Resources, Population Growth, and Level of Living

A society's wealth depends on the use it makes of raw materials, energy, and especially ingenuity.

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Most critical observers agree that the human race is currently facing the most crucial period in its entire history. The world population is exploding, for it is now more than 2.7 billion and is increasing at the rate of 45 million per year (*1*). If this rate of growth were to continue it would be only a few hundred years until there would be standing room only, and "a little after this the hypothetical human population would weigh more than the planet" (*2*). Even if population growth miraculously ceased now, known deposits of metals and fossil fuels of the quality currently mined would not sustain the present standard of living for more than a few scores of years. And, as if these problems were not enough, the major part of the civilized world is engaged in a debilitating cold war, the principal parties to which are equipped with weapons powerful enough to destroy the world's major cities in a matter of hours, and to make much of the rest of the world nearly uninhabitable in a matter of days or weeks. These problems are not insurmountable, but as Brown (*3*, p. 265) and others have emphasized, the rates at which the population is increasing, usable resources are being exhausted, and international relations are worsening are so rapid that we must act at once if we are to avoid catastrophe.

Effective action can be based only on an understanding of the interrelations of the basic factors controlling population growth and level of living (*4*), not only among scientists but also among political leaders, business men, and the public at large. Unfortunately, however, there seems to be so little agreement among the scientists that the general public cannot help but be confused (see *5*, pp. 241–262 and 285–287, and *6* for summaries of divergent views). Many believe, as Malthus did in 1798 and as Sir Charles Galton Darwin (*7, 8*) does today, that the population will grow until food requirements outstrip supply; it will then be brought to equilibrium by famine or disaster. Others believe that advancing technology will make it possible to obtain raw materials and energy from sources that cannot now be exploited economically (*3, 9, 10*), so that shortages of natural resources will not curb population growth or depress the level of living, or at least will do so only in the very remote future. Some feel that since population growth appears to follow a logistic curve (*11*) that flattens as the population becomes literate and industrialized (*12, 13*), world population will stabilize before the starvation level is reached. According to this view, "it is by no means certain that the maximum population will be determined by the food supply. It may well be that comfort and convenience will determine the limit" (*13*). And while some believe that population growth is likely to reduce the level of living (*14*), others believe that it has a beneficial effect on economic prosperity (*15*); that "in an advancing technology, more people mean more plenty" (*16*). Even war and preparation for war are sometimes regarded as beneficial economic stimulants (*17*).

Because the extremes of these views are nearly those expressed by Thomas Malthus and William Godwin at the start of the controversy 160 years ago, it seems safe to conclude either that little progress has been made since then in the understanding of basic principles or that new information is not widely understood. The latter explanation is the better, I believe, but in either case it is important that we make a strong effort to establish basic principles that can be applied to the solution of our problems. My purpose in this article is to try to improve understanding of the underlying principles both by examining theoretical relations and by analyzing observations on the relation of natural and human resources to population growth and level of living (*18*).

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Limitations on Growth of Populations of Simple Organisms

A spatially limited medium favorable to the existence of some simple organism could nourish only some finite number of individuals if the food supply were not replenished. The total number of individuals that could be supported in such a medium would vary directly with the initial size of the food supply, and inversely with the mean life-time food consumption of the individual. This situation, in which an unreplenished food supply sustains only a limited number of individuals, is usually observed only in the laboratory culture of such organisms as yeast, bacteria, fruit flies, and flour beetles (*19; 12*, p. 31); but natural populations of certain insects are known to die because of having completely exhausted their food supply (*20*).

Most animal populations, however, are supported by a continually or periodically replenished food supply. The growth of a given population is limited not only by the size of the available food supply but also by disease, predators, or unfavorable extremes of temperature, salinity, moisture, or other physical or chemical variables in the environment. The maximum size such a population could attain would tend to increase as some function of the rate at which food generally becomes available and of the organism's comparative resistance to its physical and biologic enemies, and to decrease in some way with increasing mean rate of food consumption of the individual organism. It should be noted that while the organism may exert some ingenuity in searching for food, it is unable to increase the amount of food available in its environment.

Many observations of natural and laboratory populations show that when small numbers of a species are introduced into a bountiful environment, the rate of growth is slow at first but then increases rapidly (*12*). The maximum is reached in a surprisingly small number of generations. After this, the size of the population oscillates slightly with seasonal changes in food supply and environment, but it may fluctuate greatly and perhaps even decrease to zero if the food supply or the organisms' comparative resistance diminish sufficiently. Where food is the most critical factor, as it is likely to be, the size of the population is limited by competition for food among the individual members; many, particularly the young, are undernourished and do not live out their normal life spans.

Growth of Population and Level of Living in a Human Society

The limitations on the growth of populations of simple organisms are essentially those cited by Malthus as controlling the growth of human populations. Although he recognized that man can increase his own food supply, he believed that it can be increased only in "arithmetic ratio," whereas population tends to increase in "geometric ratio." Malthus also recognized that man might exercise "moral restraint" to limit the growth of his numbers. He largely discounted this possibility, however, and considered that growth of human populations is likely to be kept in check by undernourishment, disease, war, and disasters, and that because the population would always grow to the very limit of its subsistence, most of mankind would always be doomed to subsist at the minimum level.

Since Malthus' analysis and predictions were published, both the population and the level of living have risen to levels that he would not have dreamed possible (*3,* p. 5). Although his reasoning is thought to have been sound by some of his present-day supporters—who believe that the development of new lands, new resources, and new techniques merely postponed the fulfillment of Malthus' predictions—subsequent developments and further analysis of the principles involved show that he vastly oversimplified the relation man bears to his environment and underestimated man's ingenuity in developing and utilizing its resources. For example, because man not only seeks but, in all but the most primitive cultures, grows his food and makes his clothing and shelter, his essential needs include not only food but also tools and raw materials; and even in primitive societies he wants many more things than are necessary for mere subsistence (*21,* p. 86). He can satisfy both his needs and his wants only by exercising ingenuity, and his success in defending himself against his natural enemies is in large part a measure of his ingenuity. In addition, man helps satisfy his requirements by capturing nonfood energy for his own use, and—most important—his ingenuity permits him to satisfy his needs from new kinds of sources, many of which are more copious than the older ones.

Fairfield Osborn (*22,* p. 202) speaks of the "eternal equation" that controls the level of living and the growth of human population in various areas or societies, and he implies that this equation may be stated as follows:

$$\text{Level of living} = \frac{\text{resources of the earth}}{\text{number of people}}$$

This is a fuller concept of the relation man bears to his environment than Malthus had, because it recognizes that man, unlike simple organisms, makes direct use of many other things besides food, and that the consumption of goods and services is a variable in human populations analogous in importance to the number of people. But even this concept does not adequately represent the relation among the factors that control human life, for it implies that the "resources of the earth" constitute a fixed quantity that will yield a given output per capita.

A similar but less adequate concept is that of Vogt (*23*), in which population and level of living are determined mainly by the "carrying capacity" (C) of the land; this, he says, is equal to the ratio of the biotic potential (B) of the land to produce plants for shelter, clothing, and food and the environmental resistance or the limitations (E) that the environment places on the productive capacity of the land ("$C = B: E$"). Vogt recognizes that it is possible for man to alter the environmental resistance and hence to increase the carrying capacity, but the statement itself does not take into account the importance of other resources, nor does it give any direct indication that the carrying capacity of the land varies with ingenuity. The carrying capacity of the land, for example, for a food-gathering culture is several orders of magnitude less than it is for the modern science and machine culture. Both Osborn's and Vogt's concepts imply that the land will support no more than some optimum number of people, but, as Bauer and Yamey (*21,* p. 61) point out, "the most fundamental weakness of the concept of optimum population . . . is the underlying idea that, with given natural resources, output per head is a function of numbers alone. In fact, however, real income is vitally affected by the quality of the population, and the theoretical optimum would depend upon the skill, resourcefulness, and thriftiness of the population." As Kuznets (*21,* p. 129) put it, the major capital stock of an industrialized country is not its physical equipment; it is its body of knowledge and the capacity and training of the population to use its equipment effectively.

Although the factors that control human life are highly complex and in large part intangible, the fundamental ones, therefore, must include constructive technologic, socioeconomic, and political ingenuity—the collective ability of a group to obtain, distribute, and use raw materials and energy efficiently and to defend itself from its enemies, including disease and natural disaster. And instead of thinking of "resources of the earth" as a fundamental factor controlling the level of living and population at a given time, it is better to think of the net constructive rate of consumption and use of all types of raw materials, such as minerals, food, and water; and of the net constructive rate of consumption of all forms of energy, including a relatively small but essential amount of human energy as well as energy derived from other animate and inanimate sources. We can then say that the average level of living of an individual in a given society would tend to increase as some function of the net constructive rate of consumption or use of raw materials, energy, and ingenuity, and to decrease in some way with increase in the number of consumers.

This means that if the total consumption and use of raw materials, energy, and human ingenuity is at some fixed value (as it is in a given society at a given time), the level of living of the average individual decreases as the population increases; it also means that both population and level of living can be relatively high if consumption and use of raw materials, energy, or constructive ingenuity is also high. The expression does not tell us, however, what the potential maximum limit to the means of human subsistence is, nor does it tell whether or not population in a given society will come to equilibrium at a low or a high level of living.

These questions will be considered later, but before going on it is desirable to mention that the dependence of level of living and population on consumption of natural and human resources in the various countries of the world today is shown semiquantitatively by published statistics (see *5, 24*). For example, the per capita income in various countries correlates closely with the per capita consumption of steel and of energy obtained from commercial sources. A fair correlation exists also between per capita income and such things as literacy, percentage of students in secondary schools and colleges, per capita consumption of newsprint, and numbers of books published per capita. The correlation among these things is not exact because they are only partial measures of the controlling factors. Per capita income, for example, is a measure of level of living, but because it takes no account of materials already purchased and in use, it is only a partial measure of it. Steel is a key raw material, but it is only one of hundreds that are essential to industry, and again the annual production is merely suggestive of the amount in use. The consumption of energy is hard to evaluate, for published statistics exclude solar energy and energy from other noncommercial sources. And of course no statistic provides more than a feeble clue to the amount of ingenuity accumulated and in use.

Yet, in spite of the difficulty of measuring the controlling factors, the evidence is ample to show that level of living is generally a function of the per capita consumption and use of natural and human resources. Perhaps some optimum combination of raw materials, energy, and ingenuity is required to raise the level of living of the individual to the maximum, but it seems obvious that a large quantity of one will offset a shortage of the others, to some extent at least. Thus, it is due to "the skill and efficiency of the Swiss people that they have secured one of the highest standards of living in the world" despite their poverty in natural resources (*25*, p. 154).

Limitations on Growth of Population and Rise of Level of Living in Time

Is it possible to predict the potential population and level of living of a given area or of the world as a whole? This problem is far more complex than the one just considered. As a beginning, we could say that the potential level of living is an increasing function of the potential resources of raw materials, energy, and human ingenuity and a decreasing function of the potential population. This is not an adequate expression, however, for it does not take adequate account of additional complexities, such as the fact that some things, like war and population growth, that tend to decrease prosperity in the long run may tend to increase it for short periods because they create an expanding market and full employment. These stimulants are only of temporary value, however, and if they come at a time when they cannot be adequately supported by available resources they reduce the level of living and may even lead to disaster (*26*). With respect to ultimate world population growth, another factor not previously considered is man's requirement of a minimum amount of space in which to live. The amount of space required is not known, but whether it is an acre or a square yard need not concern us here; the point is that there is a minimum space requirement and that this would ultimately limit the earth's population if other factors did not.

The most important complication, however, is that man himself has demonstrated the ability to control every one of the variables (*27*, p. 18). He has not often deliberately fixed his standard of living at a low level, although he has done even this in certain religious societies, but in both primitive and advanced societies he has shown at times the willingness and ability to control population growth by one or another means of family limitation. And human history records an endless succession of discoveries that enabled man to utilize resources that were not utilizable before.

The discovery of fire, for example, made it possible for man to eat foods not edible before and to live in places not previously habitable. The discovery of agricultural methods made it possible for him to obtain many times as much food from a given area as the area yielded to the food gatherer, and the discovery of irrigation methods and of the use of fertilizers during earlier civilizations increased the yield many times more (*28*, p. 12; *3*, pp. 13–45). And the application of modern science and engineering to agriculture—the development of mechanized farm implements, fertilizers, insecticides, modern breeding practices, and so on—has increased the productivity of the land beyond anything imaginable even a half century ago. For the first users of copper, the only minable copper ore consisted of good-sized masses of native copper, but the discovery of smelting and similar technological advances made it possible to mine impure ores; the cut-off grade has dropped steadily until it is now about 0.4 percent in the large porphyry deposits. Aluminum, magnesium, and titanium were not even known to the ancients and were not thought to be valuable as structural materials even by the technologists of the early 20th century. Examples of discoveries that created *usable* resources where none existed before could be added indefinitely. Sociological, economic, and political discoveries, such as the invention of writing, money, and banking, the development of trade and of specialization in labor, and the development of systems of government that encouraged individual initiative, had a similar and perhaps even greater effect in making it possible to obtain more goods and services from a given area than had been possible before.

If it were possible, therefore, to write an equation showing the interrelations of potential population, potential level of living, and potential resources, the expression would show these variables to depend in some way on potential human ingenuity. It is unlikely, of course, that man will be able to control the other variables entirely, at least in the near future, but it is highly probably that even within short periods he will make new discoveries or acquire new knowledge that may alter his future completely. A recent and important example is the new look given the energy picture by the discovery of nuclear power. Prior to 1939, the world's energy supplies were thought to consist mainly of the fossil fuels—a few scores of years' supply in the form of petroleum and at most a few thousand years' supply in coal. No one considered that fissionable or fusionable elements might one day be a source of power, and the outlook for future supplies of power was dark. As recently as five years ago, well after the production of power by fission was known to be possible, Ayres and Scarlott (*29*), Darwin (*7*, p. 65), and others who did not have the benefit of the then classified data on results of postwar exploration for uranium, considered it likely that the energy derivable from nuclear power would not be any greater than that in the world's coal reserves, if as great. The energy in high-grade deposits of uranium in Western countries alone, however, is now known to be several times that in all the fossil-fuel reserves combined; the amount in the uranium in black shales and phosphorites (which is being extracted in a few places now as a by-product of other operations) is at least ten and perhaps several hundred times larger (*30*), and that in granites and similar rocks is almost incalculable (*31*). And it now appears that enormous amounts of power will be available from thermonuclear fusion (*32*). Progress in mineral technology has also been impressive and may be expected to make available progressively lower grades and increasingly larger resources of minerals in the future, just as it has in the past (*10*).

This does not mean that William Godwin was right in his belief that natural resources, if used and distributed properly, would be adequate to support man's needs in spite of his reproductive proclivities; it does not mean that at any given time or even ultimately there will not be a limit to the resources-ingenuity product, or that at any given time or ultimately the population will not press closely on the means of its subsistence; and it certainly does not mean that something will turn up to solve all of man's problems whether he tries to solve them or not. It means, rather, that because man is potentially capable of controlling his numbers, his environment, his usable resources, and his very destiny to an *unimaginable* degree, it is not possible to predict the limit, temporary or ultimate, to his means of subsistence or his level of living (*33*).

Stimuli to Technologic Advance and Population Control

Although it is not practical to make long-range forecasts of growth of population or rise or fall of the level of living, it is of utmost importance to learn the circumstances under which man uses his fabulous capacity to increase the means of his subsistence and to control his numbers. Doubtless modern behavioral science can cast much light on these questions, but for the purpose here it suffices to approach them by analyzing present and previous patterns of population and economic growth. The rate of population growth differs considerably in different parts of the world now, and it probably always has. For example, the world population is at present more than 2.7 billion and it is increasing at the rate of about 1.7 percent per year (*1*); but the population of northern Europe is increasing at the rate of only about 0.6 percent per year, while that of Canada and Australia is increasing at the rate of 2.4 percent and that of certain underdeveloped areas like Mexico is increasing at rates of more than 3 percent (*26*). The current average rate of population growth has prevailed for only about two decades; the largest growth has taken place since about 1650. The world population is thought to have been about 0.2 billion at the beginning of the Christian era, and by 1650 it had grown to not much more than 0.5 billion (*5*, p. 33). It took about 200 years to double that figure and less than 100 years to double it again. The distribution of the relative increase was extremely irregular: From 1650 to 1950 the population of Africa doubled; that of Asia increased 3.8 times; Europe, 5.6 times; that of Central and South America, 13.5 times; and that of America, 166 times. The largest absolute increase in number of people, however, took place in Asia, whose population in 1950 was about 1.3 billion.

Populations of Western Europe

Although the population growth of recent centuries has been unequally distributed, it shows in the aggregate a rapid increase. In most of the Western European populations, where the increase took place first, this rapid increase has been followed by a decrease in rate of growth. The curve representing their growth since about 1700 is the *S*-shaped logistic curve similar to that found in the growth of animal populations (*12*, pp. 11–18); the growth it reflects has been called the population cycle, which is broken into four stages, as follows (*25*, p. 9): (i) the high-fluctuation stage, characterized by high birth and death rates and by a very slow, irregular increase in population; (ii) the early-expansion stage, characterized by a high birth rate and a falling death rate; (iii) the late-expansion stage, characterized by a falling birth rate as well as a falling death rate; and (iv) the low-fluctuation stage, characterized by a low death rate and a low birth rate, oscillating slightly with booms, depressions, and wars. Transition from one to another of these stages represents the effect of a change in the ratio of births to deaths, and perhaps also of changes in direction and amount of migration. But what are the fundamental causes of these changes?

The high-fluctuation stage in the history of the Western Europeans seems to have been one in which population was pretty much in equilibrium with food production. Population increased in time of plenty and declined sharply when famine or pestilence raised the death rate; in the meantime substantial growth was prevented by a high death rate that was the direct or indirect product of undernourishment among a large segment of the population. The early-expansion stage, which began during the 17th century, was due "in part to gradually improving agricultural techniques, but probably in greater degree to better transportation, which in turn stimulated commerce and handicraft production, and, through these, commercial agriculture," both in Europe and in new lands settled or dominated by Europeans (*13*). This tended to reduce famine, undernourishment, and susceptibility to disease, and hence led to a decline in the death rate. Even though this early growth was not stimulated by much increase in the use of fossil fuel and steel, it was made possible, nevertheless, by increased availability and use of raw materials, energy, and ingenuity, all of which expanded the supply of food and other necessities.

The late-expansion stage of the population growth of Western peoples is closely tied to the industrial or scientific revolution. Thus, Hubbert (*34*) has shown that the population growth of the last 150 years, the largest in human history, is closely correlated with the greatly increased use of energy from fossil fuels; the latter is directly paralleled by increased consumption of metals and many other raw materials. Mere production figures, however, do not adequately describe the intellectual explosion that permitted man not only to prolong life by the conquest of disease (*35*, p. 7) but also to discover and utilize natural treasures whose very existence was previously unknown. The vastly increased amount of goods, services, and knowledge available for man's use performed "the western miracle" of simultaneously increasing population and raising the level of living (*22*, p. 75).

The low-fluctuation stage is a recent development, reached in western European countries only within the last century. It is characterized not only by a relatively stable population but also by a rise in the level of living—an enigma from the standpoint of Malthusian doctrine. The causes for the decline in birth rate are complex, but three things seem especially significant: (i) Recent studies of birth rates among various socioeconomic groups show that group differences are mainly due to the differential prevalence of birth-control practices (*36*); (ii) the net reproduction rate among families within individual countries or areas generally varies inversely with family income and degree of educational attainment (*12*, p. 158; *37; 5,* p. 156); and (iii) over the world as a whole, areas that have the highest birth rates are those in which the highest proportion of the population is illiterate and dependent on agriculture (*13*; *27*, p. 50). These observations indicate that in relatively well educated and wealthy nations and social groups, the birth rate drops because married couples *want* to have fewer children, presumably because they want to attain or maintain a higher level of living for themselves and their children, or because they do not "wish to bear the physical and social burdens which a large family brings" (*38*). The birth rate remains high among low-income and poorly educated groups because their outlets for nervous and emotional tension are restricted (*12*, p. 203; *35*, p. 296), they are not educated in the art of contraception, they are not able to afford contraceptive devices, and they are not well informed as to the consequences of having a large family.

It is important to note that the drop in birth rate in Western countries has taken place in spite of strong opposition to family limitation. In Ireland, where both the Catholic Church and the state have encouraged large families, the population decreased from about 8.2 million in 1845 to about 4.4 million in 1950 (*35,* pp. 53, 92). Death and emigration reduced the population by about two million during the potato famine years of 1847–1852, but the remainder of the reduction results from a low birth rate due to few and late marriages.

Until recently it was thought that after a particular nation once reached the low-fluctuation stage of the population cycle its population would be stable, or at least its further growth would be slow. In the United States, Canada, and Australasian countries, however, it has been found that under certain circumstances population stability or slow growth is merely temporary. In the United States the birth rate declined rather steadily during the first third of the 20th century, reaching a low of about 19 per thousand per year during the 1930's (*39*), but in 1940 it started to rise, and since 1951 it has been about 25 per thousand. The reversal in the trend of the birth rate is generally thought to be related to increased payrolls and employment resulting from the defense and war efforts, but the high postwar birth rate is puzzling (*25; 40,* p. 46). At first glance it does not appear to be caused by national prosperity, for per capita income rose in the early part of the century while the birth rate declined. But inasmuch as the size of the family in the United States is now largely a result of a decision made by the parents, it seems likely that the increased birth rate in the United States reflects a recognition on the part of our young people that their potential income does not require them to restrict the size of their families closely in order to realize their wants and fulfill their responsibilities adequately. The wish to avoid the physical and social burdens of a large family may still militate against large families, but the leisure afforded by a shorter work week and by labor-saving devices, such as the dishwasher and automatic washing machine, makes it possible to have a medium-sized family without having as burdensome or complex a life as the same responsibilities would have entailed in the 1920's. It seems safe to conclude that a rise in national prosperity may stimulate population growth in late as well as early stages of industrial development.

Population Cycle in Earlier Epochs

The main aspects of this population cycle or growth curve appear to have been repeated during each of the successive cultural epochs in the history of mankind (*12*, p. 19) and during each of the earlier civilizations. Clough (*28*), in his analysis of the factors controlling the rise and fall of civilizations, finds that all civilizations were marked by, and to a large extent caused by, an increased output per capita of goods and services and the accumulation of an economic surplus. This permitted both an increase in population and a rise in the level of living, and it also provided time for intellectual and esthetic achievements—the hallmarks of civilization. The increased output resulted from improvements in technology, greater exploitation of natural resources, increased efficiency of labor resulting from specialization, accumulation of capital, increased business enterprise and leadership, improved techniques of distribution, and development of an economic and political system that not only encouraged individual and group enterprise but also permitted wide enough distribution of wealth to enable the laborer to be a heavy consumer of goods and services. When the population reached a size at which existing techniques, resources, capital, trade, and political organization were unable to provide a further increase in goods and services per capita, population growth tapered off and the level of living gradually declined. If for any reason the political and economic framework of the civilization deteriorated, population actually decreased and entered the high-fluctuation stage. Later, when political or technologic conditions once again favored the accumulation of an economic surplus, a new cycle of growth sometimes began, either in the same area or, more commonly, in adjacent areas.

In contrast to the causes of decline in the rate of growth of western European populations—family limitation stimulated by desire for a higher level of living and a less complex life—the decline in growth of population of most earlier societies was due mainly to the positive checks cited by Malthus. A great variety of methods of family limitation, ranging from abortion and infanticide to various sexual taboos and marriage bans, were practiced in early societies; when practiced extensively they helped make it possible to avoid widespread starvation, but they do not seem to have been effective in maintaining a high standard of living.

Why did earlier civilizations rise and decline? What stimulated and then depressed technologic, economic, social, and esthetic progress? Toynbee (*41*, p. 570) explains that civilization arises "not as a result of superior biological endowment or geographical environment but as a response to a challenge in a situation of special difficulty which rouses him [man] to make a hitherto unprecedented effort." He lists a number of adversities that provide the necessary initial challenge—hard country, new ground, defeat in war, threat of war, and penalization imposed by reason of race, religion, or class; further growth, he thinks, results from "an overcoming of material obstacles which releases the energies of the society to make responses to challenges which henceforth are internal rather than external, spiritual rather than material." Though granting that necessity is often the mother of invention, I believe that the growth of civilizations must have been stimulated by more than this, for many more peoples have been exposed to adversity and spiritual challenges than have made the grand response that the development of a civilization demands.

Clough (*28*, p. 9) supplies the missing link in emphasizing the importance of the ideologies of a culture, which generally become established at its very beginning. If in its formative stage "the culture embraces the idea that great works of art should be created, that knowledge of the universe should be acquired, and that man should extend his control over human and physical environment, then subsequently more of the energies of the culture will be devoted to the attainment of a high degree of civilization than would otherwise be the case. . . . Another ideology which is important for the effective development of civilization is a desire for a social and political organization which will permit individuals to realize their total potential as contributors to civilization." He stresses also the importance of avoiding destructive strife, of placing leadership in the hands of those who would advance civilization rather than some other cause, of preventing such a rigid structuring of the culture that the individual has no choice of action, and of increasing "the range of opportunities for alternative decisions. . . . Everything which contributes to the extension of that range, whether it be economic surplus, the use of leisure, the development of cities, or the absence of stultifying rigidities, is of the utmost significance in furthering the process of civilization."

Whereas the rise of earlier civilizations was marked by a gain in control over both the physical and human environments, their decline reflected a reversal of these trends. Specific causes may have been disappearance of economic surplus, resulting from population growth, exhaustion of natural resources, war, or diversion of capital from productive investments to nonproductive expenditures on costly works of art (for example, the Pyramids) or luxurious living (*28*, p. 261); enemy conquest, the success of which may be the result of the diffusion of the fallen civilization's techniques to bordering peoples; disease or pestilence; social and political disorders, leading to debilitating internal strife; deterioration of leadership or government; or loss of creativity as a consequence of a stultifying religion, tradition, or social order (*41*, p. 581). The relative importance of these causes is hard to assess. Population growth outstripped the production of food and other necessities in the homeland in some and perhaps in all of the earlier civilizations, so that they became dependent on trade and conquest to maintain their level of living (*3*, p. 24–30). Yet nearly all of these areas are now supporting more people at a higher level of living; obviously, then, they did not exhaust their resources but merely reached the production ceiling permitted by their technology and their economic and sociopolitical systems. It seems likely that even without further technologic advance they could have avoided or postponed decline if they could have dealt with subjugated peoples, competitors, and envious barbarians by means more effective and less expensive than military force, and if they could have prevented or satisfactorily dissolved internal social disorders. Failure to maintain or extend control over the human environment, to organize their "society in such a way that differences among individuals and groups may be at a minimum and that what conflicts do exist may be settled in an equitable manner according to previously established rules," and to place sufficient value on human life and freedom (*28*, p. 260) seems to have been at the root of the decline.

Populations of Underdeveloped Countries

If judged wholly by their rapid rate of increase, the populations of many of the underdeveloped countries today would appear to be in the early expanding stage of the population cycle. Unlike the Western countries and earlier civilizations, however, the underdeveloped countries began their recent growth not because they opened new geographic, technologic, or economic frontiers but because Western countries introduced better methods of transportation, communication, agriculture, and—most important—medicine and sanitation (*35*; *3*, pp. 57–58). Deposits of minerals and fuels have been developed in these countries, to be sure, but because these have been largely exported to Western countries they have not done much to raise the level of living of the native populace, which has remained dominantly agricultural. The result of all this is that death rates have been reduced, the populations have grown, and in some countries the amount of food and goods available per person has diminished (*42*; *40*, p. 48). No significant rise in level of education, which might check population growth as it has in Western countries, has taken place in most of the underdeveloped countries, and population growth seems to follow a strictly Malthusian pattern.

Summary of Basic Relations

This brief analysis of the relations of population growth and level of living to natural and human resources yields several relatively simple but important principles, as follows. The means for man's subsistence increase with increasing constructive consumption of raw materials and energy and, especially, constructive use of ingenuity. Resources of usable raw materials and energy may be increased to an unpredictable extent by the development and application of ingenuity. The most fundamental stimulus to ingenuity is a basic ideology that challenges, encourages, and rewards individual initiative, freedom of thought, desire for economic gain, and thirst for knowledge. The attainment of a high standard of living requires that the ratio of consumption to consumers be high. Such a ratio can be maintained most easily if the population is sufficiently educated to understand the benefits and the means of family limitation and to extend its control over its physical and human environments by peaceful means.

References and Notes

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Francisco Duran-Reynals, Bacteriologist

Francisco Duran-Reynals was born in Barcelona, Spain, on 5 December 1899. He died in New Haven, Connecticut, on 27 March 1958.

His early education, from elementary school through college, was in Barcelona. There too he took his M.D. degree in 1925. In the course of his medical study he was also assistant in the laboratory of bacteriology of the city of Barcelona. On his graduation he became a fellow of the "Junta para ampliación de Estudios." The first year of his fellowship, 1925–26, he spent at the Pasteur Institute in Paris. In 1926, still under the fellowship, he came to James B. Murphy's laboratory in the department of cancer research at the Rockefeller Institute in New York. In 1928, when his fellowship ended, he was appointed an assistant in that department, and in 1934, an associate.

In 1938, Duran-Reynals left the Rockefeller Institute to accept an appointment as research professor at Yale University School of Medicine, under the Jane Coffin Childs Memorial Fund for Medical Research. He was also appointed lecturer and research associate at Yale in 1952.

He was a member of the Academia de Medicina and of the Sociedad de Biologia of Barcelona and a corresponding member of the Institut d'Estudis Catalans and of the Sociedad de Biologia of Havana. He was also a member of the Harvey Society, the American Association for Cancer Research, and many other societies. He was for many years a scientific associate of the Jackson Memorial Laboratory in Bar Harbor, Maine, and spent many summers there. In 1957 he received the honorary degree of Doctor of Science from the Hahnemann Medical College of Philadelphia. He held medals from the Pasteur Institute and from universities of Liège, Brussels, and Montreal. In 1952 he received the Anna Fuller Memorial Prize for medical research. He was a consultant to the U.S. Public Health Service, the National Research Council, and the American Cancer Society.

During his stay at the Pasteur Institute, Duran-Reynals' work had dealt primarily with the lysis of certain bacteria, but soon after coming to the United States he began to take an active interest in viruses. This interest deepened and widened. At the same time the influence of testicular extract as a "spreading factor" was noted and was used fruitfully to study cell physiology (the ground substances of the mesenchyme). The two lines of research seized his imagination, and he held to both of them eagerly and vigorously.

His studies of the ground substances showed them to be a system of fundamental importance influencing the rate or success of infection, metabolic changes in cells, stability of crystalloids, intimate effects of hormones, allergy, and other phenomena.

Through investigation of a variety of known cancer viruses, notably avian, Duran-Reynals established a number of important facts concerning the nature and activity of those agents. Among these principles may be listed the following: (i) These agents can exert necrotizing effects on cells under certain conditions, notably in the young host. (ii) They can vary, adapting themselves to new hosts. When an "adaptation" occurs, a different type of cancer is induced. Thus, a single virus may be involved in the induction of many types of cancer. (iii) They have definite antigenic properties. (iv) They have their highest power of infection when injected in young hosts. (v) They have a definite epidemiological pattern.

From this work Duran-Reynals concluded that "cancer viruses" behaved fundamentally like other viruses and that possibly cancer could be considered to be of viral origin. For the sympathetic consideration of this hypothesis he was a willing and tireless crusader.

These conclusions led to the development of the second phase of his program in this field of research. This consisted in trying to discover whether ordinary viruses, especially those of the pox group, could, under certain conditions, induce cancer. Interesting and suggestive results were obtained, but the problem was unsolved and he was hard at work on it when his final illness set in.

He was an extremely versatile and imaginative investigator. His bibliography attests strikingly to this fact. Throughout his activity as a brilliant research worker he was strengthened and encouraged by the complete partnership and active as-