L., others, "Growth of a Thermophilic Bacterium on Hydrocarbons: A New Source of Single-Cell Protein," *Science*, 153, 1322, Sept. 15, 1967.

Meet the Author

Daniel I. C. Wang is assistant professor of biochemical engineering in the Dept. of Nutrition and Food Science at Massachusetts Institute of Technology, Cambridge, Mass. 02139. He has a Ph.D. in chemical engineering from the University of Pennsylvania, and an M.S. in biochemical engineering and a B.S. in chemical engineering, both from M.I.T. He is a member of AIChE, Institute of Food Technologists, American Society for Microbiology, Sigma Xi, and Tau Beta Pi.



The Tragedy of the Commons

The population problem has no technical solution;
it requires a fundamental extension in morality.

Garrett Hardin

At the end of a thoughtful article on the future of nuclear war, Wiesner and York (1) concluded that: "Both sides in the arms race are . . . confronted by the dilemma of steadily increasing military power and steadily decreasing national security. It is our considered professional judgment that this dilemma has no technical solution. If the great powers continue to look for solutions in the area of science and technology only, the result will be to worsen the situation."

I would like to focus your attention not on the subject of the article (national security in a nuclear world) but on the kind of conclusion they reached, namely that there is no technical solution to the problem. An implicit and almost universal assumption of discussions published in professional and semipopular scientific journals is that the problem under discussion has a technical solution. A technical solution may be defined as one that requires a change only in the techniques of the natural sciences, demanding little or nothing in the way of change in human values or ideas of morality.

In our day (though not in earlier times) technical solutions are always welcome. Because of previous failures in prophecy, it takes courage to assert that a desired technical solution is not possible. Wiesner and York exhibited this courage; publishing in a science journal, they insisted that the solution to the problem was not to be found in the natural sciences. They cautiously qualified their statement with the phrase, "It is our considered profes-

sional judgment. . . ." Whether they were right or not is not the concern of the present article. Rather, the concern here is with the important concept of a class of human problems which can be called "no technical solution problems," and, more specifically, with the identification and discussion of one of these.

It is easy to show that the class is not a null class. Recall the game of tick-tack-toe. Consider the problem, "How can I win the game of tick-tack-toe?" It is well known that I cannot, if I assume (in keeping with the conventions of game theory) that my opponent understands the game perfectly. Put another way, there is no "technical solution" to the problem. I can win only by giving a radical meaning to the word "win." I can hit my opponent over the head; or I can drug him; or I can falsify the records. Every way in which I "win" involves, in some sense, an abandonment of the game, as we intuitively understand it. (I can also, of course, openly abandon the game—refuse to play it. This is what most adults do.)

The class of "No technical solution problems" has members. My thesis is that the "population problem," as conventionally conceived, is a member of this class. How it is conventionally conceived needs some comment. It is fair to say that most people who anguish over the population problem are trying to find a way to avoid the evils of overpopulation without relinquishing any of the privileges they now enjoy. They think that farming the seas or developing new strains of wheat will solve the problem—technologically. I try to show here that the solution they seek cannot be found. The population problem cannot be solved in a technical way, any more than can the problem of winning the game of tick-tack-toe.

Population, as Malthus said, naturally tends to grow "geometrically," or, as we would now say, exponentially. In a finite world this means that the per capita share of the world's goods must steadily decrease. Is ours a finite world?

A fair defense can be put forward for the view that the world is infinite; or that we do not know that it is not. But, in terms of the practical problems that we must face in the next few generations with the foreseeable technology, it is clear that we will greatly increase human misery if we do not, during the immediate future, assume that the world available to the terrestrial human population is finite. "Space" is no escape (2).

A finite world can support only a finite population; therefore, population growth must eventually equal zero. (The case of perpetual wide fluctuations above and below zero is a trivial variant that need not be discussed.) When this condition is met, what will be the situation of mankind? Specifically, can Bentham's goal of "the greatest good for the greatest number" be realized?

No—for two reasons, each sufficient by itself. The first is a theoretical one. It is not mathematically possible to maximize for two (or more) variables at the same time. This was clearly stated by von Neumann and Morgenstern (3), but the principle is implicit in the theory of partial differential equations, dating back at least to D'Alembert (1717–1783).

The second reason springs directly from biological facts. To live, any organism must have a source of energy (for example, food). This energy is utilized for two purposes: mere maintenance and work. For man, maintenance of life requires about 1600 kilocalories a day ("maintenance calories"). Anything that he does over and above merely staying alive will be defined as work, and is supported by "work calories" which he takes in. Work calories are used not only for what we call work in common speech; they are also required for all forms of enjoyment, from swimming and automobile racing to playing music and writing poetry. If our goal is to maximize population it is obvious what we must do: We must make the work calories per person approach as close to zero as possible. No gourmet meals, no vacations, no sports, no music, no literature, no art. . . . I think that everyone will grant, without

The author is professor of biology, University of California, Santa Barbara. This article is based on a presidential address presented before the meeting of the Pacific Division of the American Association for the Advancement of Science at Utah State University, Logan, 25 June 1968.

argument or proof, that maximizing population does not maximize goods. Bentham's goal is impossible.

In reaching this conclusion I have made the usual assumption that it is the acquisition of energy that is the problem. The appearance of atomic energy has led some to question this assumption. However, given an infinite source of energy, population growth still produces an inescapable problem. The problem of the acquisition of energy is replaced by the problem of its dissipation, as J. H. Pirenin has so wittily shown (5). The arithmetic signs in the analysis are, as it were, reversed; but Bentham's goal is still unobtainable.

The optimum population is, then, less than the maximum. The difficulty of defining the optimum is enormous; so far as I know, no one has seriously tackled this problem. Reaching an acceptable and stable solution will surely require more than one generation of hard analytical work—and much persuasion.

We want the maximum good per person; but what is good? To one person it is wilderness, to another it is ski lodges for thousands. To one it is estuaries to nourish ducks for hunters to shoot; to another it is factory land. Comparing one good with another is, we usually say, impossible, because goods are incommensurable. Incommensurables cannot be compared.

Theoretically this may be true; but in real life incommensurables are commensurable. Only a criterion of judgment and a system of weighting are needed. In nature the criterion is survival. Is it better for a species to be small and hideable, or large and powerful? Natural selection commensurates the incommensurables. The compromise achieved depends on a natural weighting of the values of the variables.

Man must imitate this process. There is no doubt that in fact he already does, but unconsciously. It is when the hidden decisions are made explicit that the arguments begin. The problem for the years ahead is to work out an acceptable theory of weighting. Synergistic effects, nonlinear variation, and difficulties in discounting the future make the intellectual problem difficult, but not (in principle) insoluble.

Has any cultural group solved this practical problem at the present time, even on an intuitive level? One simple fact proves that none has: there is no prosperous population in the world today that has, and has not, suffered

time, a growth rate of zero. Any people that has intuitively identified its optimum point will soon reach it, after which its growth rate becomes and remains zero.

Of course, a positive growth rate might be taken as evidence that a population is below its optimum. However, by any reasonable standards, the most rapidly growing populations on earth today are (in general) the most miserable. This association (which need not be invariable) casts doubt on the optimistic assumption that the positive growth rate of a population is evidence that it has yet to reach its optimum.

We can make little progress in working toward optimum population size until we explicitly exorcise the spirit of Adam Smith in the field of practical demography. In economic affairs, *The Wealth of Nations* (1776) popularized the "invisible hand," the idea that an individual who "intends only his own gain," is, as it were, "led by an invisible hand to promote . . . the public interest" (5). Adam Smith did not assert that this was invariably true, and perhaps neither did any of his followers. But he contributed to a dominant tendency of thought that has ever since interfered with positive action based on rational analysis, namely, the tendency to assume that decisions reached individually will, in fact, be the best decisions for an entire society. If this assumption is correct it justifies the continuance of our present policy of laissez-faire in reproduction. If it is correct we can assume that men will control their individual fecundity so as to produce the optimum population. If the assumption is not correct, we need to reexamine our individual freedoms to see which ones are defensible.

Tragedy of Freedom in a Commons

The rebuttal to the invisible hand in population control is to be found in a scenario first sketched in a little-known pamphlet (6) in 1833 by a mathematical amateur named William Forster Lloyd (1794-1852). We may well call it "the tragedy of the commons," using the word "tragedy" as the philosopher Whitehead used it (7): "The essence of dramatic tragedy is not unhappiness. It resides in the solemnity of the remorseless working of things." He then goes on to say, "This inevitableness of destiny can only be illustrated in terms of hu-

man unhappiness. For it is only by them that the futility of escape can be made evident in the drama."

The tragedy of the commons develops in this way. Picture a pasture open to all. It is to be expected that each herdsman will try to keep as many cattle as possible on the commons. Such an arrangement may work reasonably satisfactorily for centuries because tribal wars, poaching, and disease keep the numbers of both man and beast well below the carrying capacity of the land. Finally, however, comes the day of reckoning, that is, the day when the long-desired goal of social stability becomes a reality. At this point, the inherent logic of the commons remorselessly generates tragedy.

As a rational being, each herdsman seeks to maximize his gain. Explicitly or implicitly, more or less consciously, he asks, "What is the utility to me of adding one more animal to my herd?" This utility has one negative and one positive component.

1) The positive component is a function of the increment of one animal. Since the herdsman receives all the proceeds from the sale of the additional animal, the positive utility is nearly +1.

2) The negative component is a function of the additional overgrazing created by one more animal. Since, however, the effects of overgrazing are shared by all the herdsmen, the negative utility for any particular decision-making herdsman is only a fraction of -1.

Adding together the component partial utilities, the rational herdsman concludes that the only sensible course for him to pursue is to add another animal to his herd. And another; and another. . . . But this is the conclusion reached by each and every rational herdsman sharing a commons. Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit—in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all.

Some would say that this is a platitude. Would that it were! In a sense, it was learned thousands of years ago, but natural selection favors the forces of psychological denial (8). The individual benefits as an individual from his ability to deny the truth even though society as a whole suffers. The individual suffers.

Education can counteract the natural tendency to do the wrong thing, but the inexorable succession of generations requires that the basis for this knowledge be constantly refreshed.

A simple incident that occurred a few years ago in Leominster, Massachusetts, shows how perishable the knowledge is. During the Christmas shopping season the parking meters downtown were covered with plastic bags that bore tags reading: "Do not open until after Christmas. Free parking courtesy of the mayor and city council." In other words, facing the prospect of an increased demand for already scarce space, the city fathers reinstituted the system of the commons. (Cynically, we suspect that they gained more votes than they lost by this retrogressive act.)

In an approximate way, the logic of the commons has been understood for a long time, perhaps since the discovery of agriculture or the invention of private property in real estate. But it is understood mostly only in special cases which are not sufficiently generalized. Even at this late date, cattlemen leasing national land on the western ranges demonstrate no more than an ambivalent understanding, in constantly pressuring federal authorities to increase the head count to the point where overgrazing produces erosion and weed-dominance. Likewise, the oceans of the world continue to suffer from the survival of the philosophy of the commons. Maritime nations still respond automatically to the shibboleth of the "freedom of the seas." Professing to believe in the "inexhaustible resources of the oceans," they bring species after species of fish and whales closer to extinction (9).

The National Parks present another instance of the working out of the tragedy of the commons. At present, they are open to all, without limit. The parks themselves are limited in extent—there is only one Yosemite Valley—whereas population seems to grow without limit. The values that visitors seek in the parks are steadily eroded. Plainly, we must soon cease to treat the parks as commons or they will be of no value to anyone.

What shall we do? We have several options. We might sell them off as private property. We might keep them as public property, but allocate the right to enter them. The allocation might be on the basis of wealth, by the use of an auction system. It might be on the basis of merit, as defined by some agreed-

upon standards. It might be by lottery. Or it might be on a first-come, first-served basis, administered to long queues. These, I think, are all the reasonable possibilities. They are all objectionable. But we must choose—or acquiesce in the destruction of the commons that we call our National Parks.

Pollution

In a reverse way, the tragedy of the commons reappears in problems of pollution. Here it is not a question of taking something out of the commons, but of putting something in—sewage, or chemical, radioactive, and heat wastes into water; noxious and dangerous fumes into the air; and distracting and unpleasant advertising signs into the line of sight. The calculations of utility are much the same as before. The rational man finds that his share of the cost of the wastes he discharges into the commons is less than the cost of purifying his wastes before releasing them. Since this is true for everyone, we are locked into a system of "fouling our own nest," so long as we behave only as independent, rational, free-enterprisers.

The tragedy of the commons as a food basket is averted by private property, or something formally like it. But the air and waters surrounding us cannot readily be fenced, and so the tragedy of the commons as a cesspool must be prevented by different means, by coercive laws or taxing devices that make it cheaper for the polluter to treat his pollutants than to discharge them untreated. We have not progressed as far with the solution of this problem as we have with the first. Indeed, our particular concept of private property, which deters us from exhausting the positive resources of the earth, favors pollution. The owner of a factory on the bank of a stream—whose property extends to the middle of the stream—often has difficulty seeing why it is not his natural right to muddy the waters flowing past his door. The law, always behind the times, requires elaborate stitching and fitting to adapt it to this newly perceived aspect of the commons.

The pollution problem is a consequence of population. It did not much matter how a lonely American frontiersman disposed of his waste. "Flowing water purifies itself every 10 miles," my grandfather used to say, and the myth was near enough to the truth when he

was a boy, for there were not too many people. But as population became denser, the natural chemical and biological recycling processes became overloaded, calling for a redefinition of property rights.

How To Legislate Temperance?

Analysis of the pollution problem as a function of population density uncovers a not generally recognized principle of morality, namely: *the morality of an act is a function of the state of the system at the time it is performed* (10). Using the commons as a cesspool does not harm the general public under frontier conditions, because there is no public; the same behavior in a metropolis is unbearable. A hundred and fifty years ago a plainsman could kill an American bison, cut out only the tongue for his dinner, and discard the rest of the animal. He was not in any important sense being wasteful. Today, with only a few thousand bison left, we would be appalled at such behavior.

In passing, it is worth noting that the morality of an act cannot be determined from a photograph. One does not know whether a man killing an elephant or setting fire to the grassland is harming others until one knows the total system in which his act appears. "One picture is worth a thousand words," said an ancient Chinese; but it may take 10,000 words to validate it. It is as tempting to ecologists as it is to reformers in general to try to persuade others by way of the photographic shortcut. But the essence of an argument cannot be photographed: it must be presented rationally—in words.

That morality is system-sensitive escaped the attention of most codifiers of ethics in the past. "Thou shalt not . . ." is the form of traditional ethical directives which make no allowance for particular circumstances. The laws of our society follow the pattern of ancient ethics, and therefore are poorly suited to governing a complex, crowded, changeable world. Our epicyclic solution is to augment statutory law with administrative law. Since it is practically impossible to spell out all the conditions under which it is safe to burn trash in the back yard or to run an automobile without smog-control, by law we delegate the details to bureaus. The result is administrative law, which is rightly feared for an ancient reason—*Quis custodiet ipsos custodes?*—"Who shall

watch the watchers themselves?" John Adams said that we must have "a government of laws and not men." Bureau administrators, trying to evaluate the morality of acts in the total system, are singularly liable to corruption, producing a government by men, not laws.

Prohibition is easy to legislate (though not necessarily to enforce); but how do we legislate temperance? Experience indicates that it can be accomplished best through the mediation of administrative law. We limit possibilities unnecessarily if we suppose that the sentiment of *Quis custodiet* denies us the use of administrative law. We should rather retain the phrase as a perpetual reminder of fearful dangers we cannot avoid. The great challenge facing us now is to invent the corrective feedbacks that are needed to keep custodians honest. We must find ways to legitimate the needed authority of both the custodians and the corrective feedbacks.

Freedom To Breed Is Intolerable

The tragedy of the commons is involved in population problems in another way. In a world governed solely by the principle of "dog eat dog"—if indeed there ever was such a world—how many children a family had would not be a matter of public concern. Parents who bred too exuberantly would leave fewer descendants, not more, because they would be unable to care adequately for their children. David Lack and others have found that such a negative feedback demonstrably controls the fecundity of birds (11). But men are not birds, and have not acted like them for millennia, at least.

If each human family were dependent only on its own resources; if the children of improvident parents starved to death; if, thus, overbreeding brought its own "punishment" to the germ line—then there would be no public interest in controlling the breeding of families. But our society is deeply committed to the welfare state (12), and hence is confronted with another aspect of the tragedy of the commons.

In a welfare state, how shall we deal with the family, the religion, the race, or the class (or indeed any distinguishable and cohesive group) that adopts overbreeding as a policy to secure its own aggrandizement (13)? To couple the concept of freedom to breed with the belief that everyone born has an

equal right to the commons is to lock the world into a tragic course of action.

Unfortunately this is just the course of action that is being pursued by the United Nations. In late 1967, some 30 nations agreed to the following (14):

The Universal Declaration of Human Rights describes the family as the natural and fundamental unit of society. It follows that any choice and decision with regard to the size of the family must irrevocably rest with the family itself, and cannot be made by anyone else.

It is painful to have to deny categorically the validity of this right; denying it, one feels as uncomfortable as a resident of Salem, Massachusetts, who denied the reality of witches in the 17th century. At the present time, in liberal quarters, something like a taboo acts to inhibit criticism of the United Nations. There is a feeling that the United Nations is "our last and best hope," that we shouldn't find fault with it; we shouldn't play into the hands of the archconservatives. However, let us not forget what Robert Louis Stevenson said: "The truth that is suppressed by friends is the readiest weapon of the enemy." If we love the truth we must openly deny the validity of the Universal Declaration of Human Rights, even though it is promoted by the United Nations. We should also join with Kingsley Davis (15) in attempting to get Planned Parenthood-World Population to see the error of its ways in embracing the same tragic ideal.

Conscience Is Self-Eliminating

It is a mistake to think that we can control the breeding of mankind in the long run by an appeal to conscience. Charles Galton Darwin made this point when he spoke on the centennial of the publication of his grandfather's great book. The argument is straightforward and Darwinian.

People vary. Confronted with appeals to limit breeding, some people will undoubtedly respond to the plea more than others. Those who have more children will produce a larger fraction of the next generation than those with more susceptible consciences. The difference will be accentuated, generation by generation.

In C. G. Darwin's words: "It may well be that it would take hundreds of generations for the progenitive instinct to develop in this way, but if it should do so, nature would have taken her revenge, and the variety *Homo contra-*

ciens would become extinct and would be replaced by the variety *Homo progenitivus* (16).

The argument assumes that conscience or the desire for children (no matter which) is hereditary—but hereditary only in the most general formal sense. The result will be the same whether the attitude is transmitted through germ cells, or exosomatically, to use A. J. Lotka's term. (If one denies the latter possibility as well as the former, then what's the point of education?) The argument has here been stated in the context of the population problem, but it applies equally well to any instance in which society appeals to an individual exploiting a commons to restrain himself for the general good—by means of his conscience. To make such an appeal is to set up a selective system that works toward the elimination of conscience from the race.

Pathogenic Effects of Conscience

The long-term disadvantage of an appeal to conscience should be enough to condemn it; but has serious short-term disadvantages as well. If we ask a man who is exploiting a commons to desist "in the name of conscience," what are we saying to him? What does he hear?—not only at the moment but also in the wee small hours of the night when, half asleep, he remembers not merely the words we used but also the nonverbal communication cues we gave him unawares? Sooner or later, consciously or subconsciously, he senses that he has received two communications, and that they are contradictory: (i) (intended communication) "If you don't do as we ask, we will openly condemn you for not acting like a responsible citizen"; (ii) (the unintended communication) "If you do behave as we ask, we will secretly condemn you for a simpleton who can be shamed into standing aside while the rest of us exploit the commons."

Everyman then is caught in what Bateson has called a "double bind." Bateson and his co-workers have made a plausible case for viewing the double bind as an important causative factor in the genesis of schizophrenia (17). The double bind may not always be so damaging, but it always endangers the mental health of anyone to whom it is applied. "A bad conscience," said Nietzsche, "is a kind of illness."

To conjure up a conscience in others

is tempting to anyone who wishes to extend his control beyond the legal limits. Leaders at the highest level succumb to this temptation. Has any President during the past generation failed to call on labor unions to moderate voluntarily their demands for higher wages, or to steel companies to honor voluntary guidelines on prices? I can recall none. The rhetoric used on such occasions is designed to produce feelings of guilt in noncooperators.

For centuries it was assumed without proof that guilt was a valuable, perhaps even an indispensable, ingredient of the civilized life. Now, in this post-Freudian world, we doubt it.

Paul Goodman speaks from the modern point of view when he says: "No good has ever come from feeling guilty, neither intelligence, policy, nor compassion. The guilty do not pay attention to the object but only to themselves, and not even to their own interests, which might make sense, but to their anxieties" (18).

One does not have to be a professional psychiatrist to see the consequences of anxiety. We in the Western world are just emerging from a dreadful two-centuries-long Dark Ages of Eros that was sustained partly by prohibition laws, but perhaps more effectively by the anxiety-generating mechanisms of education. Alex Comfort has told the story well in *The Anxiety Makers* (19); it is not a pretty one.

Since proof is difficult, we may even concede that the results of anxiety may sometimes, from certain points of view, be desirable. The larger question we should ask is whether, as a matter of policy, we should ever encourage the use of a technique the tendency (if not the intention) of which is psychologically pathogenic. We hear much talk these days of responsible parenthood; the coupled words are incorporated into the titles of some organizations devoted to birth control. Some people have proposed massive propaganda campaigns to instill responsibility into the nation's (or the world's) breeders. But what is the meaning of the word responsibility in this context? Is it not merely a synonym for the word conscience? When we use the word responsibility in the absence of substantial sanctions are we not trying to browbeat a free man in a commons into acting against his own interest? Responsibility is a verbal counterfeit for a substantial *quid pro quo*. It is an attempt to get something for nothing.

If the word responsibility is to be used at all, I suggest that it be in the sense Charles Frankel uses it (20). "Responsibility," says this philosopher, "is the product of definite social arrangements." Notice that Frankel calls for social arrangements—not propaganda.

Mutual Coercion

Mutually Agreed upon

The social arrangements that produce responsibility are arrangements that create coercion, of some sort. Consider bank-robbing. The man who takes money from a bank acts as if the bank were a commons. How do we prevent such action? Certainly not by trying to control his behavior solely by a verbal appeal to his sense of responsibility. Rather than rely on propaganda we follow Frankel's lead and insist that a bank is not a commons; we seek the definite social arrangements that will keep it from becoming a commons. That we thereby infringe on the freedom of would-be robbers we neither deny nor regret.

The morality of bank-robbing is particularly easy to understand because we accept complete prohibition of this activity. We are willing to say "Thou shalt not rob banks," without providing for exceptions. But temperance also can be created by coercion. Taxing is a good coercive device. To keep downtown shoppers temperate in their use of parking space we introduce parking meters for short periods, and traffic fines for longer ones. We need not actually forbid a citizen to park as long as he wants to; we need merely make it increasingly expensive for him to do so. Not prohibition, but carefully biased options are what we offer him. A Madison Avenue man might call this persuasion; I prefer the greater candor of the word coercion.

Coercion is a dirty word to most liberals now, but it need not forever be so. As with the four-letter words, its dirtiness can be cleansed away by exposure to the light, by saying it over and over without apology or embarrassment. To many, the word coercion implies arbitrary decisions of distant and irresponsible bureaucrats; but this is not a necessary part of its meaning. The only kind of coercion I recommend is mutual coercion, mutually agreed upon by the majority of the people affected.

To say that we mutually agree to

coercion is not to say that we are required to enjoy it, or even to pretend we enjoy it. Who enjoys taxes? We all grumble about them. But we accept compulsory taxes because we recognize that voluntary taxes would favor the conscienceless. We institute and (grumblingly) support taxes and other coercive devices to escape the horror of the commons.

An alternative to the commons need not be perfectly just to be preferable. With real estate and other material goods, the alternative we have chosen is the institution of private property coupled with legal inheritance. Is this system perfectly just? As a genetically trained biologist I deny that it is. It seems to me that, if there are to be differences in individual inheritance, legal possession should be perfectly correlated with biological inheritance—that those who are biologically more fit to be the custodians of property and power should legally inherit more. But genetic recombination continually makes a mockery of the doctrine of "like father, like son" implicit in our laws of legal inheritance. An idiot can inherit millions, and a trust fund can keep his estate intact. We must admit that our legal system of private property plus inheritance is unjust—but we put up with it because we are not convinced, at the moment, that anyone has invented a better system. The alternative of the commons is too horrifying to contemplate. Injustice is preferable to total ruin.

It is one of the peculiarities of the warfare between reform and the status quo that it is thoughtlessly governed by a double standard. Whenever a reform measure is proposed it is often defeated when its opponents triumphantly discover a flaw in it. As Kingsley Davis has pointed out (21), worshippers of the status quo sometimes imply that no reform is possible without unanimous agreement, an implication contrary to historical fact. As nearly as I can make out, automatic rejection of proposed reforms is based on one of two unconscious assumptions: (i) that the status quo is perfect; or (ii) that the choice we face is between reform and no action; if the proposed reform is imperfect, we presumably should take no action at all, while we wait for a perfect proposal.

But we can never do nothing. That which we have done for thousands of years is also action. It also produces evils. Once we are aware that the

status quo is action, we can then compare its discoverable advantages and disadvantages with the predicted advantages and disadvantages of the proposed reform, discounting as best we can for our lack of experience. On the basis of such a comparison, we can make a rational decision which will not involve the unworkable assumption that only perfect systems are tolerable.

Recognition of Necessity

Perhaps the simplest summary of this analysis of man's population problems is this: the commons, if justifiable at all, is justifiable only under conditions of low-population density. As the human population has increased, the commons has had to be abandoned in one aspect after another.

First we abandoned the commons in food gathering, enclosing farm land and restricting pastures and hunting and fishing areas. These restrictions are still not complete throughout the world.

Somewhat later we saw that the commons as a place for waste disposal would also have to be abandoned. Restrictions on the disposal of domestic sewage are widely accepted in the Western world; we are still struggling to close the commons to pollution by automobiles, factories, insecticide sprayers, fertilizing operations, and atomic energy installations.

In a still more embryonic state is our recognition of the evils of the commons in matters of pleasure. There is almost no restriction on the propagation of sound waves in the public medium. The shopping public is assaulted with mindless music, without its consent. Our

government is paying out billions of dollars to create supersonic transport which will disturb 50,000 people for every one person who is whisked from coast to coast 3 hours faster. Advertisers muddy the airwaves of radio and television and pollute the view of travelers. We are a long way from outlawing the commons in matters of pleasure. Is this because our Puritan inheritance makes us view pleasure as something of a sin, and pain (that is, the pollution of advertising) as the sign of virtue?

Every new enclosure of the commons involves the infringement of somebody's personal liberty. Infringements made in the distant past are accepted because no contemporary complains of a loss. It is the newly proposed infringements that we vigorously oppose; cries of "rights" and "freedom" fill the air. But what does "freedom" mean? When men mutually agreed to pass laws against robbing, mankind became more free, not less so. Individuals locked into the logic of the commons are free only to bring on universal ruin; once they see the necessity of mutual coercion, they become free to pursue other goals. I believe it was Hegel who said, "Freedom is the recognition of necessity."

The most important aspect of necessity that we must now recognize, is the necessity of abandoning the commons in breeding. No technical solution can rescue us from the misery of overpopulation. Freedom to breed will bring ruin to all. At the moment, to avoid hard decisions many of us are tempted to propagandize for conscience and responsible parenthood. The temptation must be resisted, because an appeal to independently acting con-

sciences selects for the disappearance of all conscience in the long run, and an increase in anxiety in the short.

The only way we can preserve and nurture other and more precious freedoms is by relinquishing the freedom to breed, and that very soon. "Freedom is the recognition of necessity"—and it is the role of education to reveal to all the necessity of abandoning the freedom to breed. Only so, can we put an end to this aspect of the tragedy of the commons.

References

1. J. B. Wiesner and H. F. York, *Sci. Amer.* 211 (No. 4), 27 (1964).
2. G. Hardin, *J. Hered.* 50, 68 (1959); S. von Hoerner, *Science* 127, 18 (1962).
3. J. von Neumann and O. Morgenstern, *Theory of Games and Economic Behavior* (Princeton Univ. Press, Princeton, N.J., 1947), p. 11.
4. J. H. Frenlin, *New Sci.* No. 415 (1964), p. 285.
5. A. Smith, *The Wealth of Nations* (Modern Library, New York, 1937), p. 423.
6. W. F. Lloyd, *Two Lectures on the Checks to Population* (Oxford Univ. Press, Oxford, England, 1833), reprinted (in part) in *Population, Evolution, and Birth Control*, G. Hardin, Ed. (Freeman, San Francisco, 1964), p. 37.
7. A. N. Whitehead, *Science and the Modern World* (Mentor, New York, 1948), p. 17.
8. G. Hardin, Ed. *Population, Evolution, and Birth Control* (Freeman, San Francisco, 1964), p. 56.
9. S. McVay, *Sci. Amer.* 216 (No. 8), 13 (1966).
10. J. Fletcher, *Situation Ethics* (Westminster, Philadelphia, 1966).
11. D. Lack, *The Natural Regulation of Animal Numbers* (Clarendon Press, Oxford, 1954).
12. H. Givets, *From Wealth to Welfare* (Stanford Univ. Press, Stanford, Calif., 1950).
13. G. Hardin, *Perspect. Biol. Med.* 6, 365 (1963).
14. U. Thant, *Int. Planned Parenthood News*, No. 168 (February 1968), p. 3.
15. K. Davis, *Science* 158, 730 (1967).
16. S. Tax, Ed., *Evolution after Darwin* (Univ. of Chicago Press, Chicago, 1960), vol. 2, p. 469.
17. G. Bateson, D. D. Jackson, J. Haley, J. Weakland, *Behav. Sci.* 1, 251 (1956).
18. P. Goodman, *New York Rev. Books* 10(8), 22 (23 May 1968).
19. A. Comfort, *The Anxiety Makers* (Nelson, London, 1967).
20. C. Frankel, *The Case for Modern Man* (Harper, New York, 1955), p. 203.
21. J. D. Rosalovsky, *Genetics and the Future of Man* (Appleton-Century-Crofts, New York, 1966), p. 177.

Population Policy: Will Current Programs Succeed?

Grounds for skepticism concerning the demographic effectiveness of family planning are considered.

Kingsley Davis

Throughout history the growth of population has been identified with prosperity and strength. If today an increasing number of nations are seeking to curb rapid population growth by reducing their birth rates, they must be driven to do so by an urgent crisis. My purpose here is not to discuss the crisis itself but rather to assess the present and prospective measures used to

meet it. Most observers are surprised by the swiftness with which concern over the population problem has turned from intellectual analysis and debate to policy and action. Such action is a welcome relief from the long opposition, or timidity, which seemed to block forever any governmental attempt to restrain population growth, but relief that "at last something is being done"

is no guarantee that what is being done is adequate. On the face of it, one could hardly expect such a fundamental re-orientation to be quickly and successfully implemented. I therefore propose to review the nature and (as I see them) limitations of the present policies and to suggest lines of possible improvement.

The Nature of Current Policies

With more than 30 nations now trying or planning to reduce population growth and with numerous private and international organizations helping, the degree of unanimity as to the kind of measures needed is impressive. The consensus can be summed up in the phrase "family planning." President Johnson declared in 1965 that the United States will "assist family planning programs in nations which request such help." The Prime Minister of India

The author is professor of sociology and director of International Population and Urban Research, University of California, Berkeley. This article is abridged from a paper presented at the annual meeting of the National Research Council, 14 March 1967.

said a year later, "We must press forward with family planning. This is a programme of the highest importance." The Republic of Singapore created in 1966 the Singapore Family Planning and Population Board "to initiate and undertake population control programmes" (1).

As is well known, "family planning" is a euphemism for contraception. The family-planning approach to population limitation, therefore, concentrates on providing new and efficient contraceptives on a national basis through mass programs under public health auspices. The nature of these programs is shown by the following enthusiastic report from the Population Council (2):

No single year has seen so many forward steps in population control as 1965. Effective national programs have at last emerged, international organizations have decided to become engaged, a new contraceptive has proved its value in mass application, . . . and surveys have confirmed a popular desire for family limitation. . . .

An accounting of notable events must begin with Korea and Taiwan. . . . Taiwan's program is not yet two years old, and already it has inserted one IUD [intrauterine device] for every 4-6 target women (those who are not pregnant, lactating, already sterile, already using contraceptives effectively, or desirous of more children). Korea has done almost as well. . . . has put 2,200 full-time workers into the field, . . . has reached operational levels for a network of IUD quotas, supply lines, local manufacture of contraceptives, training of hundreds of M.D.'s and nurses, and mass propaganda. . . .

Here one can see the implication that "population control" is being achieved through the dissemination of new contraceptives, and the fact that the "target women" exclude those who want more children. One can also note the technological emphasis and the medical orientation.

What is wrong with such programs? The answer is, "Nothing at all, if they work." Whether or not they work depends on what they are expected to do as well as on how they try to do it. Let us discuss the goal first, then the means.

Goals

Curiously, it is hard to find in the population-policy movement any explicit discussion of long-range goals. By implication the policies seem to promote a goal that is shown by the use of expressions like *population control* and *population planning* (as in

the passages quoted above). It is also shown by the characteristic style of reasoning. Expositions of current policy usually start off by lamenting the speed and the consequences of runaway population growth. This growth, it is then stated, must be curbed—by pursuing a vigorous family-planning program. That family planning can solve the problem of population growth seems to be taken as self-evident.

For instance, the much-heralded statement by 12 heads of state, issued by Secretary-General U Thant on 10 December 1966 (a statement initiated by John D. Rockefeller III, Chairman of the Board of the Population Council), devotes half its space to discussing the harmfulness of population growth and the other half to recommending family planning (3). A more succinct example of the typical reasoning is given in the Provisional Scheme for a Nationwide Family Planning Programme in Ceylon (4):

The population of Ceylon is fast increasing. . . . [The] figures reveal that a serious situation will be created within a few years. In order to cope with it a Family Planning programme on a nationwide scale should be launched by the Government.

The promised goal—to limit population growth so as to solve population problems—is a large order. One would expect it to be carefully analyzed, but it is left imprecise and taken for granted, as is the way in which family planning will achieve it.

When the terms *population control* and *population planning* are used, as they frequently are, as synonyms for current family-planning programs, they are misleading. Technically, they would mean deliberate influence over all attributes of a population, including its age-sex structure, geographical distribution, racial composition, genetic quality, and total size. No government attempts such full control. By tacit understanding, current population policies are concerned with only the *growth* and *size* of populations. These attributes, however, result from the death rate and migration as well as from the birth rate; their control would require deliberate influence over the factors giving rise to all three determinants. Actually, current policies labeled population control do not deal with mortality and migration, but deal only with the birth input. This is why another term, *fertility control*, is frequently used to describe current policies. But, as I show below, family planning (and hence current policy) does

not undertake to influence most of the determinants of human reproduction. Thus the programs should not be referred to as population control or planning, because they do not attempt to influence the factors responsible for the attributes of human populations, taken generally; nor should they be called fertility control, because they do not try to affect most of the determinants of reproductive performance.

The ambiguity does not stop here, however. When one speaks of controlling population size, any inquiring person naturally asks, What is "control"? Who is to control whom? Precisely what population size, or what rate of population growth, is to be achieved? Do the policies aim to produce a growth rate that is nil, one that is very slight, or one that is like that of the industrial nations? Unless such questions are dealt with and clarified, it is impossible to evaluate current population policies.

The actual programs seem to be aiming simply to achieve a reduction in the birth rate. Success is therefore interpreted as the accomplishment of such a reduction, on the assumption that the reduction will lessen population growth. In those rare cases where a specific demographic aim is stated, the goal is said to be a short-run decline within a given period. The Pakistan plan adopted in 1966 (5, p. 889) aims to reduce the birth rate from 50 to 40 per thousand by 1970; the Indian plan (6) aims to reduce the rate from 40 to 25 "as soon as possible"; and the Korean aim (7) is to cut population growth from 2.9 to 1.2 percent by 1980. A significant feature of such stated aims is the rapid population growth they would permit. Under conditions of modern mortality, a crude birth rate of 25 to 30 per thousand will represent such a multiplication of people as to make use of the term *population control* ironic. A rate of increase of 1.2 percent per year would allow South Korea's already dense population to double in less than 60 years.

One can of course defend the programs by saying that the present goals and measures are merely interim ones. A start must be made somewhere. But we do not find this answer in the population-policy literature. Such a defense, if convincing, would require a presentation of the next steps, and these are not considered. One suspects that the entire question of goals is instinctively left unasked, for the limitation of population growth would run counter

to national and group aspirations. A consideration of hypothetical goals throws further light on the matter.

Industrialized nations as the model. Since current policies are confined to family planning, their maximum demographic effect would be to give the underdeveloped countries the same level of reproductive performance that the industrial nations now have. The latter, long oriented toward family planning, provide a good yardstick for determining what the availability of contraceptives can do to population growth. Indeed, they provide more than a yardstick; they are actually the model which inspired the present population policies.

What does this goal mean in practice? Among the advanced nations there is considerable diversity in the level of fertility (8). At one extreme are countries such as New Zealand, with an average gross reproduction rate (GRR) of 1.91 during the period 1960-64; at the other extreme are countries such as Hungary, with a rate of 0.91 during the same period. To a considerable extent, however, such divergencies are matters of timing. The birth rates of most industrial nations have shown, since about 1940, a wave-like movement, with no secular trend. The average level of reproduction during this long period has been high enough to give these countries, with their low mortality, an extremely rapid population growth. If this level is maintained, their population will double in just over 50 years—a rate higher than that of world population growth at any time prior to 1950, at which time the growth in numbers of human beings was already considered fantastic. The advanced nations are suffering acutely from the effects of rapid population growth in combination with the production of ever more goods per person (9). A rising share of their supposedly high per capita income, which itself draws increasingly upon the resources of the underdeveloped countries (who fall farther behind in relative economic position), is spent simply to meet the costs, and alleviate the nuisances, of the unrelenting production of more and more goods by more people. Such facts indicate that the industrial nations provide neither a suitable demographic model for the nonindustrial peoples to follow nor the leadership to plan and organize effective population-control policies for them.

Most discussions of the population crisis

lead logically to zero population growth as the ultimate goal, because any growth rate, if continued, will eventually use up the earth. Yet hardly ever do arguments for population policy consider such a goal, and current policies do not dream of it. Why not? The answer is evidently that zero population growth is unacceptable to most nations and to most religious and ethnic communities. To argue for this goal would be to alienate possible support for action programs.

Goal peculiarities inherent in family planning. Turning to the actual measures taken, we see that the very use of family planning as the means for implementing population policy poses serious but unacknowledged limits on the intended reduction in fertility. The family-planning movement, clearly devoted to the improvement and dissemination of contraceptive devices, states again and again that its purpose is that of enabling couples to have the number of children they want. "The opportunity to decide the number and spacing of children is a basic human right," say the 12 heads of state in the United Nations declaration. The 1965 Turkish Law Concerning Population Planning declares (10):

Article 1. Population Planning means that individuals can have as many children as they wish, whenever they want to. This can be ensured through preventive measures taken against pregnancy. . . .

Logically, it does not make sense to use family planning to provide national population control or planning. The "planning" in family planning is that of each separate couple. The only control they exercise is control over the size of their family. Obviously, couples do not plan the size of the nation's population, any more than they plan the growth of the national income or the form of the highway network. There is no reason to expect that the millions of decisions about family size made by couples in their own interest will automatically control population for the benefit of society. On the contrary, there are good reasons to think they will not do so. At most, family planning can reduce reproduction to the extent that unwanted births exceed wanted births. In industrial countries the balance is often negative—that is, people have fewer children as a rule than they would like to have. In underdeveloped countries the reverse is normally true, but the elimination of unwanted births would still leave an ex-

tremely high rate of multiplication.

Actually, the family-planning movement does not pursue even the limited goals it professes. It does not fully empower couples to have only the number of offspring they want because it either condemns or disregards certain tabooed but nevertheless effective means to this goal. One of its tenets is that "there shall be freedom of choice of method so that individuals can choose in accordance with the dictates of their consciences" (11), but in practice this amounts to limiting the individual's choice, because the "conscience" dictating the method is usually not his but that of religious and governmental officials. Moreover, not every individual may choose: even the so-called recommended methods are ordinarily not offered to single women, or not all offered to women professing a given religious faith.

Thus, despite its emphasis on technology, current policy does not utilize all available means of contraception, much less all birth-control measures. The Indian government wasted valuable years in the early stages of its population-control program by experimenting exclusively with the "rhythm" method, long after this technique had been demonstrated to be one of the least effective. A greater limitation on means is the exclusive emphasis on contraception itself. Induced abortion, for example, is one of the surest means of controlling reproduction, and one that has been proved capable of reducing birth rates rapidly. It seems peculiarly suited to the threshold stage of a population-control program—the stage when new conditions of life first make large families disadvantageous. It was the principal factor in the halving of the Japanese birth rate, a major factor in the declines in birth rate of East-European satellite countries after legalization of abortions in the early 1950's, and an important factor in the reduction of fertility in industrializing nations from 1870 to the 1930's (12). Today, according to *Studies in Family Planning* (13), "abortion is probably the foremost method of birth control throughout Latin America." Yet this method is rejected in nearly all national and international population-control programs. American foreign aid is used to help stop abortion (14). The United Nations excludes abortion from family planning, and in fact justifies the latter by presenting it as a means of combating abortion (15).

Studies of abortion are being made in Latin America under the presumed auspices of population-control groups, not with the intention of legalizing it and thus making it safe, cheap, available, and hence more effective for population control, but with the avowed purpose of reducing it (16).

Although few would prefer abortion to efficient contraception (other things being equal), the fact is that both permit a woman to control the size of her family. The main drawbacks to abortion arise from its illegality. When performed, as a legal procedure, by a skilled physician, it is safer than childbirth. It does not compete with contraception but serves as a backstop when the latter fails or when contraceptive devices or information are not available. As contraception becomes customary, the incidence of abortion recedes even without its being banned. If, therefore, abortions enable women to have only the number of children they want, and if family planners do not advocate—in fact decry—legalization of abortion, they are to that extent denying the central tenet of their own movement. The irony of anti-abortionism in family-planning circles is seen, particularly in hair-splitting arguments over whether or not some contraceptive agent (for example, the IUD) is in reality an abortifacient. A Mexican leader in family planning writes (17):

One of the chief objectives of our program in Mexico is to prevent abortions. If we could be sure that the mode of action [of the IUD] was not interference with nidation, we could easily use the method in Mexico.

The questions of sterilization and unnatural forms of sexual intercourse usually meet with similar silent treatment or disapproval, although nobody doubts the effectiveness of these measures in avoiding conception. Sterilization has proved popular in Puerto Rico and has had some vogue in India (where the new health minister hopes to make it compulsory for those with a certain number of children), but in both these areas it has been for the most part ignored or condemned by the family-planning movement.

On the side of goals, then we see that a family-planning orientation limits the aims of current population policy. Despite reference to "population control" and "fertility control," which pre-

as a whole, the movement gives control only to couples, and does this only if they use "respectable" contraceptives.

The Neglect of Motivation

By sanctifying the doctrine that each woman should have the number of children she wants, and by assuming that if she has only that number this will automatically curb population growth to the necessary degree, the leaders of current policies escape the necessity of asking why women desire so many children and how this desire can be influenced (18, p. 41; 19). Instead, they claim that satisfactory motivation is shown by the popular desire (shown by opinion surveys in all countries) to have the means of family limitation, and that therefore the problem is one of inventing and distributing the best possible contraceptive devices. Overlooked is the fact that a desire for availability of contraceptives is compatible with high fertility.

Given the best of means, there remain the questions of how many children couples want and of whether this is the requisite number from the standpoint of population size. That it is not is indicated by continued rapid population growth in industrial countries, and by the very surveys showing that people want contraception—for these show, too, that people also want numerous children.

The family planners do not ignore motivation. They are forever talking about "attitudes" and "needs." But they pose the issue in terms of the "acceptance" of birth control devices. At the most naive level, they assume that lack of acceptance is a function of the contraceptive device itself. This reduces the motive problem to a technological question. The task of population control then becomes simply the invention of a device that will be acceptable (20). The plastic IUD is acclaimed because, once in place, it does not depend on repeated acceptance by the woman, and thus it "solves" the problem of motivation (21).

But suppose a woman does not want to use any contraceptive until after she has had four children. This is the type of question that is seldom raised in the family-planning literature. In that literature, wanting a specific number of children is taken as complete motivation, for it implies a wish to control the size of one's family. The individual

woman, from the standpoint of family planners, is the one who wants "as many as come," or "as many as God sends." Her attitude is construed as due to ignorance and "cultural values," and the policy deemed necessary to change it is "education." No compulsion can be used, because the movement is committed to free choice, but movie strips, posters, comic books, public lectures, interviews, and discussions are in order. These supply information and supposedly change values by discounting superstitions and showing that unrestrained procreation is harmful to both mother and children. The effort is considered successful when the woman decides she wants only a certain number of children and uses an effective contraceptive.

In viewing negative attitudes toward birth control as due to ignorance, apathy, and outworn tradition, and "mass-communication" as the solution to the motivation problem (22), family planners tend to ignore the power and complexity of social life. If it were admitted that the creation and care of new human beings is socially motivated, like other forms of behavior, by being a part of the system of rewards and punishments that is built into human relationships, and thus is bound up with the individual's economic and personal interests, it would be apparent that the social structure and economy must be changed before a deliberate reduction in the birth rate can be achieved. As it is, reliance on family planning allows people to feel that "something is being done about the population problem" without the need for painful social changes.

Designation of population control as a medical or public health task leads to a similar evasion. This categorization assures popular support because it puts population policy in the hands of respected medical personnel, but, by the same token, it gives responsibility for leadership to people who think in terms of clinics and patients, of pills and IUD's, and who bring to the handling of economic and social phenomena a self-confident naiveté. The study of social organization is a technical field; an action program based on intuition is no more apt to succeed in the control of human beings than it is in the area of bacterial or viral control. Moreover, to alter a social system, by deliberate policy, so as to regulate births in accord with the demands of the collective well-being, requires a different power, and

this is not likely to inhere in public health officials, nurses, midwives, and social workers. To entrust population policy to them is "to take action," but not dangerous "effective action."

Similarly, the Janus-faced position on birth-control technology represents an escape from the necessity, and onus, of grappling with the social and economic determinants of reproductive behavior. On the one side, the rejection or avoidance of religiously tabooed but otherwise effective means of birth prevention enables the family-planning movement to avoid official condemnation. On the other side, an intense preoccupation with contraceptive technology (apart from the tabooed means) also helps the family planners to avoid censure. By implying that the only need is the invention and distribution of effective contraceptive devices, they allay fears, on the part of religious and governmental officials, that fundamental changes in social organization are contemplated. Changes basic enough to affect motivation for having children would be changes in the structure of the family, in the position of women, and in the sexual mores. Far from proposing such radicalism, spokesmen for family planning frequently state their purpose as "protection" of the family—that is, closer observance of family norms. In addition, by concentrating on new and scientific contraceptives, the movement escapes taboos attached to old ones (the Pope will hardly authorize the condom, but may sanction the pill) and allows family planning to be regarded as a branch of medicine: overpopulation becomes a disease, to be treated by a pill or a coil.

We thus see that the inadequacy of current population policies with respect to motivation is inherent in their overwhelmingly family-planning character. Since family planning is by definition private planning, it eschews any societal control over motivation. It merely furnishes the means, and, among possible means, only the most respectable. Its leaders, in avoiding social complexities and seeking official favor, are obviously activated not solely by expediency but also by their own sentiments as members of society and by their background as persons attracted to the family-planning movement. Unacquainted for the most part with technical economics, sociology, and demography, they tend honestly and instinctively to believe that something they vaguely call population control can be achieved by making better contraceptives available.

The Evidence of Ineffectiveness

If this characterization is accurate, we can conclude that current programs will not enable a government to control population size. In countries where couples have numerous offspring that they do not want, such programs may possibly accelerate a birth-rate decline that would occur anyway, but the conditions that cause births to be wanted or unwanted are beyond the control of family planning, hence beyond the control of any nation which relies on family planning alone as its population policy.

This conclusion is confirmed by demographic facts. As I have noted above, the widespread use of family planning in industrial countries has not given their governments control over the birth rate. In backward countries today, taken as a whole, birth rates are rising, not falling; in those with population policies, there is no indication that the government is controlling the rate of reproduction. The main "successes" cited in the well-publicized policy literature are cases where a large number of contraceptives have been distributed or where the program has been accompanied by some decline in the birth rate. Popular enthusiasm for family planning is found mainly in the cities, or in advanced countries such as Japan and Taiwan, where the people would adopt contraception in any case, program or no program. It is difficult to prove that present population policies have even speeded up a lowering of the birth rate (the least that could have been expected), much less that they have provided national "fertility control."

Let us next briefly review the facts concerning the level and trend of population in underdeveloped nations generally, in order to understand the magnitude of the task of genuine control.

Rising Birth Rates in Underdeveloped Countries

In ten Latin-American countries, between 1940 and 1959 (23), the average birth rates (age-standardized), as estimated by our research office at the University of California, rose as follows: 1940-44, 43.4 annual births per 1000 population; 1945-49, 44.6; 1950-54, 46.4; 1955-59, 47.7.

In another study made in our office, in 1958, it was found that the population growth from the theory of quasi-stable popula-

tions were used, the recent trend was found to be upward in 27 underdeveloped countries, downward in six, and unchanged in one (24). Some of the rises have been substantial, and most have occurred where the birth rate was already extremely high. For instance, the gross reproduction rate rose in Jamaica from 1.8 per thousand in 1947 to 2.7 in 1960; among the natives of Fiji, from 2.0 in 1951 to 2.4 in 1964; and in Albania, from 3.0 in the period 1950-54 to 3.4 in 1960.

The general rise in fertility in backward regions is evidently not due to failure of population-control efforts, because most of the countries either have no such effort or have programs too new to show much effect. Instead, the rise is due, ironically, to the very circumstance that brought on the population crisis in the first place—to improved health and lowered mortality. Better health increases the probability that a woman will conceive and retain the fetus to term; lowered mortality raises the proportion of babies who survive to the age of reproduction and reduces the probability of widowhood during that age (25). The significance of the general rise in fertility, in the context of this discussion, is that it is giving would-be population planners a harder task than many of them realize. Some of the upward pressure on birth rates is independent of what couples do about family planning, for it arises from the fact that, with lowered mortality, there are simply more couples.

Underdeveloped Countries with Population Policies

In discussions of population policy there is often confusion as to which cases are relevant. Japan, for instance, has been widely praised for the effectiveness of its measures, but it is a very advanced industrial nation and, besides, its government policy had little or nothing to do with the decline in the birth rate, except unintentionally. It therefore offers no test of population policy under peasant-agrarian conditions. Another case of questionable relevance is that of Taiwan, because Taiwan is sufficiently developed to be placed in the urban-industrial class of nations. However, since Taiwan is offered as the main showpiece by the sponsors of current policies in underdeveloped areas, and since the data are available, Taiwan is acclaimed as a showpiece

Table 1. Decline in Taiwan's fertility rate, 1951 through 1966.

Year	Registered births per 1000 women aged 15-49	Change in rate (percent)*
1951	211	
1952	198	-5.6
1953	194	-2.2
1954	193	-0.5
1955	197	+2.1
1956	196	-0.4
1957	182	-7.1
1958	185	+1.3
1959	184	-0.1
1960	180	-2.5
1961	177	-1.5
1962	174	-1.5
1963	170	-2.6
1964	162	-4.9
1965	152	-6.0
1966	149	-2.1

* The percentages were calculated on unrounded figures. Source of data through 1965, Taiwan Demographic Fact Book (1964, 1965); for 1966, Monthly Bulletin of Population Registration Statistics of Taiwan (1966, 1967).

because it has responded favorably to a highly organized program for distributing up-to-date contraceptives and has also had a rapidly dropping birth rate. Some observers have carelessly attributed the decline in the birth rate—from 50.0 in 1951 to 32.7 in 1965—to the family-planning campaign (26), but the campaign began only in 1963 and could have affected only the end of the trend. Rather, the decline represents a response to modernization similar to that made by all countries that have become industrialized (27). By 1950 over half of Taiwan's population was urban, and by 1964 nearly two-thirds were urban, with 29 percent of the population living in cities of 100,000 or more. The pace of economic development has been extremely rapid. Between 1951 and 1963, per capita income increased by 4.05 percent per year. Yet the island is closely packed, having 870 persons per square mile (a population density higher than that of Belgium). The combination of fast economic growth and rapid population increase in limited space has put parents of large families at a relative disadvantage and has created a brisk demand for abortions and contraceptives. Thus the favorable response to the current campaign to encourage use of the IUD is not a good example of what birth-control technology can do for a genuinely backward country. In fact, when the program was started, one reason for expecting receptivity was that the island was already on its way to modernization and family planning (28).

At most, the recent family-planning campaign, which has had a significant

proportions only in 1964, when some 46,000 IUD's were inserted (in 1965 the number was 99,253, and in 1966, 111,242) (29; 30, p. 45)—could have caused the increase observable after 1963 in the rate of decline. Between 1951 and 1963 the average drop in the birth rate per 1000 women (see Table 1) was 1.73 percent per year; in the period 1964-66 it was 4.35 percent. But one hesitates to assign all of the acceleration in decline since 1963 to the family-planning campaign. The rapid economic development has been precisely of a type likely to accelerate a drop in reproduction. The rise in manufacturing has been much greater than the rise in either agriculture or construction. The agricultural labor force has thus been squeezed, and migration to the cities has skyrocketed (31). Since housing has not kept pace, urban families have had to restrict reproduction in order to take advantage of career opportunities and avoid domestic inconvenience. Such conditions have historically tended to accelerate a decline in birth rate. The most rapid decline came late in the United States (1921-33) and in Japan (1947-55). A plot of the Japanese and Taiwanese birth rates (Fig. 1) shows marked similarity of the two curves, despite a difference in level. All told, one should not attribute all of the post-1963 acceleration in the decline of Taiwan's birth rate to the family-planning campaign.

The main evidence that some of this acceleration is due to the campaign comes from the fact that Taichung, the city in which the family-planning effort was first concentrated, showed subsequently a much faster drop in fertility than other cities (30, p. 69; 32). But the campaign has not reached throughout the island. By the end of 1966, only 260,745 women had been fitted with an IUD under auspices of the campaign, whereas the women of reproductive age on the island numbered 2.86 million. Most of the reduction in fertility has therefore been a matter of individual initiative. To some extent the campaign may be simply substituting sponsored (and cheaper) services for those that would otherwise come through private and commercial channels. An island-wide survey in 1964 showed that over 150,000 women were already using the traditional Ota ring (a metallic intrauterine device popular in Japan); almost as many had been sterilized; about 40,000 were using foam tablets; some 50,000 admitted to having had at least one abortion; and

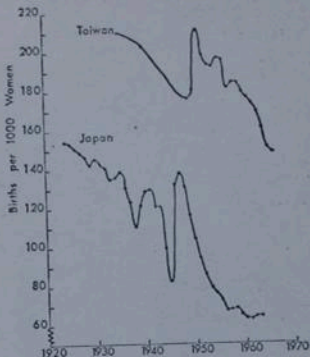


Fig. 1. Births per 1000 women aged 15 through 49 in Japan and Taiwan.

many were using other methods of birth control (30, pp. 18, 31).

The important question, however, is not whether the present campaign is somewhat hastening the downward trend in the birth rate but whether, even if it is, it will provide population control for the nation. Actually, the campaign is not designed to provide such control and shows no sign of doing so. It takes for granted existing reproductive goals. Its aim is "to integrate, through education and information, the idea of family limitation within the existing attitudes, values, and goals of the people" [30, p. 8 (italics mine)]. Its target is married women who do not want any more children; it ignores girls not yet married, and women married and wanting more children.

With such an approach, what is the maximum impact possible? It is the difference between the number of children women have been having and the number they want to have. A study in 1957 found a median figure of 3.75 for the number of children wanted by women aged 15 to 29 in Taipei, Taiwan's largest city; the corresponding figure for women from a satellite town was 3.93; for women from a fishing village, 4.90; and for women from a farming village, 5.03. Over 60 percent of the women in Taipei and over 90 percent of those in the farming village wanted 4 or more children (33). In a sample of wives aged 25 to 29 in Taichung, a city of over 300,000, Freedman and his co-workers found the average number of children wanted was 4; only 9 percent wanted less than 3, 20 percent wanted 5 or more (34). If, therefore, Taiwanese women used

contraceptives that were 100-percent effective and had the number of children they desire, they would have about 4.5 each. The goal of the family-planning effort would be achieved. In the past the Taiwanese woman who married and lived through the reproductive period had, on the average, approximately 6.5 children; thus a figure of 4.5 would represent a substantial decline in fertility. Since mortality would continue to decline, the population growth rate would decline somewhat less than individual reproduction would. With 4.5 births per woman and a life expectancy of 70 years, the rate of natural increase would be close to 3 percent per year (35).

In the future, Taiwanese views concerning reproduction will doubtless change, in response to social change and economic modernization. But how far will they change? A good indication is the number of children desired by couples in an already modernized country long oriented toward family planning. In the United States in 1966, an average of 3.4 children was considered ideal by white women aged 21 or over (36). This average number of births would give Taiwan, with only a slight decrease in mortality, a long-run rate of natural increase of 1.7 percent per year and a doubling of population in 41 years.

Detailed data confirm the interpretation that Taiwanese women are in the process of shifting from a "peasant-agrarian" to an "industrial" level of reproduction. They are, in typical fashion, cutting off higher-order births at age 30 and beyond (37). Among young wives, fertility has risen, not fallen. In sum, the widely acclaimed family-planning program in Taiwan may, at most, have somewhat speeded the later phase of fertility decline which would have occurred anyway because of modernization.

Moving down the scale of modernization, to countries most in need of population control, one finds the family-planning approach even more inadequate. In South Korea, second only to Taiwan in the frequency with which it is cited as a model of current policy, a recent birth-rate decline of unknown extent is assumed by leaders to be due overwhelmingly to the government's family-planning program. However, it is just as plausible to say that the net effect of government involvement in population control has been, so far, to delay rather than hasten a decline in reproduction. In the United States, the

and economic changes. Although the government is advocating vasectomies and providing IUD's and pills, it refuses to legalize abortions, despite the rapid rise in the rate of illegal abortions and despite the fact that, in a recent survey, 72 percent of the people who stated an opinion favored legalization. Also, the program is presented in the context of maternal and child health; it thus emphasizes motherhood and the family rather than alternative roles for women. Much is made of the fact that opinion surveys show an overwhelming majority of Koreans (89 percent in 1965) favoring contraception (38, p. 27), but this means only that Koreans are like other people in wishing to have the means to get what they want. Unfortunately, they want sizable families: "The records indicate that the program appeals mainly to women in the 30-39 year age bracket who have four or more children, including at least two sons . . ." (38, p. 25).

In areas less developed than Korea the degree of acceptance of contraception tends to be disappointing, especially among the rural majority. Faced with this discouragement, the leaders of current policy, instead of reexamining their assumptions, tend to redouble their effort to find a contraceptive that will appeal to the most illiterate peasant, forgetting that he wants a good-sized family. In the rural Punjab, for example, "a disturbing feature . . . is that the females start to seek advice and adopt family planning techniques at the fag end of their reproductive period" (39). Among 5196 women coming to rural Punjabi family-planning centers, 38 percent were over 35 years old, 67 percent over 30. These women had married early, nearly a third of them before the age of 15 (40); some 14 percent had eight or more living children when they reached the clinic, 51 percent six or more.

A survey in Tunisia showed that 68 percent of the married couples were willing to use birth-control measures, but the average number of children they considered ideal was 4.3 (41). The corresponding averages for a village in eastern Java, a village near New Delhi, and a village in Mysore were 4.3, 4.0, and 4.2, respectively (42, 43). In the cities of these regions women are more ready to accept birth control and they want fewer children than village women do, but the number they consider desirable is still wholly unsatisfactory from the standpoint of population control. In the United States, the

ning center in Tunisia, more than 600 of 900 women accepting contraceptives had four living children already (44). In Bangalore, a city of nearly a million at the time (1952), the number of offspring desired by married women was 3.7 on the average; by married men, 4.1 (45). In the metropolitan area of San Salvador (350,000 inhabitants) a 1964 survey (45) showed the number desired by women of reproductive age to be 3.9, and in seven other capital cities of Latin America the number ranged from 2.7 to 4.2. If women in the cities of underdeveloped countries used birth-control measures with 100-percent efficiency, they still would have enough babies to expand city populations senselessly, quite apart from the added contribution of rural-urban migration. In many of the cities the difference between actual and ideal number of children is not great; for instance, in the seven Latin-American capitals mentioned above, the ideal was 3.4 whereas the actual births per woman in the age range 35 to 39 was 3.7 (46). Bombay City has had birth-control clinics for many years, yet its birth rate (standardized for age, sex, and marital distribution) is still 34 per 1000 inhabitants and is tending to rise rather than fall. Although this rate is about 13 percent lower than that for India generally, it has been about that much lower since at least 1951 (47).

Is Family Planning the "First Step" in Population Control?

To acknowledge that family planning does not achieve population control is not to impugn its value for other purposes. Freeing women from the need to have more children than they want is of great benefit to them and their children and to society at large. My argument is therefore directed not against family-planning programs as such but against the assumption that they are an effective means of controlling population growth.

But what difference does it make? Why not go along for awhile with family planning as an initial approach to the problem of population control? The answer is that any policy on which millions of dollars are being spent should be designed to achieve the goal it purports to achieve. If it is only a first step, it should be so labeled, and its connection with the next step (and the nature of that next step) should be made clear. In the United States, the

since no "next step" seems ever to be mentioned, the question arises, Is reliance on family planning in fact a basis for dangerous postponement of effective steps? To continue to offer a remedy as a cure long after it has been shown merely to ameliorate the disease is either quackery or wishful thinking, and it thrives most where the need is greatest. Today the desire to solve the population problem is so intense that we are all ready to embrace any "action program" that promises relief. But postponement of effective measures allows the situation to worsen.

Unfortunately, the issue is confused by a matter of semantics. "Family planning" and "fertility control" suggest that reproduction is being regulated according to some rational plan. And so it is, but only from the standpoint of the individual couple, not from that of the community. What is rational in the light of a couple's situation may be totally irrational from the standpoint of society's welfare.

The need for societal regulation of individual behavior is readily recognized in other spheres—those of explosives, dangerous drugs, public property, natural resources. But in the sphere of reproduction, complete individual initiative is generally favored even by those liberal intellectuals who, in other spheres, most favor economic and social planning. Social reformers who would not hesitate to force all owners of rental property to rent to anyone who can pay, or to force all workers in an industry to join a union, balk at any suggestion that couples be permitted to have only a certain number of offspring. Invariably they interpret societal control of reproduction as meaning direct police supervision of individual behavior. Put the word *compulsory* in front of any term describing a means of limiting births—*compulsory sterilization, compulsory abortion, compulsory contraception*—and you guarantee violent opposition. Fortunately, such direct controls need not be invoked, but conservatives and radicals alike overlook this in their blind opposition to the idea of collective determination of a society's birth rate.

That the exclusive emphasis on family planning in current population policies is not a "first step" but an escape from the real issues is suggested by two facts. (i) No country has taken the "next step." The industrialized countries have had family planning for half a century, but no regular control over either the birth rate or population

increase. (ii) Support and encouragement of research on population policy other than family planning is negligible. It is precisely this blocking of alternative thinking and experimentation that makes the emphasis on family planning a major obstacle to population control. The need is not to abandon family-planning programs but to put equal or greater resources into other approaches.

New Directions in Population Policy

In thinking about other approaches, one can start with known facts. In the past, all surviving societies had institutional incentives for marriage, procreation, and child care which were powerful enough to keep the birth rate equal to or in excess of a high death rate. Despite the drop in death rates during the last century and a half, the incentives tended to remain intact because the social structure (especially in regard to the family) changed little. At most, particularly in industrial societies, children became less productive and more expensive (48). In present-day agrarian societies, where the drop in death rate has been more recent, precipitate, and independent of social change (49), motivation for having children has changed little. Here, even more than in industrialized nations, the family has kept on producing abundant offspring, even though only a fraction of these children are now needed.

If excessive population growth is to be prevented, the obvious requirement is somehow to impose restraints on the family. However, because family roles are reinforced by society's system of rewards, punishments, sentiments, and norms, any proposal to demote the family is viewed as a threat by conservatives and liberals alike, and certainly by people with enough social responsibility to work for population control. One is charged with trying to "abolish" the family, but what is required is selective restructuring of the family in relation to the rest of society.

The lines of such restructuring are suggested by two existing limitations on fertility. (i) Nearly all societies succeed in drastically discouraging reproduction among unmarried women. (ii) Advanced societies unintentionally reduce reproduction among married women when conditions worsen in such a way as to penalize childbearing more severely than it was penalized before. In both cases the causes are motivational and economic rather than technological.

It follows that population-control policy can de-emphasize the family in two ways: (i) by keeping present controls over illegitimate childbirth yet making the most of factors that lead people to postpone or avoid marriage, and (ii) by instituting conditions that motivate those who do marry to keep their families small.

Postponement of Marriage

Since the female reproductive span is short and generally more fecund in its first than in its second half, postponement of marriage to ages beyond 20 tends biologically to reduce births. Sociologically, it gives women time to get a better education, acquire interests unrelated to the family, and develop a cautious attitude toward pregnancy (50). Individuals who have not married by the time they are in their late twenties often do not marry at all. For these reasons, for the world as a whole, the average age at marriage for women is negatively associated with the birth rate: a rising age at marriage is a frequent cause of declining fertility during the middle phase of the demographic transition; and, in the late phase, the "baby boom" is usually associated with a return to younger marriages.

Any suggestion that age at marriage be raised as a part of population policy is usually met with the argument that "even if a law were passed, it would not be obeyed." Interestingly, this objection implies that the only way to control the age at marriage is by direct legislation, but other factors govern the actual age. Roman Catholic countries generally follow canon law in stipulating 12 years as the minimum legal age at which girls may marry, but the actual average age at marriage in these countries (at least in Europe) is characteristically more like 25 to 28 years. The actual age is determined, not by law, but by social and economic conditions. In agrarian societies, postponement of marriage (when postponement occurs) is apparently caused by difficulties in meeting the economic prerequisites for matrimony, as stipulated by custom and opinion. In industrial societies it is caused by housing shortages, unemployment, the requirement for overseas military service, high costs of education, and inadequacy of consumer services. Since almost no research has been devoted to the subject, it is difficult to assess the relative weight of the factors

Encouraging Limitation of Births within Marriage

As a means of encouraging the limitation of reproduction within marriage, as well as postponement of marriage, a greater rewarding of nonfamilial than of familial roles would probably help. A simple way of accomplishing this would be to allow economic advantages to accrue to the single as opposed to the married individual, and to the small as opposed to the large family. For instance, the government could pay people to permit themselves to be sterilized (51); all costs of abortion could be paid by the government; a substantial fee could be charged for a marriage license; a "child-tax" (52) could be levied; and there could be a requirement that illegitimate pregnancies be aborted. Less sensationally, governments could simply reverse some existing policies that encourage childbearing. They could, for example, cease taxing single persons more than married ones; stop giving parents special tax exemptions; abandon income-tax policy that discriminates against couples when the wife works; reduce paid maternity leaves; reduce family allowances (53); stop awarding public housing on the basis of family size; stop granting fellowships and other educational aids (including special allowances for wives and children) to married students; cease outlawing abortions and sterilizations; and relax rules that allow use of harmless contraceptives only with medical permission. Some of these policy reversals would be beneficial in other than demographic respects and some would be harmful unless special precautions were taken. The aim would be to reduce the number, not the quality, of the next generation.

A closely related method of de-emphasizing the family would be modification of the complementarity of the roles of men and women. Men are now able to participate in the wider world yet enjoy the satisfaction of having several children because the housework and childcare fall mainly on their wives. Women are impelled to seek this role by their idealized view of marriage and motherhood and by either the scarcity of alternative roles or the difficulty of combining them with family roles. To change this situation women could be required to work outside the home, or compelled by circumstances to do so. If, at the same time, women were paid as well as men and given

equal educational and occupational opportunities, and if social life were organized around the place of work rather than around the home or neighborhood, many women would develop interests that would compete with family interests. Approximately this policy is now followed in several Communist countries, and even the less developed of these currently have extremely low birth rates (54).

That inclusion of women in the labor force has a negative effect on reproduction is indicated by regional comparisons (18, p. 1195; 55). But in most countries the wife's employment is subordinate, economically and emotionally, to her family role, and is readily sacrificed for the latter. No society has restructured both the occupational system and the domestic establishment to the point of permanently modifying the old division of labor by sex.

In any deliberate effort to control the birth rate along these lines, a government has two powerful instruments—its command over economic planning and its authority (real or potential) over education. The first determines (as far as policy can) the economic conditions and circumstances affecting the lives of all citizens; the second provides the knowledge and attitudes necessary to implement the plans. The economic system largely determines who shall work, what can be bought, what rearing children will cost, how much individuals can spend. The schools define family roles and develop vocational and recreational interests; they could, if it were desired, redefine the sex roles, develop interests that transcend the home, and transmit realistic (as opposed to moralistic) knowledge concerning marriage, sexual behavior, and population problems. When the problem is viewed in this light, it is clear that the ministries of economics and education, not the ministry of health, should be the source of population policy.

The Dilemma of Population Policy

It should now be apparent why, despite strong anxiety over runaway population growth, the actual programs purporting to control it are limited to family planning and are therefore ineffective. (i) The goal of zero, or even slight, population growth is one that nations and groups find difficult to accept. (ii) The measures that would be required to implement such a goal,

though not so revolutionary as a Brave New World or a Communist Utopia, nevertheless tend to offend most people reared in existing societies. As a consequence, the goal of so-called population control is implicit and vague; the method is only family planning. This method, far from de-emphasizing the family, is familistic. One of its stated goals is that of helping sterile couples to have children. It stresses parental aspirations and responsibilities. It goes along with most aspects of conventional morality, such as condemnation of abortion, disapproval of premarital intercourse, respect for religious teachings and cultural taboos, and obedience to medical and clerical authority. It deflects hostility by refusing to recommend any change other than the one it stands for: availability of contraceptives.

The things that make family planning acceptable are the very things that make it ineffective for population control. By stressing the right of parents to have the number of children they want, it evades the basic question of population policy, which is how to give societies the number of children they need. By offering only the means for couples to control fertility, it neglects the means for societies to do so.

Because of the predominantly profamily character of existing societies, individual interest ordinarily leads to the production of enough offspring to constitute rapid population growth under conditions of low mortality. Childless or single-child homes are considered indicative of personal failure, whereas having three to five living children gives a family a sense of continuity and substantiality (56).

Given the existing desire to have moderate-sized rather than small families, the only countries in which fertility has been reduced to match reduction in mortality are advanced ones temporarily experiencing worsened economic conditions. In Sweden, for instance, the net reproduction rate (NRR) has been below replacement for 34 years (1930–63), if the period is taken as a whole, but this is because of the economic depression. The average replacement rate was below unity (NRR = 0.81) for the period 1930–42, but from 1942 through 1963 it was above unity (NRR = 1.08). Hardships that seem particularly conducive to deliberate lowering of the birth rate are (in managed economies) scarcity of housing and other consumer goods despite full employment, and required high partici-

Because
family of
individual

pation of women in the labor force, or (in freer economies) a great deal of unemployment and economic insecurity. When conditions are good, any nation tends to have a growing population.

It follows that, in countries where contraception is used, a realistic proposal for a government policy of lowering the birth rate reads like a catalogue of horrors: squeeze consumers through taxation and inflation; make housing very scarce by limiting construction; force wives and mothers to work outside the home to offset the inadequacy of male wages, yet provide few child-care facilities; encourage migration to the city by paying low wages in the country and providing few rural jobs; increase congestion in cities by starving the transit system; increase personal insecurity by encouraging conditions that produce unemployment and by haphazard political arrests. No government will institute such hardships simply for the purpose of controlling population growth. Clearly, therefore, the task of contemporary population policy is to develop attractive substitutes for family interests, so as to avoid having to turn to hardship as a corrective. The specific measures required for developing such substitutes are not easy to determine in the absence of research on the question.

In short, the world's population problem cannot be solved by pretense and wishful thinking. The unthinking identification of family planning with population control is an ostrich-like approach in that it permits people to hide from themselves the enormity and unconventionality of the task. There is no reason to abandon family-planning programs; contraception is a valuable technological instrument. But such programs must be supplemented with equal or greater investments in research and experimentation to determine the required socioeconomic measures.

References and Notes

1. *Studies in Family Planning*, No. 16 (1967).
2. *Ibid.*, No. 9 (1966), p. 1.
3. The statement is given in *Studies in Family Planning* (I, p. 1), and in *Population Bull.* 23, 6 (1967).
4. The statement is quoted in *Studies in Family Planning* (I, p. 2).
5. *Hearings on S. 1676, U.S. Senate, Subcommittee on Foreign Aid Expenditures, 89th Congress, Second Session, April 7, 8, 11 (1966)*, p. 4.
6. B. L. Kozin, in *Family Planning and Population Programs*, B. Berelson, R. K. Anderson, O. Harkavy, G. Maier, W. P. Mauldin, S. G. Segal, Eds. (Univ. of Chicago Press, Chicago, 1966).
7. D. Kirk, *Amer. Acad. Polit. Soc. Sci.* 269, 53 (1967).

8. As used by English-speaking demographers, the word *fertility* designates actual fecundity, not performance, not a theoretical capacity.
9. K. Davis, *Rotarian* 91, 10 (1959); *Health Educ. Monographs* 9, 2 (1960); L. Day and A. Day, *Too Many Americans* (Houghton Mifflin, Boston, 1964); R. A. Fiddling, *Limits of Mankind* (Wright, Bristol, England, 1956).
10. *Official Gazette* (15 Apr. 1965); quoted in *Studies in Family Planning* (I, p. 7).
11. J. W. Gardner, Secretary of Health, Education, and Welfare, "Monotony to Health of Operating Agencies" (Jan. 1966), reproduced in *Hearings on S. 1676* (5), p. 783.
12. C. Tietze, *Demography* 1, 119 (1964); *J. Chronic Diseases* 18, 1161 (1964); M. Muramatsu, *Milbank Mem. Fund Quart.* 28, 153 (1960); K. Davis, *Population Index* 29, 345 (1963); R. Armijo and T. Monreal, *J. Sex Res.* 1964, 143 (1964); *Proceedings World Population Conference, Belgrade, 1965; Proceedings International Planned Parenthood Federation*.
13. *Studies in Family Planning*, No. 4 (1964), p. 3.
14. D. Bell (then administrator for Agency for International Development), in *Hearings on S. 1676* (5), p. 862.
15. *World Population Conference* (United Nations, New York, 1964), p. 30.
16. R. Armijo and T. Monreal, in *Components of Population Change in Latin America* (Milbank Fund, New York, 1965), p. 272; E. 180e-Wray, *Amer. J. Public Health* 54, 313 (1964).
17. E. Rice-Wray, in "Intra-Uterine Contraceptive Devices," *Excerpta Med. Intern. Congr. Ser. No. 54* (1962), p. 135.
18. J. Blake, in *Public Health and Population Change*, M. C. Sheps and J. C. Ridley, Eds. (Univ. of Pittsburgh Press, Pittsburgh, 1965).
19. J. Blake and K. Davis, *Amer. Behavioral Scientist*, 5, 24 (1963).
20. See "Panel discussion on comparative acceptability of different methods of contraception," in *Research in Family Planning*, C. V. Klier, Ed. (Princeton Univ. Press, Princeton, 1962), pp. 373-86.
21. "From the point of view of the woman concerned, the whole problem of continuing population expansion," D. Kirk, in *Population Dynamics*, M. Muramatsu and P. A. Harper, Eds. (Johns Hopkins Press, Baltimore, 1965).
22. "For influencing family size norms, certainly the examples and statements of public figures are of great significance. . . also . . . use of mass-communication methods which help to legitimize the small-family style, to provoke conversation, and to establish a vocabulary for discussion of family planning." (M. W. Freymann, in *Population Dynamics*, M. Muramatsu and P. A. Harper, Eds. (Johns Hopkins Press, Baltimore, 1965)).
23. O. A. Collier, *Birth Rates in Latin America* (International Population and Urban Research, Berkeley, Calif. 1965), pp. 27-28; the ten countries were Colombia, Costa Rica, El Salvador, Ecuador, Guatemala, Honduras, Mexico, Panamá, Peru, and Venezuela.
24. J. R. Rele, *Fertility Analysis through Extension of Stable Population Concepts* (International Population and Urban Research, Berkeley, Calif. 1967).
25. J. C. Ridley, M. C. Sheps, J. W. Lingner, J. A. Menken, *Milbank Mem. Fund Quart.* 45, 77 (1967); E. Arias, unpublished paper.
26. "South Korea and Taiwan appear successfully to have checked population growth by the use of intrauterine contraceptive devices" (U. Borck, *Hearings on S. 1676* (3), p. 556).
27. K. Davis, *Population Index* 29, 345 (1963).
28. R. Freedman, *ibid.* 31, 421 (1965).
29. Before 1964 the Family Planning Association had given advice to fewer than 60,000 wives in 10 years and a Pre-Pregnancy Health Program had reached some 10,000, and in the current campaign, 3550 IUD's were inserted in 1965, in a total population of 2½ million women of reproductive age. See *Studies in Family Planning*, No. 19 (1967), p. 4, and R. Freedman et al., *Population Studies* 16, 231 (1963).
30. R. W. Gillespie, *Family Planning on Taiwan* (Population Council, Taichung, 1965).
31. During the period 1950-60 the ratio of growth of the city to growth of the noncity population was 5:3; during the period 1960-64 the ratio was 5:3; these ratios are based on data of Shao-shing Chen, *J. Sociol. Taiwan* 1, 74 (1963) and data in the United Nations *Demographic Yearbook*.
32. R. Freedman, *Population Index* 31, 434 (1965). Taichung's rate of decline in 1963-64 was roughly double the average in four other cities, whereas just prior to the campaign its rate of decline had been much less than theirs.
33. S. H. Chen, *J. Soc. Sci. Taipei* 13, 72 (1965).
34. R. Freedman et al., *Population Studies* 16, 227 (1963); *ibid.*, p. 232.
35. In 1964 the life expectancy at birth was already 66 years in Taiwan, as compared to 70 for the United States.
36. J. Blake, *Eugenics Quart.* 14, 68 (1967).
37. Women accepting IUD's in the family-planning program are typically 30 to 34 years old and have already had four children. (*Studies in Family Planning* No. 19 (1967), p. 5).
38. Y. K. Cha, in *Family Planning and Population Programs*, B. Berelson et al., Eds. (Univ. of Chicago Press, Chicago, 1966).
39. H. S. Ayali and S. S. Johl, *J. Family Welfare* 12, 60 (1965).
40. Sixty percent of the women had borne their first child before age 19. Early marriage is strongly supported by public opinion. Of couples polled in the Punjab, 48 percent said that girls should marry before age 16, and 94 percent said they should marry before age 20 (H. S. Ayali and S. S. Johl, *ibid.*, p. 57). A study of 2380 couples in 60 villages of Uttar Pradesh found that the women had consummated their marriage at an average age of 14.6 years (J. R. Rele, *Population Studies* 15, 268 (1962)).
41. J. Morsa, in *Family Planning and Population Programs*, B. Berelson et al., Eds. (Univ. of Chicago Press, Chicago, 1966).
42. H. Gilks, in *Family Planning and Population Programs*, B. Berelson et al., Eds. (Univ. of Chicago Press, Chicago, 1966).
43. S. N. Agarwal, *Med. Dig. Bombay* 4, 653 (1961).
44. *Mysoor Population Study* (United Nations, New York, 1961), p. 140; see *World Population Program*, B. Berelson et al., Eds. (Univ. of Chicago Press, Chicago, 1966).
45. C. J. Gómez, paper presented at the World Population Conference, Belgrade, 1965.
46. C. Miro, in *Family Planning and Population Programs*, B. Berelson et al., Eds. (Univ. of Chicago Press, Chicago, 1966).
47. *Demographic Training and Research Centre* (Indian Newsletter 20, 4 (Aug. 1966)).
48. K. Davis, *Population Index* 29, 345 (1963). For economic and sociological theory of motivation for bare children, see J. Blake [Univ. of California (Berkeley)], in preparation.
49. K. Davis, *Amer. Economic Rev.* 46, 305 (1956); *Sci. Amer.* 209, 68 (1963).
50. J. Blake, *World Population Conference* (Belgrade, 1965) (United Nations, New York, 1967), vol. 2, pp. 132-36.
51. S. Enke, *Rev. Economics Statistics* 42, 175 (1960); ———, *Econ. Develop. Cult. Change* 8, 339 (1960); ———, *ibid.* 10, 427 (1962); A. O. Krueger and L. A. Sjaastad, *ibid.*, p. 423.
52. T. J. Samuel, *J. Family Welfare India* 13, 12 (1966).
53. Sixty-two countries, including 27 in Europe, give cash payments to people for having children (U.S. Social Security Administration, *Social Security Programs Throughout the World, 1967* (Government Printing Office, Washington, D.C., 1967), pp. xxvii-xxviii).
54. Average gross reproduction rates in the early 1960's were as follows: Hungary, 0.91; Bulgaria, 1.09; Romania, 1.15; Yugoslavia, 1.32; O. A. Collier and E. Langlois, *Econ. Develop. Cult. Change* 10, 367 (1962); J. Weeks, [Univ. of California (Berkeley)], unpublished paper.
55. Roman Catholic textbooks condemn the "small" family (one with fewer than four children) as being abnormal (J. Blake, *Population Studies* 20, 27 (1966)).
56. Judith Blake's critical readings and discussions have greatly helped in the preparation of this article.

CITY OF BOULDER, COLORADO

October 27, 1969

Department of Housing and Urban Development
Contracts and Agreements Division
Room 2132
451 Seventh Street, S.W.
Washington, D. C. 20410

PROPOSAL, Submitted in Response
to RFP H-2-70, Municipal
Information Systems

Gentlemen:

The City of Boulder is pleased to submit the attached proposal to develop and implement the four (4) subsystems of a

COMPREHENSIVE, COMPUTER - BASED INTEGRATED MUNICIPAL INFORMATION SYSTEM (IMIS).

We have formed a consortium consisting of qualified senior personnel to implement our proposed approach. The personnel selected have a depth of experience in the design and development of information systems from both a manual and computer oriented standpoint.

Each member of the consortium has the breadth of professional resources necessary to insure a professional product to meet your requirements. Further, each member's financial and personnel resources will guarantee the successful completion and availability of a continued relationship in further implementation in the future.

This submission represents Volume I (TECHNICAL AND MANAGEMENT PROPOSAL) and is intended to be responsive to all of the items in the RFP H-2-70 and contains the commitments required of the City of Boulder as the prime contractor for this project.

Any questions concerning the proposal can be addressed to:

Paul Fasching, Director of Data Processing
City of Boulder
Municipal Building
Boulder, Colorado 80302
(303) 442-2020 Ext. 202

or

THE ECOLOGY OF INDONESIAN CITIES¹

NATHAN KEYFITZ

ABSTRACT

The problem of Indonesia, as of every new country of Asia, is to make its cities centers of industry, producing manufactured goods attractive enough to draw food from the countryside through trade. Its need to do this becomes more pressing as cities grow in numbers of residents. But the creation of productive facilities requires capital, including some in the form of foreign exchange. Much of the income which could be saved and invested is in the Outer Islands, and it is sought by the Outer Islands for their own development purposes, by the cities of Java for purchases of food and improvement of housing and other amenities, and by the cities of Java for the industrial development that would give them a national ecological base. The longer the delay in applying capital for the last-named purpose, the more difficult the task. For as the village populations increase they overtake their food supply, and the rice surplus which they could exchange for manufactured goods steadily diminishes.

Cities must be in an economic or political relation with areas of countryside that can produce the food to keep them alive. This basic rule determines the main lines of the ecology of cities and will continue to do so, at least until technology advances to the point where cities can produce their own food by mechanical means. Since the cities of precolonial, colonial, and independent Asia have had distinctive relations to their hinterlands, the operation of the rule has resulted in cities of different function and physical layout in the three periods.

Asian cities from earliest times to the present differ from those of North America in being as much political as economic centers. They were the points from which rulers administered their large or small domains. Where the domain was an expanse of countryside consisting of more or less self-contained villages, the problems of administration centered on the control of the hierarchy of officials who collected the taxes. Through these, sometimes mediated by money, flowed the food on which the chief city lived; on them depended the armies that would defend the city and surrounding territory, the craftsmen who would produce its art, and the scholars and theologians who would make it conscious of itself. Ancient Indian writers speak of periods of prosperity when the countryside was filled with industrious

peasants and of periods of harsh rule when the peasants deserted their farms and there was no one to pay the taxes. In times of peace when the administration was strong with that blend of cruelty and paternalism that held the ancient empires together, taxes were large and the capital city expanded its area and population. When administrations were weak and viceroys broke away or were not assiduous in getting food from the villages, the capital city diminished and provincial towns grew. The best system could break down under foreign attack or a ruler whose building programs were too ambitious.

The facts of ecology alone cannot tell us whether the surplus made possible by the technology of agriculture produced the towns or whether it was the organization for collecting the harvest instituted by the ruler which forced the improvement of technology and brought a surplus into view. We do know that even inefficient irrigated rice culture can support five hundred people per square mile of good land at the same time as it sells part of its product to pay taxes. The terracing and irrigation of land started in an earlier millennium in Central and East Java and has spread in a course which is only now reaching the extreme west of the island. This spread was part of a process of diffusion that carried irrigated rice culture through most of Southeast Asia and South China.

The internal structure of the ancient Javanese cities can be inferred from their present

form, although by much subsequent court is central, in the comfort of the tainers. Near it is square on which market place and are covered market place various other built Wertheim believes town was more a prince than of economically based, the town on a cross hold the kingdom to, internal arrangement ly prescribed by a sense it is hardly analyze.

This is the inland of rice. Kediri, Ma other Hindu-Javanese type; some idea of can be seen in Djokj; depended on the skill inertia of the tr. pious, respectful of initiative or the urge who did not have to exercise of justice at that even the most rebel when pressed to of rebellion and of life tolerable for peasants powers established a and population growth which flight was possible.

Different in their food, and their internal cities, where the product exchanged for the of the Moluccas; the Bengal for the pepper of Java for the tin likewise under the but one whose domain much as the land. It

¹W. F. Wertheim, *Indonesian Cities* (The Hague and Ltd., 1959), p. 171.

form, although by now it is overlaid with much subsequent building. The *kraton* or court is central, imposing, large enough for the comfort of the ruler and his host of retainers. Near it is the *alun-alun*, a great square on which many communal activities took place and around which an open or covered market place, houses of nobles, and various other buildings were arranged. Wertheim believes that the location of the town was more a matter of the will of the prince than of economics.² If the will was ecologically based, for instance by centering the town on a crossroads, this would help hold the kingdom together. In any case, the internal arrangement of the town was strictly prescribed by a tradition whose ecological sense it is hardly worth going back to analyze.

This is the inland city, living on exactions of rice. Kediri, Mataram, Singosari, and other Hindu-Javanese capitals were of this type; some idea of their physical nature can be seen in Djokja and Solo today. They depended on the skill of a ruler and on the inertia of the tradition-bound peasantry—pious, respectful of their elders, lacking in initiative or the urge to innovation. A ruler who did not have facility in the judicious exercise of justice and severity discovered that even the most pious peasantry would rebel when pressed too hard. The possibility of rebellion and of flight helped to make life tolerable for peasants before the colonial powers established a stronger central rule and population growth took up all land to which flight was possible.

Different in their relation to sources of food, and their internal form, were the coastal cities, where the porcelains of China were exchanged for the cloves and nutmegs of the Moluccas; the cloth of Gujarat and Bengal for the pepper of Sumatra; the rice of Java for the tin of Malaya. They were likewise under the absolute rule of a prince, but one whose domain was the water as much as the land. He maintained himself

by taxes on the town market and the harbor, by the profits of his own ships which went out to trade, by piracy, by providing slaves or other easily available local commodities to the passing trade. The harbors contrasted with the conservative inland empires in that they were the points of entry of all the new fashions in religion, language, and custom: Hinduism, Islam, and Christianity, each in its turn. Islam was introduced by Gujarati Muslims as late as the fourteenth century. Mohammed was a member of a trading community, and princes who adopted Islam became part of the continent-wide trading network that had been built up in the seven hundred years following the death of the Prophet. Islam had barely made its entrance before it was under attack by the Christianity of the Portuguese Albuquerque; only during the succeeding centuries did it work its way through the interior, and paradoxically enough it gained most of its present dominance during Dutch rule.

Perlak, Pedir, Cheribon, Grisek, all on the north and east coasts of Sumatra and Java convenient to the main water route from India to China, were cities of this type. The prince's palace again dominated, but the market place was bigger; there were settlements of foreigners privileged to trade but not to become citizens, living in their designated areas; the sails of Chinese junks flapped against the houses.

The colonial powers started, as their Muslim predecessors had done, by taking over existing coastal cities or building new ones, like Batavia. In due course, however, they came to inherit the land empires as well. The goods produced by peasants under their traditional organizations filled but a few ships bound for Italy, Holland, or England each year; the increase of the European market during the eighteenth and nineteenth centuries demanded much larger supplies. And so the Dutch persuaded, bribed, and compelled local rulers to bring extensive areas under forced cultivation. Peasants had to deliver quotas of sugar and coffee. Estates under Western management succeeded this system, and, as the nineteenth

² W. F. Wertheim, *Indonesian Society in Transition* (The Hague and Bandung: W. van Hoeve Ltd., 1959), p. 171.

century progressed, railways appeared, along with banks to finance the long period between planting and producing and harbor installations to handle the increasing ship traffic. The cities became centers of both administration and trade; they still fed themselves by collecting taxes in the countryside, but they had a new economic function as a transfer point for the rapidly increasing export crops on their way to the European market. Through them flowed a succession of commodities: coffee, then tea, then rubber; sugar during three centuries ending with World War II; palm oil, sisal, kapok, and cinchona bark; petroleum and tin. Flowing in were some of Europe's new and cheap manufactured products, especially cloth and minor consumption goods from kerosene lamps to hairpins. After 1800 the prices of these were determined by machine production in Europe; village methods of manufacture languished in Java as they did in Holland. The difference was that Java did not develop urban manufacturing of its own. The main point for an understanding of the colonial cities is that they combined the functions of the two kinds of cities that preceded them: they lived both on the sea and by dominion over interior agricultural areas.

The internal constitution of the cities changed drastically through this period. The Dutch dug canals in early Batavia and along them their tall buildings touched one another but it was not long before the East changed their thrifty style of life and a new mestizo culture, as Wertheim calls it, developed. This included spacious villas for the new administrators and traders; a class of officials who had not existed before built houses that were neither Dutch nor Indonesian in style, made of plastered brick with highly polished red tile floors; the front of each house consisted of a series of broad doors which could be folded back so that the living space within was continuous with an outdoor terrace shaded by trees. The villas were ranged along tree-lined streets which needed no sidewalks; the Dutch administrators always drove, and the Indone-

sians were not considered. The Indonesian middle class lived in brick dwellings in more crowded sections, often not on streets at all but on footpaths; here, too, lived the Chinese, who found various commercial niches in the colonial enterprises and who were able to pursue their own trade and money-lending under the rule of law established by the colonial system. Throughout the city, wherever they were tolerated, were the kampongs in which lower-class Indonesians lived: the policemen, messengers, domestic servants, and ricksha-pullers drawn in by the new regime.

The cities so formed have been both the strength and the weakness of the nations of South Asia created after World War II. Their functions have continued to be trade and administration, and they have at no time come to include any important amount of manufacturing or other production. A two-way traffic by which manufactured articles are shipped into the countryside and so draw food into the cities has barely started; yet this exchange is crucial not only for the survival of the cities as such, but also for the economic and political stability of the nation which the cities dominate ecologically.

Meanwhile, the cities are centers of trade and government have grown faster than has the population of Indonesia as a whole. The largest of them seem recently to have been doubling in size every ten to fifteen years; thus the 1955 population of Djakarta was 3,250,000 against 533,000 in the 1930 census; and that of Surabaya 1,800,000 compared with 342,000.⁸ The six cities of population greater than 100,000 held 2.83 per cent of the population of Java and Madura in 1930, 3.75 per cent by 1940 (Wertheim). On the other hand, the smaller towns, those of under 25,000 population, were declining as early as the 1920's; this may have been for the same reason that small towns in parts of America have lost out to larger cities: the improvement of rail and road transport.

During the 1930's the flow of plantation goods through the cities and harbors de-

⁸ "Indonesia," in *Encyclopaedia Britannica* (1959), XII, 267.

clined sharply, and people that the cities and the Japanese of trade, and the need to compel people to side. But neither did the size of the cities. World War II a new in. This consisted of areas of the countryside still dangerous and cities had now lost the new national government. Some of the plantations the peasantry were inese occupation of markets; others, from the scorched-lutionary war. The burned to the ground is useless, since export as such. They have not yet reached prewar million tons.

It became evident very diminution of the countryside the cities also deprived prewar banking, its functions. But many had been deprived independence, and organized its response for them. The public 150,000 strong in 500,000 in 1954.

How have these in money terms? In new sovereign government on the payroll with ever-fresh procedure referred to ports of the Bank rose, there was government money had been largely lost their could not retreat salaries. The government by printing more

sidered. The Indonesian brick dwellings in more than not on streets at all here, too, lived the Chinese commercial niches prizes and who were able to trade and money-lend- of law established by the oughout the city, where- ated, were the kampungs Indonesians lived: the ers, domestic servants, drawn in by the new

ned have been both the skness of the nations of after World War II. e continued to be trade and they have at no time y important amount of ther production. A two- h manufactured articles countryside and so draw has barely started; yet ial not only for the sur- such, but also for the al stability of the nation inate ecologically.

ities are centers of trade e grown faster than has donesia as a whole. The n recently to have been y ten to fifteen years; ation of Djakarta was 33,000 in the 1930 cen- rabaya 1,800,000 com- The six cities of popu- 100,000 held 2.83 per on of Java and Madura t by 1940 (Wertheim). he smaller towns, those ulation, were declining 's; this may have been hat small towns in parts t out to larger cities; ail and road transport.

the flow of plantation cities and harbors de-

de pacifica Britannica (1959),

clined sharply, and so did the number of people that the cities could support. War and the Japanese occupation further reduced trade, and the occupation authorities tried to compel people to return to the countryside. But neither depression nor war reduced the size of the cities appreciably, and after World War II a new and rapid increase set in. This consisted in part of refugees from areas of the countryside in which life was still dangerous and was in part because the cities had now become the stage on which the new national life was being acted out. Some of the plantations that had employed the peasantry were abandoned when Japanese occupation cut them off from prewar markets; others, particularly sugar, suffered from the scorched-earth policy of the revolutionary war. The sugar factories were burned to the ground, and without them cane is useless, since it is too perishable to export as such. Indonesian exports of sugar have not yet reached one quarter of their prewar million tons per year.

It became evident after the war that the very diminution of the productive power of the countryside that brought people to the cities also deprived the cities of some of their prewar banking, transport, and marketing functions. But many of the people who came in had been displaced by the struggle for independence, and the new government recognized its responsibilities by making jobs for them. The public service, which had been 150,000 strong in 1939, employed over 500,000 in 1954.

How have these people been maintained? In money terms there was no difficulty: the new sovereign government was able to put them on the payroll and to meet the payroll with ever-fresh supplies of currency, a procedure referred to in successive annual reports of the Bank of Indonesia. As prices rose, there was dissatisfaction among the government personnel for whose pay the money had been printed; they had now largely lost their base in the countryside and could not retreat from their dependence on salaries. The government's attempt to help by printing more money was anticipated by

foreigners and the local Chinese alike; the former were able to avoid some of its effect by buying their rupiahs on the black market, the latter to speculate by hoarding hard goods and so to corner an additional portion of the real wealth of the country.

But money is of secondary interest for ecological study, and we must bring the argument back to the movement of goods with which the people of the city are fed and clothed. Before the war they were able to buy the rice marketed by peasants who needed cash to pay their taxes; in years when the local supply was short, non-edible rubber and other commercial goods could be exchanged through international markets for Burmese, Thai, or Vietnamese rice. The movement of food from the Javanese countryside was strengthened by collection of land rents. When the landlord received rent, he used some of it to provide for his local retainers but also caused some food to be moved to the city to be exchanged for city goods. Some manufactured goods were produced in the cities of Java, but most were imported from abroad and paid for by the foreign exchange earned from the sale of plantation products. The rent taken by the landlord contributed through one route or another to the feeding of the city people, who either made or handled the luxuries the landlord bought for his personal comfort.

I have referred elsewhere to the institutions by which the peasant in the Javanese village shares whatever food there is among the members of his extended family and with his fellow villagers who do not have direct access to the land as owners or tenants.⁴ These institutions include the finer and finer division of the work of tilling, planting, weeding, and harvesting, always on a crop-sharing basis, as well as the deterioration of the technology of agriculture so that the crop comes to be harvested stalk by stalk and draft animals are replaced by the man with the hoe. This in itself does not

⁴N. Keyfitz, "Développement économique et accroissement de population: Un exemple actuel en Indonésie," *Population*, XIII (July, 1958), 433-37.

cause suffering or hunger within the village, but it does steadily diminish, in the measure of the increase of village population, the amount of crop which is available for sale outside the village and hence the amount of non-food items which the villagers can purchase. As the village populations use more and more of the food they produce, the rice-purchasing power for city products steadily diminishes. This process, which has been going on for a hundred years, has made what were formerly the richest parts of Asia into the poorest.

Since the war the supplies of food to the cities of Java have diminished at the same time as the number of city people to be fed has increased. Land taxes have tended to remain the same in money terms as before the war despite a fifty-fold increase in prices, so that such taxes draw very little food. To increase land taxes has seemed impossible to a national government which depends on votes. But the main problem is not democratic government but rather the fact that taxes in underdeveloped countries can never be taken from the existing meager production; they must be a spur to more production. In Java the peasant has the time to raise more crops than he does now, but he has no land on which to apply his effort. This fact is what underlies the repeated assertion of administrators that they cannot tax poor people.

The contribution of landlords to the flow of food has been reduced by rent control and the expulsion of some owners. Meanwhile, the severe policing of the forest reserves by the Dutch has ceased, and squatters have taken over many of the slopes formerly kept under forest for the control of erosion. A vicious circle sets in, whereby shortage of food results in cutting down the forest, consequent loss of soil into the sea accentuates the shortage of food, and more forests are cut down.

The result is that much of the food consumed in the cities is now brought from abroad. Imports of food grains were \$00,000 tons in 1956. If a ton nourishes five people, it looks as though some four million people,

mostly in cities, are dependent on imported food grains, at least in some years.

Since the Korean boom in rubber and oil subsided, a chronic difficulty of the Republic has been shortage of foreign exchange. City populations are a charge on the resources which could go into the industrialization of the country. Here again is a vicious circle: investment in industry would enable the cities to solve their problem, for with efficient industrial plants they could produce goods for which peasants would trade their food. If this exchange is not possible for Javanese peasants until their numbers diminish, it is still possible for Sumatra and other less crowded parts of the Republic. These could become an economic hinterland of Djakarta. One need not ask for the present that industry attain the high degree of efficiency necessary to trade for food in world markets in competition with countries like the United States and Japan which have such a long start. Internal trade of this kind could be protected by a customs tariff from the sternness of world competition.

So long as the Republic is a unit, its cities can be fed either by a surplus of food or a balance of foreign exchange generated anywhere within its boundaries. The trouble with using the taxing and redistributing power of the state to ensure that one part—say the cities of Java—is fed by the other—the Sumatran plantations—is that this creates centrifugal tendencies in the Republic. The rich and sparse portions consider that they are entitled to use for their own development purposes the foreign exchange they earn, and sooner or later—if they take economic life seriously—they will resist taxation for the benefit of the cities of another island. They have resisted multiple rates of exchange and other devices which result in territorial redistribution of the proceeds of exports. Rangoon was able, by setting its internal buying price for rice well below the world price, to tax farmers who were in territory controlled by rebels and so feed itself; it could do this because it had physical control of the ports through which rice alone could be exported from the country. The

government of India, of the export of rice from coast ports during had to face a S 1958.

Maintaining the countryside does durable ecological conditions when quickly recognize sale of their products depend not on power but on the factoring product and Hong Kong a too much to ask of countries of the pure political power efficiency. The usual one, in which factored goods, but foreign competition of the world economies in economic conflict of interests, a tariff accepted as a

It is true that have part of their ment services a services of a city for sale but rather whether the recipient there will be inste, equal to the difficulty paid and the value this value is assessed may think them more. If they do like that provoked drance to the formed national state of all its citizens. tion out of people whose horizons limited to their a formidable one economic interest side.

We have shown

are dependent on imported
tast in some years.

can boom in rubber and oil
ic difficulty of the Republic
e of foreign exchange. City
a charge on the resources
nto the industrialization of
e again is a vicious circle:
dustry would enable the
eir problem, for with effi-
plants they could produce
peasants would trade their
ange is not possible for
s until their numbers dis-
ossible for Sumatra and
d parts of the Republic.
e an economic hinterland
need not ask for the pres-
attain the high degree of
y to trade for food in
mpetition with countries
es and Japan which have
nternal trade of this kind
by a customs tariff from
old competition.

public is a unit, its cities
y a surplus of food or a
xchange generated any-
boundaries. The trouble
ing and redistributing
ensure that one part—
—is fed by the other—
tions—is that this cre-
encies in the Republic.
portions consider that
se for their own devel-
foreign exchange they
ter—if they take eco-
—they will resist taxa-
f the cities of another
isted multiple rates of
ervices which result in
on of the proceeds of
able, by setting its
for rice well below the
ers who were in terri-
els and so feed itself;
e it had physical con-
gh which rice alone
in the country. The

government of Indonesia lost partial control
of the export of rubber from Sumatran east-
coast ports during the years 1955-57 and
had to face a Sumatran rebellion during
1958.

Maintaining cities simply by taxing the
countryside does not provide them with a
durable ecological basis under modern con-
ditions when regional interests are all too
quickly recognized. If cities live by a free
sale of their produce on world markets, they
depend not on any assertion of national
power but on the efficiency of their manu-
facturing production and services. Singapore
and Hong Kong are able to do this, but it is
too much to ask of a new country. In most
countries of the world cities live neither by
pure political power nor by pure economic
efficiency. The intermediate condition is the
usual one, in which cities produce manu-
factured goods, but less efficiently than do
foreign competitors. Nearly all the countries
of the world accept tariffs. Their shortcom-
ings in economic efficiency do produce a con-
flict of interests, but this is bridged and the
tariff accepted as a matter of national senti-
ment.

It is true that capital cities everywhere
have part of their base in providing govern-
ment services against tax payments. If the
services of a city are in the form not of goods
for sale but rather of services provided
whether the recipients want them or not,
there will be instability, or political tension,
equal to the difference between the taxes
paid and the value of services received, as
this value is assessed by the taxpayers. They
may think them worth all that they pay, or
more. If they do not, the resulting tension,
like that provoked by tariffs, will be a hin-
drance to the formation of a stable and uni-
fied national state, commanding the loyalty
of all its citizens. The task of forming a na-
tion out of people speaking many languages,
whose horizons until a few years ago were
limited to their own families and villages, is
a formidable one even without the clash of
economic interest between city and country-
side.

We have shown the difficulties of getting

food out of the villages of Java as the vil-
lage population grows. The villagers, being
closer to the food, can get to it more easily
than can either the tax collector or the land-
lord. It is politically awkward to buy it
abroad with Sumatra-produced foreign ex-
change. Foreign exchange would buy the
industrial equipment that could make the
city economically independent, and what-
ever can be mobilized should be used for this
and not for food.

Can the difficulty be resolved by a for-
eign supply of food, a kind of food loan, to
the cities of Java? The use of food grown
abroad to maintain city populations while
they do the construction work and instal the
equipment that will make them productive
seems to represent the soundest type of for-
eign aid. However, when this is done both
the donors and the receivers ought to be very
sure of the purpose to which the gift or loan
is in fact being applied. Food made available
in the cities will draw more people into them,
helping to loosen population from the village
moorings and to deprive it of the claim to
the crop which derives from proximity. The
ecological base of the city thus comes to in-
clude the production of food in America.
The process of drawing people into the city
is largely irreversible; their village source of
food closes up behind them, and they can
hardly go back to the village. Gifts of food
under foreign aid, in their tendency to bring
people into the city, contrast with gifts of
fertilizers, with agricultural extension serv-
ice, with aerial surveys which help open up
new agricultural areas, or transport facili-
ties that bring people to such new areas. If
the gifts of food are not simultaneous with
the industrialization of the cities whose in-
crease of population they make possible,
then the most serious economic, political,
and moral problems will confront any donor
who later tries to cut off the supply of gifts.

Changes are occurring within the cities at
the same time as in the relation of cities and
hinterland. Indonesia is aware of a problem
in the internal physical structure of its cities
and has invited outsiders to advise on what
might be done to make them more livable.

The town planner who comes to Djakarta seems to find his services badly needed. A city whose physical structure was designed for half a million is now the home of about six times that number. It shows in particularly intense form the overcrowding common to nearly all the cities of the world: overfull hotels, traffic tie-ups, queues in stores and markets. The post-World War II increment of population lives in thatch and bamboo huts; people queue at water fountains or buy gasoline tins of water for domestic use; they bathe and wash their clothes in the turbid canals.

Especially conscious of the need for better housing and urban facilities is the new middle class of government servants. No one could blame them for trying by the use of influence to get into tolerable houses. Inflation has reduced their real wage so that they cannot hope to buy or rent suitable housing on the free market as do the Chinese. Some building has been done by the government for their benefit; the new town of Kebajoran contains many pleasant single dwellings and apartment buildings around which gardeners work diligently to make trees and shrubs grow; its construction is a great achievement in these hard times.

How much of national effort ought to go into the physical development of cities in these circumstances? In the relatively free market of Brazil a sizable portion of the total national income goes into the magnificent skyscrapers of Rio and São Paulo. I have no opinion on whether these cities have a permanent, stable, and natural basis for

their growth in the form of manufactures and services which draw food from the countryside, but study of the situation would enable one to find out. In Indonesia there is not a free investment market, and expenditures in the city are largely determined by government. There is free movement of population, and so the erection of housing facilities in the cities, improvement of roads, introduction of subsidized bus service—in short, any alleviation of the discomfort of city life—will operate along with subsidized rice to draw people from the crowded countryside. But in the framework we have described the efforts of town planning and house construction are frustrated; people are drawn to the cities faster than decent places for them to live in can be found. The disordered physical arrangements within the city symbolize the uncertainty of their economic role.

These facts must be taken into account if the great efforts being made by devoted citizens toward Indonesian construction are to bear fruit. One admires the ingenuity with which an impossible amount of traffic has been kept moving, the splendid highways that have been laid down, the apartment houses that have been erected, such enterprises as the site for the Asian Games which bulldozers are now clearing between Djakarta and Kebajoran. The study of ecology is useful insofar as it looks behind such trends to incentives and to the directions in which they cause people to move, especially to the relation between people and the food that will maintain them.

UNIVERSITY OF TORONTO

MODIFICATIONS FOR "TESTING"

The published formulas for testing two proportions, and for testing modification. The present paper presents more satisfactory modifications are used to explicate and illustrate observed proportions is rather large here and the earlier published form

H. F. Dorn, S. A. Stouffer bits have introduced a form of the statistical significance of between the differences in two and they have suggested formulas to test the statistics of other kinds of comparison formulas have been cited in textbooks on statistics for some used rather widely by research

¹ Part of this research was carried out at the Statistical Research Center, University of California, under the sponsorship of the Statistical Office of Naval Research, and of the Research Committee, University of California. This work was done while the author was a Postdoctoral Fellow at the University of California, and a John S. Hein Memorial Foundation Fellow. Helpful comments, the author wishes to thank Allen Wallis and Louis Krisberg.

² Harold F. Dorn and Samuel Stouffer, "Criteria of Differential Mortality," *American Statistical Association*, 40: 402-14; Clark Tibblitts and Samuel Stouffer, "Testing the Significance of Comparative Data," *American Journal of Sociology*, 1934, 357-63.

³ E.g., Margaret Jarman Hagood, *Sociologists* (New York: Henry Holt & Co., 1938), pp. 338-40; and Margaret Jarman Hagood, *Statistics for Sociologists* (New York: Henry Holt & Co., 1932). In the Tibblitts-Stouffer article, Hagood is quoted as an excellent example of the reasoning, accompanying, and following procedures, which makes such procedureful, the student is urged to read this article.

Jane Rock

WORLD POPULATION

by JULIAN HUXLEY

REPRINTED FROM
SCIENTIFIC
AMERICAN
MARCH 1956
VOL. 151, NO. 3 PP. 61-76

Following is the text of the speech by Robert S. McNamara, president of the International Bank for Reconstruction and Development (World Bank), to the bank's annual meeting today:

This is my first public speech as president of the World Bank, and I speak to you with some diffidence as a newcomer with only half a year's experience in this post—but perhaps the half year in my whole life in which I have felt myself most challenged by the prospect before me.

I have always regarded the World Bank as something more than a bank, as a development agency, and when I came here six months ago I was not entirely a stranger to the problems of world development. As American Secretary of Defense I had observed, and spoken publicly about, the connection between world poverty and unstable relations among nations; as a citizen of the world I had begun to sense the truth in Pope Paul's dictum that "Development is Peace." Yet I was uneasily aware that as the peoples of the world looked at the sixties—the United Nations' development decade—they felt a deep sense of frustration and failure. The rich countries felt that they had given billions of dollars without achieving much in the way of development; the poor countries felt that too little of the enormous increases in the wealth of the developed world had been diverted to help them rise out of the pit of poverty in which they have been engulfed for centuries past.

No Clear Joint Strategy
How far is this mood of frustration and failure justified by the events of the past decade? I have sought to find out the truth about this, but I confess, though there have been many voices only too anxious to answer my question, each with a panoply of statistics to prove its point, there is no agreed situation report, nor any clear joint strategy for the future.

There have been successes: many millions in aid have been forthcoming from the developed world, and as a result of that aid and of their own increased capacity to manage their affairs, the economic growth of the poorer countries has been stimulated.

Let us make no mistake: aid does work. It is not money wasted. It is a sound investment. Even the ultimate goal of the development decade, an annual rise in national incomes in the poorer countries of 5 per cent by 1970 is likely to be achieved. The average annual growth thus far has been 4.8 per cent.

and I know that these cheerful statistics are cosmetics which conceal a far less cheerful picture in many countries. The oil-rich nations of the Middle East have prospered economically; so have some small states in East Asia. But for the nations of Africa and South Asia—nations with a population of over one billion—the average increase in national income is, at most, 3.5 per cent, and much of that is concentrated in the industrial areas while the peasant remains stuck in his immemorial poverty, living on the bare margin of subsistence.

Casting its shadow over all this scene is the mushrooming cloud of the population explosion. If we take this into account, and look at the progress for human beings rather than nations, the growth figures appear even less acceptable.

Income Growth Lags
The annual growth of per capita income in Latin America is less than two per cent, in East Asia only about two per cent, in Africa only one per cent, and in South Asia only about half a per cent. At these rates, a doubling of per capita income in East Asia would take nearly 35 years, in Latin America more than 40 years, in Africa almost 70 years and in South Asia nearly a century and a half. Even in the most progressive of these areas, the amount of improvement would be imperceptible to the average citizen from year to year.

Such a situation cries out for a greater and more urgent effort by the richer countries to assist economic growth in these poorer countries. It is clear they are financially capable of such action. During the development decade so far, they have added to their annual real incomes a sum of about \$400-billion, an addition itself far greater than the total annual incomes of the underdeveloped countries of Asia, Africa and Latin America.

But I found, and I need hardly tell you this, that while the requirement for assistance was never higher, the will to provide it was never lower in many, though not all, of the countries which provide the bulk of economic aid.

And the disenchantment of the rich with the future of development aid was fed by performing deficiencies of

many of the poorer nations. Blatant mismanagement of economies; diversion of scarce resources to wars of nationalism; perpetuation of discriminatory systems of social and economic life; and the common in these countries,

This then was the picture of the development world which I found in my first weeks at the World Bank. A confused but sharply disappointing picture, in which it was difficult to see what had gone wrong in the past (though something clearly had), or what was the right path ahead for us.

Pearson Commission

In these circumstances, I turned to a suggestion which had been put forward by my predecessor, Mr. George Woods—one of his many bits of wise advice from which we all, and I especially, have benefited. This was that we should establish a commission of men well versed in world affairs, and accustomed to influencing them, who would survey the past aid effort; seek out the lessons it can teach for the future; and then examine that future to see what needs to be done by rich and poor, developed and underdeveloped alike to promote the economic well-being of the great majority of mankind. As you know, Mr. Lester B. Pearson, formerly Prime Minister of Canada, has agreed to lead such a survey, which will now proceed independently of the bank.

The Pearson Commission will be turning our eyes to the long future, marking out guidelines not just for a decade but for a whole generation of development that will carry us to the end of this century. But here are we now, living in 1968, with much that we can and must do today and tomorrow. It is already clear beyond contradiction that during the first four-fifths of the development decade the income gap between the developed and the less-developed countries has increased, is increasing and ought to be diminished. But it is equally clear that the political will to foster development has weakened, is weakening further and needs desperately to be strengthened.

What can the bank do in this situation? I have been determined on one thing: that the bank could and would act; it would not share in the general paralysis which was afflicting aid efforts in so many parts of the world. I do not believe that the bank can go it alone and do the job of development that needs to be done around the world by itself; but I do believe that it can provide leadership in the effort, and can show that it is not resources which are lacking—for the richer countries amongst them have resources in plenty—but what is lacking is the will to employ those resources on the development of the world.

Plan for the Future

We in the bank, therefore, set out to survey the next five years, to formulate a "development plan" for each developing nation, and to see what the bank group could invest if there were no constraint of funds, and the only limits on our activities were the capacity of our member countries to use our assistance effectively and to repay our loans on the terms on which they were lent.

As a result of this survey, we have concluded that a very substantial increase in bank group activities is desirable and possible.

It is toward this objective that I shall attempt to guide the bank's activities in the next few years. In doing so I shall need the advice and support of you gentlemen, our governors, expressed through the board of executive directors. Therefore I think it prudent and fitting that I should now present to you an outline of my thinking.

Let me begin by giving you some orders of magnitude: I believe that globally the bank group should during the next five years lend twice as much as during the past five years. This means that between now and 1973 the bank group would lend in total close to as much as it has lent since it began operations 22 years ago.

This is a change of such a degree that I feel it necessary to emphasize that it is not a change of kind. We believe that we can carry out these operations within the high standards of careful evaluation and sound financing that my predecessors have made synonymous with the name of the World Bank.

Our loans will be for projects as soundly based and appraised as ever in our history. However, more and more, in looking for projects to support we shall look for those which contribute most fundamentally to the development of the total national economy, seeking to break strangleholds on development; to find those growth opportunities that stimulate further growth. And our help will be directed to those poor nations which need it most.

This, I believe, to be sound development financing, but it is not riskproof; nor do I believe that the utter avoidance of risks is the path of prudence or wisdom. I recently

visited Indonesia where, for good reasons, the bank has never made a loan of any sort in the past. What I found was the sixth largest nation in the world, rich in natural resources, striving in the wake of the most terrible disasters, both economic and political, to set itself straight on the path to development. Without external help it faces certain disaster; by giving help (as we have begun to do through the International Development Association and through the establishment of a permanent mission) we are running some risks. I do not believe you would wish it otherwise.

The parable of the talents is a parable about power—about financial power—and it illuminates the great truth that all power is given us to be used, not to be wrapped in a napkin against risk.

But if we are to lend at double the level of the past, can we raise the money? I will not speak now about the soft-loan money which is raised by government contributions—you all know how essential these funds are—but about the money we raise by bond issues in the capital markets of the world. I am confident that the money is there, because I have confidence in the immense capacity of the economies of the developed world; no country need fear bankrupting itself because it plays its full part in development.

There are, of course, certain constraints through balance-of-payments difficulties, but I am fully aware that the balance-of-payments difficulty is a problem of balance among the rich economies and not of balance between those countries as a group, and the rest of the world—very little of the money lent in aid stays in the developing countries, almost all of it returns quickly in payment for the goods purchased in the richer countries. It is our job in the World Bank to look at the world money markets as a whole, and see where there are surpluses, where there are reserves that can be tapped. Following this line we have gone to the Middle East, and successfully raised funds there, as well as in the more conventional markets of the world—in particular Germany and America.

As a result, in the first 90 days of this fiscal year the World Bank has raised more funds by borrowing than in the whole of any single year in its history.

I have been stressing that in doubling the bank group's lending activities we are not departing from our high standards of investment policy. But I would not want to leave the impression that this is simply "more of the same."

Our five-year prospect calls for considerable changes in the allocation of our resources, both to geographic areas and to economic sectors, to suit the considerably changed circumstances of today and tomorrow.

First as to area: in the past the bank group has tended to concentrate its effort on the South Asian subcontinent. Much has been achieved—the harnessing of the waters of the Indus River system for power and irrigation for instance—and much remains to be achieved. I believe World Bank lending to Asia should rise substantially over the next five years. But it is not to Asia alone that our new effort will be directed. It is to Latin America and Africa as well, where in the past our activities have been less concentrated, and to some countries in great need of our help, such as Indonesia and the U.A.R., where our past activities have been negligible.

In Latin America, I foresee our investment rate more than doubling in the next five years. But it is in Africa, just coming to the threshold of major investment for development, where the greatest expansion of our activities should take place. There, over the next five years, with effective collaboration from the African countries, we should increase our rate of investment threefold.

Further changes will flow from our shift to a greater emphasis on Africa and Latin America. The states of these two continents are smaller than the giants of Asia. There will be many more but smaller projects, demanding much more staff work per million dollars lent than in the past.

Regulating Drive

The work of the bank will also be increased because in many of the countries in which we will now be investing there is no well-established development plan or planning organization. We shall try, in conjunction with other sources of funds, to help these countries to develop plans and to adopt wise and appropriate policies for development—in some cases by establishing resident missions as we have done in Indonesia—but always remembering that it is their country, their economy, their culture and their aspirations which we seek to assist.

In particular, we will exert special efforts to right one upside-down aspect of bank group operations: the fact that many of our poorest members, despite their greater need, have had the least technical and financial assistance.

ance from the bank group. About 10 of these have had no loans or credits at all. This is largely because of their inability to prepare projects for consideration. In these cases we will provide special assistance to improve economic performance and to identify and prepare projects acceptable for bank group financing.

With the doubling of bank group lending and with the increase in the complexity of our operations, there will clearly be need for an increase in the total professional staff of the bank, as well as for some streamlining of our procedures. We are now engaged in a worldwide recruiting drive to find people with the high standards of expertise and dedication that have always been the attributes of its staff. I am anxious that this should really be an international bank, in fact as well as in name, and I intend to ensure that we move steadily in the direction of the widest possible distribution in the nationalities of our staff.

Not only should our lending double in volume and shift geographically, but we can foresee, as well, dramatic changes among sectors of investment. Great increases will occur in the sectors of education and agriculture.

Education Outlays

Education is a relatively new field for the bank on which my predecessor, George Woods, began to place increased emphasis. In recent years the bank has been seeking, uneasily but with a growing sense of urgency, to find its optimum role in this field.

We are aware of the immense numbers of illiterates in the developing world: about 30 per cent in Latin America, 60 per cent in Asia, 80 per cent in tropical Africa. We know, too, that education is relevant to all dimensions of development: it makes a more effective worker, a more creative manager, a better farmer, a more efficient administrator, a human being closer to self-sufficiency.

The need is clear, but it has been less clear how the bank's resources can be brought to bear on this labyrinthine problem. Now, after some years of collaboration with UNESCO, we believe we see a way ahead for increasing bank investment which we hope will call forth further investment by the government of the developing country itself.

provide assistance where it will contribute most to economic development. This will mean emphasis on educational planning — the starting point for the whole process of educational improvement. It will mean assistance, particularly in teacher training, at all levels, from primary to university. It will mean expansion of our support for a variety of their educational activities including the training of managers, entrepreneurs and of course of agriculturalists.

It is important to emphasize that education, normally one of the largest employers in any country, is one of the few industries which has not undergone a technological revolution. We must help to move it out of the handicraft stage. With the terrible and growing shortage of qualified teachers all over the developing world we must seek ways to make good teachers more productive. This will involve investment in text books, in audio-visual materials, and above all in the use of modern communications techniques (radio, film and television) for teaching purposes.

Aid to Agriculture

To carry out this program we would hope over the next five years to increase our lending for education development at least threefold.

But the sector of greatest expansion in our five year program is agriculture, which has for so long been the stepchild of development. Here again there has never been any doubt about its importance. About two-thirds of the people of the developing world live on the soil, yet these countries have to import annually \$4-billion of food from the industrialized nations. Even then their diet is so inadequate, in many cases, that they cannot do an effective day's work and, more ominous still, there is growing scientific evidence that the dietary deficiencies of the parents are passed as mental deficiencies to the children.

The need has stared us in the face for decades past. But how to help?

In the past, investment in agricultural improvement produced but a modest yield: the traditional seeds and plants did better with irrigation and fertilizer but the increase in yield was not dramatic. Now, as you know, as the result of research in the past 20 years, a breakthrough has taken place in the production of new strains of wheat and rice and other plants which can improve yields by three to five times. What is more, these new strains are particularly sensitive to the input of water and fertilizer; badly managed they will produce little more than the traditional plants, but with correct management

they will give the peasant an unprecedented crop.

Here is an opportunity where irrigation, fertilizer and peasant education can produce miracles in the sight of the beholder. The farmer himself in one short season can see the beneficial results of that scientific agriculture which has seemed so often in the past to be a will o' the wisp tempting him to innovation without benefit.

Our task now is to enable the peasant to make the most of this opportunity and we, with the continuing assistance of F.A.O. [Food and Agriculture Organization] intend to do so at once and in good measure. Irrigation schemes, fertilizer plants, agricultural research and extension, the production of pesticides, agricultural machinery, storage facilities — with all of these we will press ahead in the immediate future. Indeed in the coming year we plan to process more than twice the value of agricultural loans as in the last, and our agricultural dollar loan volume over the next five years should quadruple.

There is an element of risk in all this, of course. The seeds were issued before all the tests had been completed; the resistance of the crops to local diseases or pests cannot yet be assured; the splendid harvests in India and Pakistan this year cannot all be attributed to the new seeds. But I have no doubt, though setbacks may lie ahead, that there has been an agricultural revolution as significant as any development since the industrial revolution. It is one that gives us a breathing spell in the race between man and his resources.

Population Growth

This leads me to yet another area where the bank needs to take new initiatives — the control of population growth. This is a thorny subject which it would be very much more convenient to leave alone. But I cannot, because the World Bank is concerned above all with economic development, and the rapid growth of population is one of the greatest barriers to the economic growth and social well-being of our member states.

This is the aspect of the population problem with which I shall deal, because it is this aspect which most closely concerns the World Bank, and makes it impossible for any of us to brush the subject aside, however strong our inclinations to do so may be.

- 4 -

I do not need before this audience to deal with the terrifying statistics of population growth as a whole, which show that, although world population totaled only one-quarter billion in the first century A.D. and required 1,650 years to add another quarter billion, it added one billion in the next 200 years; a second billion in the following century and a third billion in the next 30 years. It is now expected to add three more billion by the end of the century. By then, at present rates, it will be increasing one billion each eight years. Nor do I need to deal with the personal tragedies and dangers to health of unwanted births, though these were suddenly illuminated for me by an item in a newspaper last month which recorded that in the two largest cities of one European country live births were outnumbered by illegal abortions which imperiled the life of each unhappy mother.

Population Impact

As a development planner, I wish to deal only with the hard facts of population impact on economic growth. Recent studies show the crippling effect of a high rate of population increase on economic growth in any developing country. For example, take two typical developing countries with similar standards of living, each with a birth rate of 40 per thousand (this is the actual rate in India and Mexico) and estimate what would happen if the birth rate in one of those countries, in a period of 25 years, were to be halved to 20 per thousand, a rate still well above that in most developed countries. The country which lowered its population growth would raise its standard of living 40 per cent above the other country in a single generation.

In terms of the gap between rich countries and poor, these studies show that more than anything else it is the population explosion which, by holding back the advancement of the poor, is blowing apart the rich and the poor and widening the already dangerous gap between them.

Furthermore, these economic studies show that this drag of excessive population growth is quite independent of the density of population. This is something that needs emphasizing in view of the fact that many policy makers in the developing countries attach only minor importance to reducing population growth. It is a false claim that some countries need more population to fill their land or accelerate their economic growth. There are no vacant lands equipped with roads, schools, homes, and the rest of agricultural or industrial employment. Therefore, the

people who are to fill those lands, before they can live at even the current low standard of living, must first eat up a portion of the present scarce supply of capital—it is the burden which defeats a nation's efforts to raise its standard of living by increasing its population.

No one can doubt then that very serious problems of population growth face most of the developing nations today; what are the chances of their being dealt with by natural causes? The answer lies in understanding the nature of the population explosion. It is not caused by any increase in the birth rate, but by a dramatic drop in the death rate due mainly to medical advances. It is this death control which has created the present emergency, and I do not believe that anyone would wish to reintroduce pestilence—or any other of the four horsemen of the apocalypse—as a "natural" solution to the population problem.

We are therefore faced with the question of what action we at the bank, as a development agency, should take to lift this burden from the backs of many of our members. I propose the following three courses:

First: to let the developing nations know the extent to which rapid population growth slows down their potential development, and that, in consequence, the optimum employment of the world's scarce development funds requires attention to this problem.

Second: to seek opportunities to finance facilities required by our member countries to carry out family planning programs.

Third: to join with others in programs of research to determine the most effective methods of family planning and of national administration of population control programs.

With these three proposals for immediate action, I hope we may contribute to the success of the U. N. system which is already working in this field, and to the well-being of the developing nations.

Gentlemen, I have spoken

long enough. Let me conclude by saying, the next few days, we examine the innumerable problems face you who exert over so much world's financial and economic power, I hope none of us will yield as we see how there is to do, no time in which to do.

These is no cause for despair. There is even hope. In the generations the world created a productive machine which could abolish poverty from the face of the earth. As we lift up our eyes contemplating our task we can fail to see the immense prospects that ahead for all mankind.

McNAMARA SAYS POPULATION B

Continued From Page 1.

addressed the opening of the annual meeting, said the McNamara thesis, "We simply cannot back on the major fellow human being world." This, he said, be a tragic end to two decades of commitment, of error, and magnificent achievements.

Schwelitzer Comments

Mr. Johnson also spoke to the spirit of cooperation among nations that I hope with the money of the last year, a province of the Fund. "Those crises," he said, "did not lead to depression," and emphasized that cooperation could avert a period of "boom and bust."

Pierre-Paul Schwelitzer, director of the Fund, also spoke of "found shocks" in the devaluation of the pound and the success of buying of gold speculators.

"But the system stood the shock."

24th October, 1968.

The President,
Westminster College,
Fulton,
Missouri.

Dear President,

Here is what one might call the official text of the Green Lectures. When I actually give them, of course, I shall make a good many emendations and additions, in order that the whole thing should not sound too lifeless. But the present script is what I should like to be printed.

I shall close the first Lecture at the end of Section II. Each Lecture, when delivered, will run, I should guess, to something like 50 minutes. I considered making them longer by the addition of a great deal more in the way of statistics, but finally decided against. I want the message to come out sharp and clear.

We leave London for the United States on 30th October, and shall be staying at the St. Regis, 55th Street and Fifth Avenue, from 30th October to 4th November.

Yours sincerely,

Snow
(LORD SNOW)

Mr. President, Ladies and Gentlemen:

I sometimes actively dislike my surname. Whenever I am in this great country some natural climatic catastrophe tends to descend. It is usually something like snow falls on Washington, snow holds up New Hampshire, snow does many other things. I sometimes think that some of the minor troubles I get into during my life are because of this rather unfortunate cognomen. However, Mr. President, I am very happy to be here to say some things which I have wanted to say for a long time.

This isn't entirely because of the beautiful church across the way which, if I may say so, I saw before most of you did. I would like to mention I think this is a most successful achievement. I think I know very few works of restoration in the entire world which are its equal. It is very much better it should be here in Fulton than as a battered hulk in the City of London.

I would like to make one suggestion. Two very worthy men were once church wardens of St. Mary Aldermanbury. They were two actors--Hemminge and Condell. We don't know how good they were as actors. We do know they were good friends of William Shakespeare and without these two it is almost certain we should have no complete edition of Shakespeare at all, possibly nothing except the very imperfect first edition "The Quartos." It was Hemminge and Condell who as a gesture of love and devotion produced the "First Folio." Anyone who is interested in the English language is indebted to them, so do spare a word or a thought for them in this church.

But, as I say, it is not the church which makes me think it appropriate to try and say some things tonight. It is really because of the nature of the John Findley Green Lectures at Westminster College. You will remember these lectures should be devoted to economic and social problems of international concern, to be treated, so I read in the rubric, with Christian tolerance and practical benevolence. You also know, in fact, almost over the rest of the world these lectures are known as the Fulton Lectures because of our illustrious fellow countryman who gave the lecture here in 1946, but I think it is right we should remember one moment John Findley Green and the actual institution which I have the honor to take part in now.

Having said that I am afraid that's almost the only cheering remark I am going to make this evening or tomorrow, for I repeat I wanted to speak here--it seems to me a most suitable place to do it--on a subject on which I have been brooding about for a very long time. I can't pretend it is going to be anything but somber. That you have to take.

THE STATE OF SIEGE

C. P. SNOW
24.10.68

THE STATE OF SIEGE

I

Last year, 1967, I travelled a good many thousand miles. This was partly out of duty and partly out of curiosity, but the reasons don't matter. The fact was, I came twice to North America, Canada as well as the United States. I also went twice to the Soviet Union, on one trip almost the whole length - though not the breadth - from the Baltic coast down to Georgia. On the way back, I stayed in Poland. And I paid another call, a little nearer home, to Scandinavian countries.

On all those journeys, as you would expect, I had a lot of conversations with friends and acquaintances. Many of them are people I have known for ten or twenty years. At the end of it all, when I was back in London in the fall, just a year ago, I was left with one overmastering impression. Nearly everyone was worried about our world and what was happening to it. Nearly everyone was uncertain about the future. There was more - I don't want to use too strong a word - uneasiness in the air than I could remember. And it was an uneasiness that I understood, that I couldn't precisely define but without question shared.

I ought to make one or two qualifications. Like anyone of my age, I had known times when people round me had been more desperately and immediately concerned. That was true in the '30's in Europe. It was true, of course, in London in 1940 and further on into the war. But then the causes of concern were not in the least mysterious, long-distance, or obscure. There was usually

something for one to do, it might be ^{try} trying or ineffective, but it took one's mind away. It was possible to hope for the end of the war, and the ^abetter time afterwards. It was possible to hope, not in a utopian fashion, but as most healthy people always want to hope.

Those situations were quite unlike the present one. Those concerns were quite unlike the present uneasiness. This is harder to shift, more ^pimpalpable, nothing like so obvious. It isn't exactly unhappiness or dread. Many of the persons I listened to last year were entirely happy in their private lives. Some were not, it goes without saying: some were ill, or had illness close to them, or the other fatalities that afflict us all. It doesn't need explanation that they should be in distress. But it does ask for explanation that robust and happy people, of different ages, in different societies, should feel an uneasiness that they can't ~~possibly part of~~ shake off. Uneasiness which seems to be becoming part of the climate of our time. Uneasiness with an edge of fear? Perhaps. It is a bad state. It can be a paralysing and self-destructive state. If I had been making the same journeys this year instead of last, I am certain that I should have felt that this uneasiness was deepening: just as I have felt it in myself.

What is going wrong with us? Of course, we are not the first people in history to have this kind of experience or ask this kind of question. But we can deal only with our own time and speak only with our own words. It does seem - and though the feeling is subjective it is strong and one can hear it expressed by the very young - that our world is closing in. It gives us the sensation of contracting, not of expanding. This is very odd. It is very odd intellectually. For, after all, ours is the time of all times when men have performed some of

their greatest triumphs. It is, or ought to be, exciting that there will soon be the first voyage round the moon: that is a technical triumph, and for many, I suspect, a release from some of our day-by-day unease. What for me is more exciting are the supreme intellectual triumphs which we are not very far from witnessing. I can remember, in Cambridge in 1932, hearing at a private gathering the first news of the discovery of the neutron. That doesn't sound dramatic: but it was extremely dramatic. From it flowed all the fantastic Alice-in-Wonderland universe of particle physics, the extraordinary collection of tiny bits which make up what we call matter. For a generation that collection has become more complicated and at times it has looked intolerably untidy. Now at last the theoretical physicists may be within touching distance of a new order - something which is still complex, but as beautiful and as revolutionary for the micro-universe as Copernicus's scheme was for the solar system. If that happens - and the betting in favour is quite heavy - it will be one of the supreme achievements of the human mind.

I can also remember, in Cambridge about the same time, listening to some of the first discussions about a new branch of science. That new branch we have now come to know as molecular biology. Remember that the first pioneering work started only thirty-odd years ago: and think what has happened since. DNA.

The genetic code.
The mechanism of heredity. / The physical structure of life itself. In the whole of scientific history, there have been perhaps half-a-dozen breakthroughs which signified as much. And, like all real breakthroughs, the significance is going to seep into us more deeply year after year. That was true with Darwin's revolution. So it is, and perhaps more startlingly, today. It is likely that before long we

shall be told of the making, in the laboratory, of a living cell.

These wonderful things have been done, and are being done, in our own time, by people like ourselves. If you read James Watson's book The Double Helix you will realise that they are remarkably like ourselves. With most of our frailties and with a similar component of original sin. But they have done these things, and that ought to make us feel proud to be living at this time, and to belong to the same species. Yet are we? I think only partially. We are not very good at counting our blessings. That is a feature of our particular uneasiness. And also we suspect, and we have some right to suspect, that for these great intellectual triumphs we shall pay a price. We can't enjoy our knowledge and our understanding as unself-consciously and innocently as once we did. Upon us all there lies the shadow of Dr. Faustus; or, to be concrete, the shadow of the cloud over Hiroshima.

To some extent, those suspicions (which are really a distrust of the whole human race) show a failure of nerve. To an almost equal extent, they are essential: essential, that is, if we are ever going to build a tolerable world. I shall come back to that point later. At any rate, the suspicions exist. They prevent the most supreme achievements of our time giving us the liberation that they might have done. They may alleviate, but they do not stop, the pressure of a world closing in.

The world closes in. We are bombarded with communications, but again those don't set us free. Television has probably affected the pattern of our lives more than any other technical device - including the automobile and the telephone.

Television bombards us with communications about the world outside - often

television of the
 unpleasant, often (at least in the west) horrific. We know incomparably more than
 any human beings before us about what is going on in other cities, in other
 countries, and particularly the immediate prospect of human suffering. We know
 it is happening. We see people starving before they have died: we know that they
 are going to die. We see the evening's killings in Mexico City the same evening
 in London. We see the victims of famine in Biafra. We know it all. We know so
 much: and we can do so little. We turn away. There may be an even more
 sinister effect, to which I shall return.

Yes, we turn away. We don't project ourselves outwards: we turn inwards.
 We draw what in England we call the curtains, and we try to make an enclave of our
 own. An enclave, a refuge, a place to shut out the noise. A group of one's own.
 Enclave-making: that is one of the characteristic symptoms of our unease. You
 can see it plain in bigger and in smaller forms. Some of the bigger forms are
 cropping up right round the world. The revival of nationalisms, particularly of
 small nationalisms which had been half-dissolved in a more outward-looking age.
 Take my own small island. It would have seemed very curious not long ago to be
 told that a large proportion of the Scotch and Welsh were going to feel intense
 emotion about walling themselves off in little enclaves of their own. Incidentally,
 making things very difficult for themselves in the process by, at least in Wales,
 immediately encouraging a first-rate language problem. Just as is happening
 in Belgium, one of the most prosperous and densely populated countries on earth:
 if there is any possibility of shutting ourselves off behind language walls, then,
 in our present mood, we rush to do so.

Further, one of the bigger forms of enclave-making, again all round the world, is the behaviour of great strata of the young. They too have turned inwards: into their own customs, and often their own private language: often into a private fairyland where what some of them describe as 'structures' do not exist. In essence, they are creating privacies, even those who go out in the streets: for once you try to dismiss structures, you are dismissing society, any kind of society, including primitive, advanced, or anarchist, and you are huddling into a private refuge of your own.

One could go on with the list of enclaves that we can see being built round us, or are building for ourselves. Race and colour, the most isolating of them all. But, clearest of all, are the smaller forms of this process. Those are the forms which so many of us are taking part in.

Let us be honest. Most of us are huddling together in our own little groups for comfort's sake. It is natural, of course, for people to like their like, and to be easier with those who have the same associations as themselves. Most people, as they get older, get support from those few they have known for a long time. That is natural. But we often use natural feelings as an excuse. We are turning inward more than is really natural. As I said before, we draw the curtains and take care not to listen to anything which is going on in the streets outside. We are behaving as though we were in a state of siege.

II

It doesn't need saying that there are some objective reasons, as well as psychological ones, why sensible persons in the cities of the advanced

world should behave as though they were in a state of siege. The modern city, the city of the last third of our century, is not an entirely reposeful place to live in. For many of us, it has a certain charm. (But it is no use pretending that it is much like classical Athens or sixteenth century Venice. It is a great deal healthier, if one's thinking of disease: on the other hand, in terms of murder and bodily harm, it is very much less physically safe. The advanced world has, we all know, become remarkably richer during the last 30 years. This is true of all industrialised countries, including the U.S.S.R. Poverty has been diminished to an extent that most of us couldn't have foreseen, and certainly didn't foresee. There is extremely little subsistence poverty, for example, in Scandinavia and Holland. Not much in my own country. Thirty years ago, it was a genial assumption that, once poverty had been effectively got rid of, so would most crime go too. Has it? In fact, even in countries where poverty is now minimal, crime is increasing by a good many per cent per year. Someone calculated, a few years ago, that at the current rate of production, the entire British population would by 2040 consist of scientists and criminals. Since that time, unfortunately, we have fallen behind in our production of scientists.

All this is hard to take. The relation between crime and poverty isn't a simple one. We don't know the Soviet crime statistics since they became more prosperous: there aren't many sets of figures which would be more interesting. But we do know the western statistics. They are bizarre. It is true that, for several special reasons, the United States is not typical: the harsh fact is that American cities are, in criminal terms, the most lethal in the advanced world. Britain has under 200 murders a year, and the United States something

like thirty times as many. But, even in comparatively non-lethal cities like London, or Stockholm, or Budapest, nevertheless there is enough crime surging round one - far more than a generation ago - to give some reason for a siege mentality. As I say, no one understands this exponential development of crime in rich countries. It may be that modern technology, on the whole, makes crime rather easier: and there are also some dark truths about human psychology, which perhaps we have been too complacent, or perhaps too kind to ourselves, to wish to see clearly.

Yet, though many of us do live in an environment with that under-current of anxiety, that isn't the whole story, or even an important part of it. The major unease is deeper, subtler, and perhaps less selfish. Why are we turning inwards? Many of us are lucky, luckier in material terms than any large numbers of men have ever been. Isn't it ridiculous, or plain cowardly, that we should let ourselves feel besieged? Yet, much of the time, we do.

There can't be one single unique cause for this condition. All we are inclined to do, according to our temperaments and our particular society, is pluck out from a whole complex of causes one which strikes our fancy - or more exactly one which touches a specially painful nerve. An obvious one is the increasing complicatedness and articulation of the modern industrial state. An articulation which is to a large extent independent of political systems and which has been produced inexorably as a result of the technological process itself. So that we really don't comprehend it, even those who boom most confidently about it. We feel although we are in a motorbus driven very fast by a probably malevolent and certainly anonymous driver; we can't stop it, all we can do is show a stiff

upper lip and pretend to smile at the passing countryside. There is no doubt that, to many people, this is a genuine response. It leads - because we like to invent names which excuse ourselves and make us seem less inadequate - to all the varieties of alienation and the existential absurd. It leads a good many to wish to return to an earlier and simpler society. About that, I'd like to remark in passing that no society when men have actually lived in it has seemed as simple as it does looking back. The 19th century seemed distressingly complex to intelligent persons who were there: just read about Dickens' Mr. Merdle or Trollope's Mr. Melmotte: Dickens and Trollope were men of great experience: their worries were not all that dissimilar from ours, they didn't see their way through any more sharply, and they were writing a hundred years ago.

Still, the complicatedness of the 1968 society weighs upon many. That is one of many causes of our unease. Nuclear weapons, biological weapons, the power to wipe out so many human lives. That is novel and peculiar to our time, and it is another cause. Any of us can produce more such causes, none of them the total answer, all of them part of the truth. I am going to produce two now. They are not original, they have been said many times. Again, they are not the total answer. But they are important. They are inter-connected. They are among the noises that we don't want to hear.

The first is the sheer scale of the human enterprise. In many places and for many purposes, including some of the fundamental human purposes, there are already too many people in the world. Within a generation, there will be far too many. Within two or three generations - unless we show more sense, goodwill and foresight than men have ever shown - there will be tragically too many. So

Digitized by the Hunt Institute for Botanical Documentation

many that the ordinary human hopes will have disappeared. Disappeared irreversibly, perhaps: or at least for so long that we can't imagine how they will emerge again.

This is an old story now. It has become a cliché, as Mr. Macnamara said in September. As he also said, the trouble about clichés is not that they are untrue: often they are too terribly true. ^{trouble} The ~~truth~~ is, we stop listening to them. Incidentally, perhaps I might be allowed to mention my admiration for Mr. Macnamara's statements. They are the bravest and most direct that any world-statesman has made so far. He is more optimistic than I can find it within myself to be: but the President of the World Bank ought to be optimistic, while I am speaking as a private citizen.

Well, it is an old story. Everyone knows the brute facts. At the time of the first English settlements in America, there were something like half-a-billion human beings alive. When people still living were born, that figure, the population of the planet, would be round one billion. It is now, in 1968, well over three billion. By 2000 A.D. it will be over six billion, and may be nearer seven billion.

Some of our thoughtful forefathers used to have somewhere where their eyes couldn't evade it, a human skull. Memento mori. A reminder that you too are going to die. I sometimes think that every politician and decision-maker in the world ought to have on his desk that graph of the human population. A reminder that they too are going to be born.

It is no use trying to comfort yourself by doubts about this kind of statistical projection. In detail, of course, such projections can go wrong.

That is specifically true for advanced countries. Before 1939, for instance, the demographic curve for the U.K. was pointing down, not up, as though the population would even out at 30,000,000 by the end of the century. It is now well over 50,000,000, and looks like being 70,000,000 by A.D. 2000. And we all realise that the Japanese cut their birth rate in half between 1951 and 1961. But that was the conscious effort of a whole people, one of the most educated on earth, and also the one with the most unusual social discipline and history. Those are minor ripples in the gross statistical projections, and there isn't a responsible person who doubts that in thirty years there will be ^{nearly} twice as many human beings living in our world. That is the least that can happen. That figure can't be lowered by any of the steps that Mr. Macnamara and other men of sense would wish to put into action tomorrow. So much is foredoomed. The best that can happen is that the increase will slow down, and that from A.D. 2000 on we begin to approach a limit. A limit which is low enough not to kill hope.

Doubling the world population in 30 years. That is something new in history. On a small scale, countries like the U.K., as they became industrialised, had rapid increases in population. The U.K. doubled its population between 1800 and 1850, and again between 1850 and 1900. We were relatively rich, and had the wheat fields of America to obtain food from. There has never been anything comparable on a world-scale. And it is only happening because of one of those paradoxes and contradictions that keep tantalising us as we try to think about the problems of our times. It is happening, in fact, because of our partial control over nature. It is not so much that more babies are being born: the point is, we are so much better at keeping people alive. Medicine has gone round the world,

he poor world as well as the rich, quicker than anything else. Not only has infantile mortality been reduced everywhere (remember, our great-grand-parents, even the privileged in the most privileged countries, took the death of children as an inevitable fact of existence): not only that, but the length of life is also increasing everywhere. That is a triumph, and any decent human being rejoices in it. But it is presenting us with a situation in some ways graver than we have known before, and one that we may not be able to control.

At this point I think I ought to make something like an apology or a confession. Nearly ten years ago I gave another lecture, which I called The Two Cultures and the Scientific Revolution, and which produced, and in fact still continues to produce, a certain amount of discussion. But the discussion has concentrated on what to me was a secondary matter. The primary intention - at least in my own mind - was to try to depict one of the major practical crises in the world, that is the gap between the rich and the poor countries, and to suggest certain ways of thinking, practical ways of thinking, which were needed before we could meet it. As you will soon notice, I am returning to this topic here and now. And I have tried to avoid distractions or provocations ^{so that} it is my own fault if I can't make myself understood.

In the Two Cultures lecture there was a curious and culpable omission. It is that for which I can acknowledge the guilt now. I was talking about world crises: and I made only the slightest of references to the growth of population. That wasn't out of ignorance. I knew the facts. It wasn't out of carelessness. It was deliberate. I didn't want this major problem to dominate the discussion. Partly because it seemed to me then to make social hope even more difficult:

partly because I didn't want to hurt other people's religious sensibilities. The religious sensibilities of people whom I knew, respected and often loved; and of others whom I didn't know. I now believe that I was dead wrong, and seriously wrong on both counts. First, any social hope that is going to be any use against the darkness ahead will have to be based upon a knowledge of the worst: the worst of the practical facts, the worst in ourselves. It will have to be a harsh and difficult hope. We have never needed it more. Second, the situation is so grave that sensibilities of any kind, any of ours, any of those we respect but disagree with, have to take their chance. We are dealing with the species-life. That responsibility has to take first place.

In smallish ways, the pattern of population is already making itself felt. Certainly it is in parts of Europe, like England or Belgium. Or in Japan. Maybe not so much in the United States, though when one flies over your gigantic conurbations, one feels that men are happier when they have room to swing a cat round. The Soviet Union, in most of its expanse, is still a surprisingly empty country, and it is much harder for a Russian than an Englishman to get psychologically involved in the population flood, though intellectually, of course, plenty of them are.

I have a suspicion that this flood is already making us more callous about human life. As I said before, the rapidity and completeness of human communications are constantly presenting us with the sight of famine, suffering, violent death. We turn away, inside our safe drawing-rooms. It may be that these communications themselves help to make us callous. And yet, perhaps also there is the unadmitted thought that human lives are plentiful beyond belief?

I don't know. There is another paradox here. For, side by side with our major callousness - which is much harsher than that of people similar to ourselves at the beginning of this century - we show, in individual instances, a concern far more extreme than they ever felt. In my own country, for example, there was a depth of emotion which swept away the vestigial relics of capital punishment that still survived - which had come down to about half-a-dozen executions a year. These individual instances occupied an enormous amount of time, both parliamentary and private; they took up energy and outward-going feeling: much more, so far as I can estimate, than the hundreds of thousands ^{of} deaths by starvation in Biafra. Yet let us chalk up a point in our own favour: at times we do care.

At other times, even within our own societies, we cease to care to an almost pathological extent. Think for a moment of the numbers of people killed in and by automobiles. In the U.S.A. upwards of 50,000 a year. In the U.K. 6,000 or so. If that happened through a disease, there would be outcries, foundations, research. As it is, we take it as an act of God: without feeling: like so many schizophrenics. In my country, there was ~~was~~ ^{even} loud protest against the introduction of stiffer laws to deal with drunken driving: as though driving when drunk was one of the more sacred rights of man. If there are sane, humane and reflective people living in a better world than ours in five hundred years, they will look back on some of our callousness with incredulity. Perhaps with pity too. They may understand our situation in a way that we are incapable of. They may say that we were overwhelmed by the population flood. Or that we were living in one of the most violent ages in history, and so lost both our nerve and a great deal of our human feeling.

Just one more indication of how much we are overwhelmed. There is no single person alive who can speak on matters of simple human decency, and he listened to by people of good-will everywhere. To anyone who knew him, Einstein spoke with moral authority unlike anything that we had ever heard or will ever hear again. But he also spoke to many men. Someone described him, about twenty years ago, as the conscience of the world. That isn't too much of an exaggeration. His voice reached across the divides and confusions of our time. Now we have no Einstein. There is no man, and no group of men, who could conceivably be called the conscience of the world.

Maybe those smallish things I have just mentioned are pointers along our way. But now we can't avoid any longer the fundamental trouble we are moving into: the trouble which, in truth, we are already in. This has certainly contributed to our state of siege. Never mind our mental states, though. The trouble is elemental. It is the contrast between the rich countries of the world and the poor. The fact that half our fellow human beings are living at or below subsistence level. The fact in the unlucky countries the population is growing faster than the food to keep it alive. The fact that we may be moving - perhaps in ten years - into large-scale famine.

III

I began by saying that, when one travels in many different countries, one finds people sharing the same uneasiness. I might have pointed out that I was speaking, so far as first-hand knowledge goes, of the lucky countries of the world. Take a great arc through the northern hemisphere. North America. Almost the

whole of Europe. The U. S. S. R. Japan. If that was the entire world, adding in a few ^{additional} ~~more~~ fortunate pockets like Australasia, there wouldn't be much, at least in terms of the most simple animal fatalities, to worry about. These are the rich countries: which doesn't mean anything very sumptuous, but merely that the great majority of their populations have enough to eat, a place to live in, and perhaps, as a luxury, the chance to buy a newspaper occasionally, or even a book. That does not sound magnificent: but it is more than any big society has been able to provide for all its members until quite recently. Starvation was a danger in the background for our not-so-distant ancestors. Now we have forgotten about it: we have a knack of remembering only the pretty past. In the rich countries, food has ceased to be a problem. Industrialized agriculture has had its spectacular successes in the United States and Canada. If we wanted, we could grow more food. All over the northern hemisphere, population is rising relatively slowly: too fast for many amenities, but not fast enough to cause us the most brutal concerns. The lucky countries, if there were no others, could see a way clear.

Unfortunately, there are nearly twice as many people in the poor countries as in the rich. Further, there will - nothing can stop it - be an extra billion people added to the world population in the next ten years. Of those, rather more than three-quarters will be added to the poor. All these statements, as Mr. Macnamara remarked with great force, are clichés. A lot of us - and most urgently of all, American demographers and food scientists - have been uttering them for years past. Here is another. The gap between the rich and poor countries is growing. Take the average daily income in a large slice of

the poor countries. It is something like 35 cents a day. The average daily income in the U.S. is about 8 dollars a day. 200 times greater. In 10 years it is likely to be 300 times greater.

Yes, those statements are clichés all right. Some of them are dreadful clichés: and I am using dreadful in its first meaning, that is full of dread. The most dreadful of all - again, men of sober judgment have been saying it for years - is that many millions of people in the poor countries are going to starve to death before our eyes - or, to complete the domestic picture, we shall see them doing so upon our television sets.

How soon? How many deaths? Can they be prevented? Can they be minimised?

Those are the most important questions in our world today. Much more important than all the things which fret us in western societies, student power, racial conflicts, the disaffection of the young. Though I believe there is an invisible connection between our local problems and the catastrophic world one.

To answer those questions we have to rely to an extent upon judgment - which is really informed guessing. Most of the expert demographers and the agronomists take the most pessimistic view. It is usually right, in matters of judgment, to take a pessimistic view - so long as it doesn't inhibit one totally from action, even inadequate action. That is a lesson which we have all learned who have had any experience of war. But I want to stress that neither the extent of this catastrophe, nor the time it will happen, nor whether it will go on indefinitely or be controlled, can be precisely calculated. There are too many unknowns. One of the unknowns, or half-knowns, gives a glimmer of partial

hope. I shall deal with that shortly. The only contribution I can make is to give my own judgment, for what it is worth. It is worth only as much or as little as anyone else's who can read the evidence. I am neither a demographer nor an agronomist. And there are different stresses of opinion among those who know most, and some areas of disagreement.

It is common ground that, in large parts of the poor world, in sections of Asia, Africa, Latin America, the collision between rising population and available food is very near. The demographers say that there is no method of curtailing population growth within ten years. With great good fortune, and world effort, ^{a little} ~~reversing~~ might just conceivably be done in twenty or thirty years. They call on the agronomists to pull something out of the bag to give the demographers enough time. The agronomists - or a large proportion of them - make exactly the same demand in reverse. Can the demographers reduce the human increase soon enough to give them - the people working on tropical agriculture - enough time?

Most informed opinion believes that neither step is going to happen in time: that is, the collision is going to take place. At best, this will mean local famines to begin with. At worst, the local famines will spread into a sea of hunger. The usual date predicted for the beginning of the local famines is 1975 - 80.

The only rational ground for putting this date further into the future is the hope of increasing food production. In fact, this is the chief area of disagreement between responsible men. Here, as it happens, there is ~~this~~ the ray of hope, glimmer that I mentioned. In the midst of the bleak prospect, there is one

genuine piece - though in the long term it mustn't be overestimated - of good news.

On July 17 the Indian Government issued a special postage stamp. It was a stamp to celebrate the wheat revolution. Stamps have been issued for many worse celebrations: it is very hard to think of a better. We have had some gloomy figures in this discussion. Let us have one heartening one. In the 1967-8 season, the wheat harvest in India was 17,000,000 metric tons. In 1964-5, which had better weather, the harvest was 12,000,000 metric tons. Very nearly the same increase, and the same kind of record harvest, has been grown in Pakistan. For the moment, the fear of hunger has been beaten back from the sub-continent.

This is a success story, carefully planned, and the result of many years work. A great deal of the credit, and it is pleasant to say it here in the middle of the United States, goes to two great private foundations; the Rockefeller - note how long ago - and the Ford. In 1942, the Rockefeller Foundation provided the finance and encouragement for the International Center for the Improvement of Wheat and Maize, set up in Mexico. The Ford Foundation now provides half this center's funds. The budget, interestingly enough, is not very large, under a million dollars a year: but the real secret has been the scientific insight. Dwarf wheat strains have been developed which have a high degree of resistance to tropical conditions. That took getting on for twenty years. In 1962 the Indians decided their best chance was to import those wheat strains. Their own research workers have introduced other genetic characteristics into them. The Pakistani did precisely the same two years later, and produced their own Mexipak strain. Both countries have shown great efficiency in educating their farmers. The

results would have seemed impossible as recently as five years ago. The Rockefeller and Ford administrations, the scientists, their Indian and Pakistani colleagues have done more concrete good to our world than is given to most men. If I were an elector to the Nobel Peace Prize, my vote would go to them.

Something of the same nature, again supported by the two foundations, is happening to rice. There is an International Rice Research Institute in the Philippines, which started in 1962 and has been producing a high yielding and disease-resisting strain of rice. The most promising one, called IR3, has already ~~already~~ been exported to Asia and South America. With any luck, more hunger will be pushed back for a while.

Well, this is good news. In making one's judgment of the future, it is a factor. We mustn't lose our heads, one way or the other. The limits to food production, even when as deeply planned as this, seem to be quite sharp. The population increase has no such limits. The collision is still on. The guess ^{should} I shall now make - as I said, this is no more useful than that of anyone else who reads the evidence - is that large-scale famine won't happen as early as 1975-80. There will probably (it is a bitter thing to say) be serious local famines, in, for instance, Latin America and parts of Africa. The major catastrophe will happen before the end of the century. We shall, in the rich countries, be surrounded by a sea of famine, involving hundreds of millions of human beings, unless three tremendous social tasks are by then in operation. Not just one alone, but all three. They are:

- (1) a concerted effort by the rich countries to produce food, money and technical assistance for the poor.
- (2) an effort by the poor countries themselves, on the lines of India and Pakistan, to revolutionise their food production.

- (3) an effort by the poor countries - with all the assistance that can be provided under (1) - to reduce or stop their population increase: with a corresponding reduction in the population increase in the rich countries also.

Those are the three conditions, all necessary, ^{if we are to} ~~by which we can~~ avoid social despair.

IV

Despair is a sin. Or, if you talk in secular terms as I do, it prevents one taking such action as one might, however small it is. I have to say that I have been nearer to despair this year, 1968, than ever in my life. With the one exception that I have just mentioned, about which we all had an intimation before this year, everything that has happened in public has pointed in the direction of anti-hope. In 1967 one could feel this in the air. This year one can see it.

I don't mean anything at all subtle. It goes without saying that to avoid major war, there has to be some sort of understanding between the U. S. and the U. S. S. R. It also goes without saying, I suggest, that to avoid the catastrophe I have just been discussing - the catastrophe a little further ahead - there has to be something more than uneasy understanding, something more positive than coexistence, between the two great power-centres of the world.

As for major war, I ought to say at once that in my view the chances are very much against. These may be famous last words, or rather words not specially famous because no one is left to know them. But major war - in the sense of a thermonuclear war between the two super powers - has in fact been most unlikely for a good many years. Great countries don't usually commit mass

suicide. The military understanding has been worked out. The balance of power has remained steady. I believe, as I shall say in a minute, that both countries will spend increasing sums on armaments. But the balance of power will still remain pretty steady. The risk of major war will be there, but it is small, and probably the least of our worries. Minor wars, and dangerous minor wars, will occur during the thirty years we are looking ahead. In some of these nuclear weapons may be used. But even that will not produce the mutual elimination of the United States and the U.S.S.R. The minimum amount of coexistence will be preserved.

But something more positive than that? The kind of co-operation which many of us have been hoping for - hoping for, not just in terms of vague good will, but simply because there, and nowhere but there, seems to lie the salvation of the planet. Or a tolerable prospect for most of our fellow human beings. For a brief period - one can even put a date to it, something like 1962 to 1965 - there seemed a realistic chance. Now it has become remote. It may not have disappeared; one has to go on hoping that it hasn't disappeared: but ^{everything} ~~anything~~ that has happened in this dark year has pushed it further away.

Everything, both big and little. We all know the obvious examples, the hardening of attitude in both countries, Czechoslovakia, all that we are witnessing: but let me take something which seems less relevant and more innocuous. Student riots in France. There was idealism there. Some ^{university} ~~university~~ reforms, which ought to have been made a long time ago, have been achieved. But, on the world-scale - in the light of the world crisis in which these students are going to live their middle-age - they did harm. There is no need to exaggerate

the harm, but it is perceptible. Most of the population of France has been thrown back, like the rest of us, to this contemporary state of siege. That was predictable to anyone with the political intelligence of a newt. The forces which hold our advanced society together are very strong. Only people whose vision of the future is limited to about a week underestimate those forces. But the cost of bringing the forces into play can be very great. You know that in the United States. It tends to make the whole society look inwards. The French society is now looking inwards. And that was the last thing that we - if we have any concern about the world - wanted to happen.

Contemporary France hasn't, of course, made things easy for my country: they tend to regard us as a minor and displeasing extension of an even more displeasing United States. Incidentally I wish General de Gaulle wouldn't insist on referring to us collectively as Anglo-Saxons. I happen to be one; but, purely on grounds of anthropological accuracy, he ought to recollect that he himself is far more likely to be of similar origin - from some related tribe which emerged from the German forests - than are about 60% or 70% of the present population of the United States. Where does he think the northern French came from? But still that doesn't matter. It is a local quarrel. In the broader sense, we need France very badly. As an independent voice which can talk to the Soviet Union. And in particular which can talk to the East European associates of the Soviet Union. Warsaw, Bukarest, Prague and to some extent Budapest still look to Paris with greater cultural sympathy than they do to New York and London. If ever we can imagine positive collaboration between the super-powers, it will need the kind of mediation which France could help supply. But France has been forced inwards.

The independent voice won't be valid for some time. Positive collaboration is that much less likely. Even small things, like the Sorbonne riots, have made their own contribution this year - in the wrong direction. It has never been more important to be tough-minded. There are a lot of gestures, protests, sacrificial actions, which aim at good things, which are in spirit progressive - and which in the result, objectively, end up by being the opposite of progressive.

Sensible persons may very well observe that this positive collaboration between the U. S. A. and the U. S. S. R. is unimaginable any way. To cope with this catastrophe that everyone is predicting needs three separate quantum-jumps in human endeavour - each of them different in kind from anything that men have had the will to do before. The effort that the poor countries have to make on their own account - in particular the major effort to limit population increase. It must come from within the poor countries themselves: it must be matched by a similar restraint in rich countries (that is a psychological necessity): it must have the unqualified support of world-opinion, including organised religion, everywhere. Can anyone, sensible persons will ask, believe that that will happen?

The first primary agreement between the super-powers to agree to collaborate for humane ends. Wouldn't it take some immediate hostile threat from elsewhere in the galaxy to make that even remotely practicable? Even then, the suspicion, the toings and froings, the possibility that hostile intelligences from outer space might perceive the superior virtues of American-type capitalism or Soviet-type communism respectively? For any lesser danger, and a danger ten or twenty years ahead, there is not even the language of discourse in which the super-powers could collaborate. Can anyone believe that that will happen?

The third quantum-jump is perhaps even more unlikely than the other two, if that is possible. Assume the wildly improbable, that some sort of collaboration is set going. Then consider the sheer magnitude of the endeavour. To avert the crisis, is going to mean sacrifices such as rich countries have never contemplated, except in major war. Much greater than the United States has ever had to bear in any war. There are various estimates of what is required. The most drastic I have seen doesn't come from an American source, though many Americans have told us the size of the problem. This extreme estimate is that, to make the world safe while there is time, the rich countries would have to devote up to 20% of their G.N.P. for a period of 10 - 15 years. Obviously that would mean a radical decrease in military expenditure: it would mean that the standard of living would stay still, and then decrease. It sounds a fantastic estimate: yet I believe it is nearer the truth than more comfortable ones. In the whole of this exercise of seeing our dangers, most of us - and this is certainly true of me - have been complacent. We have been playing at it.

Anyway, the effort needed, both in money and human resources, is immense. Even the United States - granted total benevolence - couldn't do it alone. The U.S.S.R. certainly couldn't. The United States and Western Europe together could make some sort of impact: but that couldn't and wouldn't happen - since it would mean major curbs in military spending - without the U.S.S.R. coming into partnership. Even then, the cost would be very great. Not just in the fairy arithmetic of governments, but in the ordinary lives of ordinary citizens.

Does anyone believe that that will happen? We are all selfish.

Political memory lasts about a week, the professionals say. Political foresight

stretches about another week ahead. To stint ourselves to avoid a disaster in twenty years - what body of people would ever do it? Right. When sensible persons ask me any of those three questions - does anyone believe that that will happen - the answer is, of course not. For myself, I wish I could: of course I can't.

Now I want you to consider the alternatives, that is, what will probably happen. I am going to suggest three models for the next thirty years. They are all projections, in slightly different directions, from the first part of this discussion.

Model A is the gloomiest. It is, I am afraid, the most likely. The relations between the super-powers will not alter much. They will still co-exist, in the sense of avoiding major war. They will spend increasing sums on armaments, anti-ballistic missiles and so on: there will be no greater security for either, and probably not much less. Internally, they will change less than many who live in other countries would expect. This will disappoint both their friends and their enemies. The U.S.S.R. is a very stable society. So, despite all surface appearances, is the U.S.A. Incidentally I know no country where the surface appearance is more misleading. You will go on talking about collective nervous breakdowns: and remain, except for technological irruptions, not so dissimilar to the present state. You will still be burdened with the horrible legacy from the past, for which the ancestors of my countrymen were as much or more to blame as the ancestors of yours. A great many English fortunes were made out of the negro slave trade - which, in the miscellaneous sordidness of human history, was one of the more sordid passages. And the sins of the fathers

have been visited not only on the children, but on someone else's children.

Both the American and Soviet societies will get richer. In many ways, the U. S. A. will get richer faster than the U. S. S. R.: in places the U. S. S. R. will concentrate its priorities effectively, and will keep up. The rest of the advanced world will polarise, as now, towards one or the other of the super-powers. The increase of population all over the rich world may get a little less. In the poor world it won't, except in one or two pockets. Despite local successes, as in India, the food-population collision will duly occur. The attempts to prevent it, or meliorate it, will be too feeble. Famine will take charge in many countries. It may become, by the end of the period, endemic famine. There will be suffering and desperation on a scale as yet unknown. This suffering will be witnessed - since our communications will be even better - by the advanced countries, whose populations will be living better than they are today. It is hard to imagine the psychological and political conditions which will be created by such a gap. Some of us are lucky who won't have to live in them. Without question, the rich populations will feel they are in a state of siege, sometimes in a literal sense; and it may be that our present unease is a shadow thrown backwards from the future.

Model B is a shade more cheerful version of Model A. It depends on several things all going right simultaneously: some, though not dramatic, relaxation between the super-powers; the success of initiatives like Mr. Macnamara's; the extension of the Indian agricultural triumph. Some sanguine observers believe that, with immense good fortune, this might conceivably be enough: not enough to avert serious suffering, but enough to tide it over, and give mankind a generation's

breathing-space to think and plan. I find it hard to believe that they are being realistic. But I respect them for saying, in effect, that in times of trouble it is better to do something rather than nothing. The worst doesn't always happen. That is an old stoical maxim that has taken us all through grim times. The truth is, it may not be adequate for these.

Model C. This is by far the most unlikely of the three: and yet we have to act as though it is more likely than it is. The only decent way to respond to a state of siege is to break out of it. Or at least to try to. Most of us are private citizens, who can only do little things. But the whole world is made up of private citizens, and if they can see the situation, then the situation may be changed. Most of the time, human beings are rapacious and selfish. Some are capable of great nobility, but we can't build on that. Many in rich countries are so selfish that they would, and maybe will - be willing to get richer and use the technological superiority which their riches gives them to fight off the hungry millions outside. I for one shouldn't like to live in such a world: and in purely material terms it couldn't be long maintained. But we have to take selfishness for granted. We can also, however, take human intelligence for granted. For all our faults, that has been the strength of the species. It is our best hope now.

We have to tell the facts. We have to make sure that people understand those ominous curves - the curve of population, the curve of food supply. We have to tell what the collision means. And this must be done, not only by high officials like Mr. Macnamara, but by private citizens like ourselves. Scientists will have to do it: people in universities are in a strong position to do so: it is the plain duty of churchmen of all kinds.

It is going to need great sacrifices. Including one of the most difficult sacrifices of all, the sacrifice of our rigidities. For, in some ways, a state of siege is comfortable. If we break out, we are going into the harshness of the streets outside. American citizens and Soviet citizens are called upon to face an unfamiliar harshness: the harsh but active assumption that the opposite society is not going to collapse, within foreseeable time. It is no use waiting until the U. S. S. R. becomes capitalist or the U. S. A. communist. If we wait that long, the world population will have doubled, re-doubled, re-doubled, 7 billions, 14 billions, 28 billions..... That is the fate which we have to drive home. By the side of that fate, our similarities as human beings ought to be stronger than our differences. Is there any hope that it will prove so?

One hears young people asking for a cause. The cause is here. It is the biggest single cause in history: simply because history has never before presented us with such a danger. It is a very difficult cause to fight, because it will be long-drawn-out, it is going to need using political means for distant ends. We have to stop being trivial. Many of our protests are absurd, judged by the seriousness of the moment in which we stand. We have to be humble and learn the nature of politics. Politics is bound to be in essence short-term. That is no one's fault. Politicians have to cope with the day's tasks. American governments have to try to keep their country safe, in the short term as well as the long. Soviet governments have to do exactly the same. But it is in the nature of politics that the short-term duties come first. It is the duty of all the rest of us, and perhaps most of all of the generations which are going to live in what is now the future, to keep before the world its long-term fate. Peace. Food. No

more people than the earth can take. That is the cause.

I should be less than honest if I told you that I thought it was likely to succeed. Yet we should be less than human if we didn't try to make it. We live in our time. This is the responsibility of our time, and it is our own. Sometimes I console myself with a piece of rabbinical wisdom:-

If I am not for myself, who am I?

If I am for myself alone, what am I?

If not now, when?

C. P. SNOW
24.10.68

Reprinted from 'Science Journal' October 1967

'Science Journal' is published monthly by Associated Iliffe Press Limited,
Dorset House, Stamford Street, London, S.E.1

Annual subscriptions can be obtained from this address at the following rates:—
U.K. £3.5.0d. including postage; Overseas £4.0.0d. including postage; U.S.A. \$12 including postage

Roger Revelle

Population

According to one estimate, the population of India and Pakistan will exceed that of China by the turn of the century. But such estimates depend fundamentally on human fertility—the one controllable variable in an otherwise uncontrollable situation

IN SOME SENSE population forecasts are the most basic of any that can be made. Nearly all the other forecasts described in this issue, for instance, will depend ultimately on the size of the human population—if only because the need for a technological advance is reflected by the number of people who require it. But however fundamental the number of people living in various regions of the world may be as a parameter, it is not an easy one to assess at the present time or to extrapolate into the future.

Like many other phenomena, changes in the size of human populations tend to follow an exponential or compound interest law over any short period. But over longer periods populations seem to grow in more or less sudden steps, from one stage of quasi-equilibrium to another. For example, consider the two major demographic revolutions in man's experience: the population growth that accompanied the development of agriculture, and the one that began in the 17th century in northern Europe and has since spread throughout the world.

ROGER REVELLE is Richard Saltonstall Professor of Population Policy and Director of the Harvard Center for Population Studies. Formerly Science Adviser to the Secretary of State of the Interior, University Dean of Research at the University of California and Director of the Scripps Institution of Oceanography, his research is now concerned with the balancing of natural resources—particularly food supplies, water and the quality of the environment—against population.

Man has existed in substantially his present biological form for perhaps a million years yet, during all but the last one per cent of that time, the number of people was never more than a few million, not much greater than the number of lions. We know this was so from the estimated density of population among peoples who were still living in a stone age culture when they were observed or studied by Europeans—certain American Indians, African tribes, Australian bushmen, Papuans in New Guinea and others. Over most of the first million years, birth rates and death rates of the world's population must have been, on the average, almost exactly equal, probably somewhere between 40 and 60 per thousand people per year. The mean rate of natural increase, taken over any set of millennia, could not have been more than 0.05 per thousand per year, corresponding to a doubling time of 20,000 years or more. Of course, the books were never so nicely balanced. In every particular region there may have been wild fluctuations from century to century, and even from generation to generation, in death rates and population size, followed in many cases by parallel fluctuations in birth rates. But the long term average of population size against time must have been almost a level line.

Agriculture was invented 6000 to 9000 years ago. Its development over the next few millennia radically changed the human condition, and destroyed the previous equilibrium between birth rates and death rates. In the Fertile Crescent from the Nile

to the Tigris-Euphrates, in China, India, Southern Europe, Middle America and Peru, human numbers may have increased a hundred fold in one or two thousand years, until a new quasi-balance between births and deaths was attained. It has been estimated that, by the time of Christ, the world population was 300 million, even though agriculture had barely begun, or had not even been started, over large areas.

Between the beginning of our era and the early part of the 17th century, the population slowly increased, to somewhere around 600 million. Then it began to rise rapidly again and at an ever accelerating pace. Whereas the average annual rate of increase from 1 A.D. to 1600 had been less than 0.5 per thousand, it rose to 4 per thousand from 1750 to 1800, to 8 per thousand from 1900 to 1950, and is now probably nearly 20. The number of human beings has increased more than five fold in three and a half centuries. At the present rate it will double again by the end of our present century.

This remarkable change was brought about largely by a decline in death rates, although fertility did rise above previous levels at some times and places. Between 1700 and 1900 the overall rate of growth was two to three times as great in Europe and areas of European settlement as in the rest of the world. Today, the situation has become almost exactly reversed. The underdeveloped countries are now growing more than twice as fast as the developed ones. At the beginning, infant and child mortalities

Malthus, Magic, and Motivation

Steven Polgar, Chapel Hill
North Carolina
December, 1968

There are few scientists today who have not given some thought to the population problem, and recent scientific and semi-popular journals contain many allusions to it. Even the government of the United States has begun to put its money where its mouth is, so that finally in 1968 the Ford Foundation was pleased to find itself in second place, behind the Agency for International Development, in the size of its population budget. Perhaps not unrelated to this recent step-up in funding, from crumbs to peanuts, a heated debate has developed on what should be done. Some appear to believe that intensive antinatalist propaganda, using the magical tricks of Madison Avenue, should be given the highest priority. Others doubt that population can be stabilized by the voluntary action of individual couples, who must rather be "motivated" or coerced by major changes in their environment to abandon deeply traditional desires for many children. And some have declared the battle already lost, recommending that the U.S. save a favored few countries by judicious exercise of grainboat diplomacy. My own view is that what is most needed right now is a lot of hard work to make good methods of birth control widely and easily available. Other measures are also important, such as efforts to reduce infant mortality, improving child-care facilities for women for whom jobs can be made available, etc. -- i.e. other measures that are consonant with positive goals aside from population planning, and which are economically feasible.

In this essay I will concentrate on whether and how population growth may be slowed, and skirt such other important -- and related -- subjects as socio-economic development, adequate food consumption, and conservation. These omissions do not mean that I believe that fewer births will solve these other problems; it is only that without a reduction in the population growth rate, progress on these other fronts will become increasingly costly, and eventually impossible.

Variations in approaches proposed to population planning may be traced to differences in values and in professional background. Here, I will deal mostly with the latter, particularly with the theories espoused by demographers. But first, a very brief review of events from the Depression to 1968.

Before the Second World War most demographers were not particularly worried about overpopulation; rather, they were exercised by the illusory prospect of declining population in the Western world. While one or two

of them did conduct studies on the operation of birth control clinics, and under the leadership of Pascal Whelpton a score became involved in the pioneering interview study in Indianapolis on the factors affecting childbearing, to the majority, Margaret Sanger's battles were irrelevant or slightly embarrassing. Historical analysis seemed to prove that the work of birth control clinics was of no real consequence: if people wanted to limit their childbearing, wouldn't they do so with any and all means available, even in the face of public disapproval; and if they wanted more children, of what earthly use could clinics be?

Busy as they were trying to establish the right of all women to regulate their maternity, and enlisting support from the medical profession and the upper crust of society, Margaret Sanger and her colleagues, on their side, paid relatively little attention to the calculations of the demographers. Later, when money from foundations was becoming more plentiful, there was considerable resentment among them that they received almost none of it, whereas other organizations, whose hands would be ever so innocent of spermicidal jelly, could get both the easy money and the prestige of scientific "objectivity."

In the 1950's a number of large household surveys were initiated both here and abroad on childbearing, desired family size and birth control. Moreover, several action-research projects were begun, among them the path-breaking studies of Stycos, Hill and Back in the Caribbean, of Gordon, Taylor *et al.*, and of Sen, Mathen *et al.* in India, and of Koya in Japan. On the biomedical research side, field trials with ovulation suppressing drugs got under way, and studies on the Graefenberg ring in Israel and the Ota ring in Japan rekindled interest in intra-uterine devices. As the post-war census results became available, from Latin America and Asia in particular, the specter of Malthusian doom became imminent again to more and more people. The non-existence of monolithic opposition from the Catholic Church began to be more widely known. In Planned Parenthood circles in this period the search for "easy" methods of contraception became intensified, in recognition of the indifferent performance of birth control clinics that relied primarily on the prescription of diaphragms by physicians.

In the early 1960's the most widely heralded change was the increasing role of governments, including our own, in supporting family planning services. Since most official birth control programs have been operated by departments of health, and increasing number of public health workers became involved in family planning. Another important event was the participation of the noted demographer, Ronald Freedman, in planning and executing an action-research study in Taichung, Taiwan. With the hiring of Bernard Berelson and the sponsorship of the Taichung Project, the Population Council moved squarely into the fray, abandoning its earlier stance of aloofness from the actual provision of services. Planned Parenthood was becoming more professionalized and less isolated, and was paying increasing attention to improving its administrative capacity to extend contraceptive care to those who wanted and needed it.

More important than any of the foregoing, in my opinion, was the discovery that the pill and the new intra-uterine devices (particularly the Lippes loop) were contraceptive methods of an acceptability and effectiveness far beyond any that had been tried before. The number of clinic patients in the United States, which had been barely creeping upwards for decades, more than doubled in four years once these new techniques were introduced. In Taiwan, Berelson and Freedman discovered that the person-to-person word about the IUD was far more important in recruiting patients than the exact "dosage" and "mix" of informational inputs from the outside.

As the numerous surveys of knowledge, attitude and practice of birth control around the world were analyzed, it also appeared that an overwhelming majority of the people in every developing country studies were favorable to the establishment of government birth control services, and a substantial number of women in their childbearing years were having more children than they wanted. This was a considerable surprise to demographers, and a few of them, like Philip Hauser, still hesitate to accept these results as true. The reasons for this should become apparent in the following discussion.

The Funnel of Love (for Children)

Ronald Freedman has likened to a funnel the schema by which his profession seeks to unravel the causes of birth rates. At the narrow end of the funnel (narrow because it consists of relatively simple phenomena measured by well-defined numbers) are the births themselves, the "output" of the system.

On the second analytical level, immediately preceding these, are the so-called "intermediate variables," which are the limited set of mechanisms through which any social or environmental force has to act to affect birth rates. While some of these mediating factors are involuntary, for example fetal mortality due to genetic defect or increasing infertility with advancing age, many others are voluntary, such as age of entry into sexual union, abstinence from intercourse following the birth of a child, use of contraception, etc. It should be noted, for reasons that will become relevant below, that the demographers' definition of factors affecting natality excludes infanticide from the list of intermediate variables, because it comes under causes of mortality. By the same token, the usual mortality rates do not include pre-natal deaths, which are placed among the causes of (live) births.

Moving outward, toward the larger end of the funnel, the third level of analysis concerns attitudes. These are often summarized as high, moderate and low family size desires. While theoretical models include attitudes relevant to the "intermediate variables" as well, these receive but spotty attention in practice.

The fourth and last level to which demographers address themselves, at the largest end of the funnel, is the realm of socio-cultural and economic patterns. This will include factors such as a degree of modernization, urbanization, inheritance laws, roles of women, religion, economic trends, poten-

tial contribution of children to family income, spaciousness of housing, and the like.

The logical consistency of this conceptual scheme helps demographers to organize their observations. But it also hampers giving attention to the complexity of the processes which affect family planning and population dynamics (a complexity, I should quickly add, which is again more likely to be recognized in theory than in practice). The first limitation of the funnel, which I call the "single outlet fallacy," is that social institutions cannot be understood merely in terms of the effects that they have on norms about family size. Norms about who should have children, and when, influence many outcomes other than the birth rate. The second difficulty, the "one-way fallacy," is that cause-effect relationships must flow from the larger end of the funnel toward the narrower one, since the independent and dependent variables in each case are already defined.

The rigidity imposed by the "funnel of love (for children)" can be illustrated by the following quote from Kingsley Davis (Science, Vol. 159, pp.481-2):

"On the principle that goals are determined by means, he (a critic of Davis) believes that reproductive desires can be altered by the provision of contraceptive services. The evidence shows the opposite: Once people have been impelled by circumstances to want fewer births, they employ a variety of means successfully to accomplish this goal, without any program to help them, and, in fact, in the teeth of opposition. Failing a change of conditions, they will not use any means of fertility control, no matter how new, except to implement their prior reproductive goal. All that a technological approach to fertility control can do is to shorten the period during which people are finding means to achieve their new family size desires."

There is no allowance here for couples to have hazy or ambivalent attitudes about family size. They may not adopt birth control so as to increase the interval between children, or just because pills will reduce their menstrual flow. And it is entirely inconceivable to Davis that they might find advantages to not having another child, while they are not having one, altering whatever ideas they may have had about the size of their completed family.

Childbearing in Pre-industrial Societies

The funnel is not the only obstacle to a better understanding of the population problem. All pre-industrial societies, demographers appear to believe nowadays, have monotonously high infant mortality rates, which impel them to maximize the number of births in compensation. The predominance of familistic over societal concerns, the utility of children in adding to production, and the sharing of the burden of child care among the several women in extended household, are all presumed to reinforce this tendency toward very high natality. But demographers are not really ignorant of such practices as infanticide, which is practically universal among hunting and

gathering peoples and common among food producers, or the frequent prescriptions on intercourse in the postpartum period; they know full well that no group has the physiological maximum of over a dozen births on the average; they just have paid little attention to these facts in recent years.

A more balanced view of the forces affecting birth rates in pre-industrial society was actually prevalent among population students in the 1920's and early 30's; but somehow, with the later discovery of very high natality in some non-industrial countries and moderately high natality in many others, the cultural forces tending in the opposite direction came to be downgraded. These high birth rates were already influenced by better communications and the introduction of famine relief, and to a lesser extent by hygienic measures and the opposition of missionaries to abortion, infanticide and polygyny. Greater availability of food mitigated epidemics, decreased pre-natal mortality and increased the total length of the fertile period of women. Infant mortality rates have historically ranged from medium to very high, depending on climate, nutritional status, and other conditions of living; they were probably lower before the beginning of food production than after (see my "Evolution and the Ills of Mankind" in Sol Tax, ed., Horizons of Anthropology, Aldine, 1964). Furthermore, in some instances where very high natality rates are found, these probably compensate not merely for long-standing infant mortality, but also for more recent drastic depopulation resulting from slavery, the importation of European diseases, and the substitution of guns for less lethal types of weapons. Very high birth rates also prevail among peoples who have, sometimes in conjunction with the acquisition of firearms, embarked on territorial expansion at the expense of their neighbors, or in the rare instances where "empty" lands are being filled. Examples, on the other hand, of non-industrial societies with culturally established (rather than pathological) low natality can also be found, e.g., in Highland Burma (see June and Manning Nash, Southwestern Journal of Anthropology 19, 25, 1963).

The important point in all this is that throughout man's history hardly any pre-industrial people wanted anywhere near the physiological maximum number of children, or allowed such a number to be born and survive. Cultural regulation of population growth has been operating, along with biological checks, since long before the establishment of agriculture. Control of reproduction during the last century in industrialized nations is, therefore, not all that unique.

The Demographic Transition in Industrial Societies

In its crudest form, the transition model posits a sequence of events starting with industrialization, followed by a sharp drop in mortality, and -- after an interval of a generation or two which experiences rapid population growth -- a sharp drop in natality. While this simple schema has not been entirely rejected, each part of the sequence has been severely criticized. Mortality and/or natality started to fall in several countries (and in many regions within countries) before manufacturing came to be a significant factor in the economy. Gradual declines of birth and death rates occurred

almost simultaneously in Eastern and Southern Europe. And in some of the prototype countries for the transition model, it is now becoming apparent that the population bulge was substantially influenced by increases in natality in the early period, not just decreases in mortality.

Population increase and the unfreezing of the social structure, nevertheless, probably were major influences in family size. When it becomes apparent that substantial socio-economic advancement is possible if a family's resources are spread over a smaller number of children, it seems reasonable that parents would act to reduce the number of potential heirs to their fixed capital. Indeed, the rewards of family planning were probably so great that even such drastic measures (for Europeans) as abortion and infant abandonment became widespread. It is also useful -- as Davis has stressed -- to regard migration to cities and delayed marriage as partly a consequence of threatened over-population in the homestead. But the advantages of late marriage or city living encompassed far more than just relief from too many children in the home. Young people could accumulate resources (money, education, goods) before marriage; cities and overseas colonies offered entirely new opportunities which were more easily exploited by those unencumbered by children. Thus, it is a gross oversimplification to regard industrialization "motivating" the adoption of any and all available means to achieve the single desired end of reduced family size. Not only were there several ends, but each technique of limitation had various costs and benefits according to social and cultural circumstances.

The Situation in Developing Countries Today

In much of the Third World, as we read every day, population growth is cancelling out economic growth. In large parts of Latin America -- the continent with the fastest growth rate -- feudal systems persist and opportunities for upward social mobility are meager indeed. In many parts of Africa infant mortality is extremely high. In the Middle East and South Asia too, the reduction of child mortality and the opening of social and economic opportunities have proceeded but in fits and starts. The European and Japanese experience may be recalled in this context, since in the early stages of their demographic transition, when only small increments were added to economic opportunity and nutrition, there was often an increase in the birth rate.

Perhaps the most important demographic trend in non-industrial countries today is migration to the cities. But, unlike the industrialized countries in this respect, there is not enough employment for these migrants, and the natality rate in the urban areas is sometimes as high as that of the rural hinterland (e.g., in Mexico). Yet it is hard to believe that "motivation" to reduce the number of children is altogether absent where obstetric wards are crowded by women suffering from the ill effects of back alley abortions. Also, when decently run birth control services are provided, which offer the loops or pills, the response often exceeds the capacity of the staff to keep pace. Sure, in the beginning it is usually the women with four or more living children who come, but, gradually, an increasing proportion is made

up of women who have two or three children, and a few with one or none. In Malaya, where the recently started government program offered pills for a very low price and did not require a pelvic examination by a physician, women spacing their births even dominated the program from its start (Studies in Family Planning No. 26, Jan. 1968). Thus, as the low psycho-social and economic cost of coitus-independent contraception comes to be appreciated, the potential "payoff" for its practice no longer needs to be high.

Rewards for not having births, moreover, for using pills or loops or getting an abortion, are several, and many have nothing to do with limiting the number of children in the household. In the United States, pills may be seen as useful for enlarging the breasts, predicting the time of menstruation, or reducing the amount of its flow. Abortions, of course, are often obtained so that one need not quit a job, hold up divorce proceedings, or contract an undesirable marriage. In developing countries, the desire to have long intervals between pregnancies is almost universal. And in quite a few societies a pill that reduces menstruation to a brief and seldom affair would be in great demand to minimize troublesome rites and prohibitions. We do not know how great an influence such "extraneous" factors play in the adoption of family planning since they are little recognized, even by those who believe that making birth control more accessible is the highest priority task today. As a matter of fact, cultural factors are often linked with religion, as dangerous rocks that skillful helmsmen of birth control programs will carefully avoid, instead of potentially powerful aids to success.

Between the Voices of Doom and Euphoria

I have spent many an evening in a small private dining room of the Columbia University faculty club, attending a Population Seminar. Abraham Jaffe, the demographer in charge of this series is typical perhaps of the pessimistic stance in the business of guessing the future. More than once he told us, with a jocularity incongruous to his meaning, how glad he was to be old, so that he won't be around any more when the inevitable Malthusian doom arrives.

More extreme than this postprandial passivity is William and Paul Paddock's book "Famine 1975" (Little, Brown and Co., 1967) which could have been hatched in that mythical cave on Iron Mountain. They not only believe that population growth will outstrip the potential food supply in ten years, but go on to suggest that the U.S. abandon India and many other countries to their Armageddon, and use its grain shipments as a major foreign policy tool. To someone who might accept their gloomy assessment of food and population prospects (based on a rather mixed bag of "authorities"), this may appear rational. But weapons and quarantines could not contain the plagues that would ravage the lands classified as "can't be saved." And the people themselves would not oblige by dying harmlessly behind their mud walls; they would have to be exterminated to prevent their crossing over into countries on the favored list.

At the other pole, "euphoria" may be too strong a word to describe the stance taken by Donald Bogue, but he himself avows that he is the most optimistic among the population forecasters. His predictions indeed sometimes

verge on the miraculous, e.g., "The rate of growth will slacken at such a pace that it will be zero or near zero at about the year 2000" (The Public Interest, Spring, 1967, p. 19). His optimism, however, is not primarily based on the technological breakthrough represented by the new coitus-independent contraceptives or on the major effort under way to distribute them. He acknowledges the importance of these, but lists them behind such factors as the decline in opposition to family planning, the slackening in the downward movement of mortality, and the "motivating force" or privation. "Motivation" is, in fact, still a cornerstone of his philosophy, and he pays correspondingly little attention to the administrative problems involved in distributing supplies and providing medical supervision.

Several eminent demographers have recently moved toward optimistic positions also, but much more cautious ones than Bogue's. Ronald Freedman's 1965 presidential address to the Population Association of America was a signpost in this trend. He called on his colleagues to study the demographic transition actually taking place in an increasing number of countries with high natality. He based the "audacious" prediction implied in this on six factors; the presence of organized efforts to "disseminate family planning ideas and information" was in fifth place among these, and the availability of IUD and pills in the sixth. The following year, Ansley Coale reiterated the dictum "that the principal change responsible for the development of controlled fertility has been a change in attitude or motivation rather than the invention of new techniques," but went on to express some glimmer of hope, based on the low "motivational" requirements of the IUD, the wide recognition of the population problem and the success of organized programs (Proc. Am. Philosophical Society, June 1967, pp. 168f). And Frank Notestein, who was for a long time the "big daddy" of traditional demography, but had gradually come to perceive the success of the programs sparked by the Population Council which he headed, recently wrote in Foreign Affairs (Oct. 1967, p. 170) that the prerequisites for a solution were at hand. The four elements giving him hope were: the development of national policies favoring family planning; the demonstrated public interest in limiting childbearing; the improvement of contraceptive technology; and the success of governmental birth control programs among several Oriental populations.

This growing consensus of guarded optimism does not by any means include all the important demographers; sceptics like Hauser, however, have confined their criticisms to technical points and voiced them mostly within the professional fraternity. But, beginning with the 1967 meetings of the National Academy of Science, came the vituperative attacks by Kingsley Davis on an undefined group of "family planners." These villains of his scenario sell their wares as the solution to the population problem, they encourage -- horrible dictu -- individual couples to decide on the number of their children, and they condemn abortion in order to seek the favor of governments in power, all instead of espousing such "radical" steps as a marriage tax or a slowdown on housing construction. There are plenty of misrepresentations in Davis's article that appeared in Science (November 10, 1967) but when the committee on population of the NAS dared to raise some mild objections,

the eminent professor completely lost his cool. In his reply (Science, Vol. 159, p. 827) he accused them, in so many words, of having been infiltrated and bought by the Population Council.

Kingsley Davis' fury highlights the fundamental role played by funnel theory for demographers. I quoted earlier from one of his rejoinders in Science, to illustrate the blinders imposed by this dogma, from which even the optimists have yet to free themselves. A number of specialists from fields other than demography -- e.g., oceanographer Revelle, economist T.W. Schultz, engineer Weinberg, and political sociologist Etzioni -- are not hemmed in like this; they were much readier to recognize the forward leap represented by the new contraceptives.

As the success of the pill has shown, once its price became reasonable, the main point of the technological breakthrough is not so much the "one-time motivation" that the IUD has in its favor, but the huge decrease in the psychological costs of contraception when it is removed from association with the sexual act. But, despite the demonstrated desire of people to use birth control, many governments are still dragging their feet in setting up an adequate network of distribution. There is a widespread belief among elites, in both industrial and developing countries, that the poor do not wish to plan their reproductive performance, that they engage in irresponsible coitus for lack of alternative ways of keeping themselves occupied in the evenings, etc., etc. (see J.M. Stycos, Marriage and Family Living Feb, 1963). A great deal of money and time is also wasted on word-magic, designed to "motivate" people towards small families. When women who have been inadequately prepared against the possibility of side effects request the removal of their IUD's, hope is shifted onto "morning after" pills and the education of the next generation (J.C. Cobb Harvard Medical Alumni Bull., Spring 1967). And when the response to shoddy services is relatively weak, those who doubt the adequacy of existing "motivation" wax enthusiastic about compulsory sterilization (see F.S. Jaffe and S. Polgar, Journal of Marriage and the Family May 1968).

Although I believe that the bulk of the work involved in disseminating birth control to those who would be eager to try it still remains ahead and takes first priority, I also favor experiments with "indirect" approaches to further the voluntary regulation of natality. Measures for encouraging later marriage, for reducing infant mortality, for emancipating women, for increasing school enrollment, and the like, may have very important consequences for slowing population growth. Only the reduction of infant mortality by the distribution of nutritional supplements, however, is as inexpensive as birth control. Studies have shown that the reduction of infant mortality, both in families and on national levels, eventually leads to reduced natality. In Europe, this "eventually" often took 50 years. In Japan, the lag was much briefer, in large measure because abortions were legally available. With widespread diffusion of several means of coitus-independent birth control, the lag can be shortened, I believe, even in the face of inadequate socio-economic advance.

Other positive measures to encourage use of birth control are in the experimental stage. Monetary incentives for casefinding are a frequent

feature of family planning programs. Bonuses for couples who have few children, and social security payments to old people without sons are being discussed. Reserving a quota of jobs for women in large bureaucracies to speed their emancipation from the home, as proposed by Jason Finkel of the University of Michigan, may have symbolic importance for their peasant sisters, if they learn about it. Delayed marriage has been a mechanism of both capital accumulation and natality control not only in Europe but many pre-industrial societies as well (e.g., the Polynesian island of Tikopia); research is needed to discover possible ways of intervention in cultures where the rewards of early marriage seem to outweigh its disadvantages. And, most important, efforts to speed the demise of feudalism and similar antiquated socio-political systems must be intensified: to repeat what I wrote in the beginning, birth control is no substitute for socio-economic, nutritional and environmental improvement, only a indispensable adjunct.

The Dimensions of World Poverty

Two-thirds of the people in the world live in countries whose annual income per capita is less than \$300. The pressing problem is hunger, and under present plans it will remain critical for at least 20 years

by David Simpson

The economic gulf that has divided the poorer countries of the world from the richer countries is rapidly widening. Whereas the affluent nations continue to become richer, the impoverished nations continue to increase in population without raising their food production fast enough to reach a state of self-sustaining growth. Even though there have been recent gains in their agricultural production, and even if one makes the most optimistic assumptions about the programs instituted to limit the growth of populations, the prospect remains bleak. It is highly probable that for at least the next 20 years most of the people in the world will continue to exist at the margin of subsistence.

Where is poverty the most serious? How many people are critically deprived of food and the other necessities of life? In this review of the available evidence concerning world poverty I shall attempt to answer these questions, concluding with some proposals as to what can be done about the groups that are critically underfed.

There is no single statistical indicator by which one can distinguish people who are seriously deprived from those who are merely poor. One can make only rough estimates based on a number of indicators, all of them crude. The justification for using such necessarily uncertain statistics is that, in Gunnar Myrdal's words, "it is better to paint with a wide brush than to paint with a fine needle on the canvas blank."

The measure of a country's material progress that has been most widely adopted is per capita national income, which is to say the net value of goods and services produced by a nation within one year per head of population. As a comparative measure of the standard of living or of the degree of well-being, it nonetheless has at least three weaknesses. The first is the difficulty of measurement: A comparison between the national incomes of two countries essentially involves valuing two bundles of goods. Inasmuch as similar goods have different prices depending on the country, two answers are possible according to which set of prices is used in the valuation. The second weakness is more fundamental: The satisfactions that people in different societies gain from similar goods are not comparable. It is argued that even if a Burmese peasant and an American housewife consumed similar goods at the same prices, and the American consumed 40 times as much as the Burmese, it would not follow that the American was 40 times better off. Finally, per capita income is an average measure; it cannot reflect the distribution of income within a country.

In spite of these shortcomings per capita income can be defended as an indicator of the level of output of goods and services within a country, and indeed it is widely used as such. Even when the estimate of income can only be in the order of magnitude of the incomes

of the rich and the poor regions of the world. Thus on the basis of figures for 1965 (or the most recent year available) the average per capita income of the poorest region of Latin America is more than twice that of the poorer regions of Asia and Africa. The countries of Europe have average incomes that are 10 times greater than those of the poorer regions of Asia and Africa; in Oceania national incomes are larger by a factor of 14 and in North America they are larger by a factor of 28. It should be mentioned, however, that the way these estimates are prepared tends to overstate the differences between the richest and the poorest regions of the world.

It is clear that within continents there is considerable variation between regions and countries. South Asia and Indonesia have much lower incomes than East Asia or West Asia. The average income of the North African region is more than twice that of eastern and southern Africa. On both continents there are rich countries such as Japan, Singapore, Israel, Cyprus, Libya and the Republic of South Africa, whose average incomes approach European levels or even surpass them.

If we regard per capita income as a first approximation to the identification of the poorest regions of the world, it indicates that these regions include eastern, northeastern, southern, western and Southeast Asia and Indonesia. This im-