Man's Fire of Life

by

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Special Report 125
10/70 1.5M

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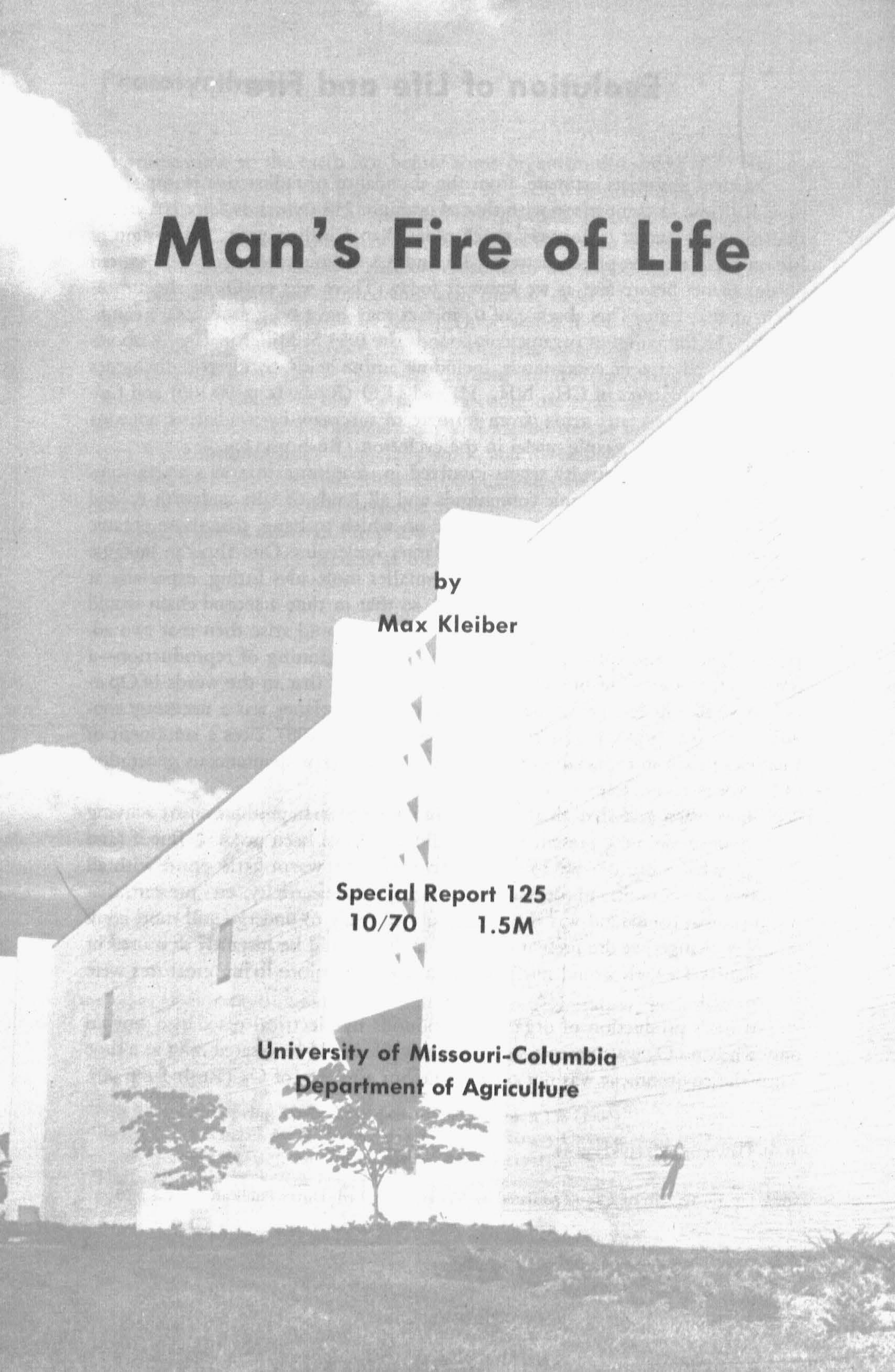

Evolution of Life and Fire

Nuclear physicists estimate, from the abundance of radioactive isotopes and their halftime in comparison with that of uranium 238 (which is 4.5×10^9 years). that the earth's crust is not very much older than 3 billion years. The origin of life on earth may be placed between 1.5 and 3.5 billion years ago.[1] Life started on our planet before fire, as we know it today. There was no O_2 in the atmosphere at that time. This absence of 0_2 in fact may have been a necessary condition for the formation of organic compounds. In 1953 S. Miller in Urey's laboratory produced organic compounds, including amino acids, by electric discharges through gas mixtures of CH_4, NH_3, H_2 and H_2O (Rush, 1c p. 90-100) and Calvin et al. obtained fatty acids (from formate to succinate by irradiating aqueous CO_2 solutions with atomic nuclei in the cyclotron (Rush p.111).

No particular difficulty seems involved in imagining that in a warm solution with a variety of organic compounds and all kinds of salts and with colloid and larger clay particles offering a surface on which to hang, that these organic compounds could combine to larger and larger molecules. One also can imagine that molecular chains could evolve with smaller molecules fitting, especially at particular places of a chain already formed, so that in time a second chain would be attached to the first as a duplicate. The chance would arise then that two adjacent chains could split apart. This would be a beginning of reproduction—a process characteristic of life. One also can understand that in the words of Oparin[2] "A sterile life-less period in the existence of our planet was a necessary condition for the primary origin of life." Rush (1c p 108) cites a statement of Charles Darwin in explanation of why a continuation of spontaneous generation of life today is unlikely.

> "It is often said that all the conditions for the first production of a living organism are now present which could ever have been present. But if (and oh! what a big if!) we could conceive in some warm little pond with all sorts of ammonia, phosphoric salts, light, heat electricity, etc. present, that a protein compound was chemically formed ready to undergo still more complex changes, at the present day such matter would be instantly devoured or absorbed which would not have been the case before living creatures were formed."

Miller's production of organic compounds by electrical discharge worked only when no O_2 was present: so presumably life could be created only at a time when the environment was not only sterile but also free of O_2 (Rush 1 c p 90).

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[1]Rush **Dawn of Life** (1957) p. 44.

[2]A. I. Oparin **Origin of Life** (Translated by Morgulis) 2nd ed. Dover Publication 1953 p 63.

Photosynthesis

Fire came to the earth not before some organism discovered the utilization of the radiation from the sun as a source of energy to make a living by photosynthesis. As a by-product of their activity in producing organic substances they added O_2 to the atmosphere of our planet. In 1935 Van Niel[3] suggested from analogy with other reactions that O_2 came from the H_2O. In 1941 Ruben Randall, Kamen and Hyde[4] proved this with the use of O^{18} [$CO^{16}_2 + 2H_2O^{18} + h{\cdot}\gamma \rightarrow {}^1/_n\ (CHO^{16}H) + H_2O^{16}$] ($h{\cdot}\gamma$, where h = Planck's constant and γ = frequency of radiation). After plants had operated photosynthesis long enough to load the atmosphere with oxygen, animals could feed on the organic substances produced by the plants. They could use some of these substances as building material for the animal body and katabolize the rest as a source of energy for animal activities—especially work, and for heat production. The animals accomplished this by metabolism, cell respiration, oxidative phosphorylation and electron transfer by their cytochrome system.

Krebs and Kornberg[5] (1c p 275) list the time sequence in the evolution of the major bio-energetic process as follows.

Figure 1

Evolution of Biological Energy Transformation

Krebs & Kornberg 1957 p.275

Anaerobic fermentations (include glycolytic enzymes, ATP and pyridine nucleotide)

↓

Pentose phosphate cycle

↓

Photosynthesis
(includes metalloporphyrins)

↓

Cell respiration
(includes tricarboxylic acid cycle, oxidative phosphorylation, cytochrome system)

[3]Van Niel, **Cold Spring Harbor Symposia Quant. Biol.** 3 138 (1935).

[4]Ruben, S., M. Randall, M. D., Kamen and T. L. Hyde **Heavy Oxygen as a Tracer in the Study of Photosynthesis.** J. Am. Chem. Soc. 63, 877-879 (1941).

[5]Krebs, H. A. and H. L. Kornberg, **Energy Transformations in Living Matter** Springer-Verlag, Berlin (1957).

To get an idea of the time involved in this evolution we are helped by a passage of the fine book of T. H. Rush, **Dawn of Life** (p. 57).

"Compress the time scale since the rocky crust of the earth was formed, say 2.5 billion years ago into a single year. On that scale the first living forms appeared about February or March, land plants and animals appeared near the end of October, dinosaurs were dominant in early December, but disappeared about the 19th when the Rocky Mountains were uplifted; the first manlike creatures appeared on the 30th or 31st and the most recent ice age began to subside 3 min. before midnight on the 31st, Rome ruled the Western World for 10 seconds from 11:59:30 to 11:59:40, Columbus discovered America 8 seconds before midnight and modern science arose a little later, 5 seconds before the end of our year of years."

Comparison of Fire and Life

Fire is a symbol for life. A burning torch means life, an extinguished torch, death. A burning heart expresses intense life, namely, love; a flame on the head of Christ's disciples indicated religious obsession, another manifestation of life at a high degree of intensity. In a most crucial moment of his life, Moses saw Jawe as a burning bush and followed a pillar of fire by night. Even nowadays students and others speak of a "hot number" when they refer to a girl who lives at an extraordinary degree of activity in contrast to a "cold cucumber."

Life is a symbolic attribute of fire which is regarded as a "lively" god—benevolent at times but always ready to do mischief; you have to be careful of "killing" your campfire when you depart, and be sure that you did not leave any "live" coal under the ashes.

The scientific analogy of fire and life is much younger than the poetic symbolism. It is about as old (or as young) as the United States of America. It has been very helpful for exploring the physical and chemical aspects of life. This is what is meant when the philosophers say that the analogy had a heuristic value.

Joseph Priestley, that "honest heretic" as Benjamin Franklin had endearingly called him, who came to America in search of religious freedom was a great theologian. He was convinced that his work as a scientist was a religious service because he felt that to explore the wonders of nature contributed to appreciation of the greatness of the Creator. Priestly observed that in a closed space:

- A flame makes air unfit for a flame.
- A flame makes air unfit for a mouse.
- A mouse makes air unfit for a flame.
- A mouse makes air unfit for a mouse.

Priestly explained the results in terms of the prevalent theory of his time that fire and animal produce the same substance, "Phlogiston," which smothers fire and poisons animals. He discovered a chemical method which he thought dephlogistated phlogistated air so that it supported again the burning of a flame or the life of an animal. Scheele in Sweden made similar observations on bees.

Lavoisier measured weight and volumes of the substances involved in Priestley's experiments and came to the conclusion that Phlogiston would have to be a substance with negative weight and negative volume. He rejected such complications and explained the observations of Priestley and Scheele in a way which still is valid today. He said flames and animals die in a closed space not because they produce Phlogiston but because they have exhausted a part of the atmosphere which is necessary for a flame or the life of an animal. What Priestley did when he thought he purified the air was actually producing a gas which is necessary for combustion and for life. Thus, Lavoisier showed that Priestley and Scheele had in fact discovered an elementary gas with positive weight and positive volume and he called this newly discovered gas "oxygene"—the former of acids. This was the fulfillment of a prophecy by Galenos—the physician of the Roman emperor Markus Aurelius—who about 2,000 years ago said there was a spirit in the air which we inhale and which is necessary for life and that some time this spirit might be extracted from air and would be a precious medicine. Indeed O_2 is precious as a medicine, especially when the flame of life is in danger of being extinguished by heart failure or other circulation trouble, or CO poisoning or when brain cells in old age are starved for 0_2 because the resistance to diffusion in the cell membrane becomes too great and senility results. Apparently there is some indication that loss of memory in senility might be restored by breathing pure O_2.

Law of Conservation of Energy

Similarity of fire and life is manifested also when one measures the heat produced by combustion of substances in the calorimetric bomb and by an animal in a calorimeter. In 1894 Rubner demonstrated that the amount of heat produced by a dog equals the heat of combustion of the fat and protein katabolized minus the heat of combustion of the urine formed. Two years later Laulanié reported that the mean caloric equivalent of 1 liter O_2 used by pigs, rabbits, ducks, and dogs, was 4.75 Kcal when measured in the calorimeter. This was equal to 4.71 Kcal calculated from C and N balance. These measurements confirmed for animal metabolism the *law of constant heat sums* first formulated by Hess in 1840 which says that in a chemical process with the same given start and end conditions the heat production is the same when different intermediary reactions are involved. For example, the oxidation of 1 mol. of glucose to CO_2 and H_2O yields 673 Kcal whether it takes place by an explosion in a calorimetric bomb or by a series of complicated enzymatic processes through Embden-Meyerhof sequence and Krebs' cycle. Atwater and Benedict 1903 measured chemical changes and heat production in men working on bicycle ergometers in a respiration calorimeter. They concluded that this observation confirmed the law of conservation of energy as applicable to metabolism and work of man.

Life Differs From Fire

Life and fire are alike concerning heat production, but they differ when we measure how much work can be obtained from a given energy source, which is expressed as efficiency—the ratio $\frac{\text{work performed}}{\text{energy spent}}$.

The *second law of thermodynamics* states that in any transformation of one form of energy to another heat is produced and the transfer of heat to work is complete (with an efficiency of 100%) only in cases which are not realizable, like the isothermal expansion of an ideal gas.

In actual processes only a part of the energy spent, the free energy (ΔF) appears in the wanted form, the rest $\Delta H - \Delta F = T\Delta S$ is the "bound heat." It is the product of the absolute temperature and the change in Entropy $T\Delta S$. The maximum efficiency of producing work from heat is the ratio of the difference of the absolute temperature divided by $\frac{\Delta A}{\Delta Q} = \frac{T_1 - T_2}{T_1}$ where ΔA = max. work; ΔQ = change of heat; T_1 T_2 = absol. temp at the place of process and the cooler (temperature). If the animal were a heat engine with $T_1 = 37 + 273 = 310°K$ and $T_2 = 20 + 273 = 293°K$, then the efficiency would be $\frac{310 - 293}{310} = \frac{17}{310} = 0.055 = 5.5\%$. The efficiency of animal muscular work is 4 times as high as the maximum efficiency of a heat engine with comparable temperatures. It amounts to 20%. The animal muscle is not a thermodynamic but a chemodynamic energy transformer.

A great deal has been learned about the way this chemodynamic machine works. A major step toward this new knowledge was accomplished by Fritz Lipmann who, in 1941, wrote a chapter in the **Advances of Enzymology** 1 p. 99 (1941), entitled "Metabolic Generation and Utilization of Phosphate Bond Energy." Krebs and Kornberg, 1957, summarize an essential part of this new knowledge as shown in Figure 1.

Only a part of the chemical energy available to animal cells as nutrients is transformed directly to heat, a considerable, possibly a major, part appears first as a "special kind of chemical energy," the energy stored in pyrophosphate bonds of adenosine triphosphate (ATP). Adenosine phosphate can function somewhat like a storage battery. By adding a phosphate atom to adenosine diphosphate (ADP), it is charged with special energy to become adenosine triphosphate (ATP). By giving off the extra phosphorus again in a coupled reaction, the ATP can drive a process which requires energy such as various chemical syntheses of the processes which in the end lead to muscular work. So instead of the process in a fireplace or a calorimetric bomb:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 673 \text{ Kcal.}$$

We may write for the formation of 50 ATP pyrophosphate bonds (with an efficiency of 67%) the following:

$C_6H_{12}O_6 + 6O_2$ $6CO_2 + 6H_2O + 224$ Kcal + 50 pyrophosphate bonds corresponding to 449 Kcal with an efficiency of $\frac{449}{673} = 0.67 = 67\%$.

Life vs. Entropic Doom

The second law of thermodynamics states that with all energy transformations in nature heat is produced, and also that heat can only be transformed to other forms of energy when heat can flow from a higher to a lower temperature. The energy of the universe according to the first law remains constant but more and more of this energy becomes heat and temperature differences tend to become smaller and smaller. The entropy of the universe $\frac{\text{Heat}}{\text{Temp.}}$ tends toward a maximum when the universe comes to rest with the most probable arrangement of things. From observations in our study, we know that the most probable arrangement to which things go without our intervention is disorder, and it takes effort to create order out of choas. Thus, people who love disorder can claim that they are in harmony with the second law of thermodynamics—the law of increasing entropy. The trend toward the result of this law, inactive choas, is called entropic doom. The flattening of mountains by erosion and filling up of lakes by deposition are examples of processes in tune with entropic doom. But some processes go in the opposite direction—such as the eruption of volcanoes, the splashing up of water when a waterfall hits a rock, the climbing of a mountaineer. The evolution of life is such a counter current, an eddy, in the general stream of energy degradation. (We regard diffuse heat with a low degree of transferability as a low grade energy.)

Obviously organisms today show greater differences than the early unicellular inhabitants of the primeval ooze. Life is a tendency away from choas, away from equalization to distinction, from conformity to variety, from the most probable and the common to the unexpected and rare.

While in a fire all chemical energy turns immediately to heat, in life some of that energy is directed to the formation of adenosine triphosphate which among various functions in processes of intermediary metabolism drives the syntheses of proteins and nucleic acids, the magic chains of RNA and DNA which are the material basis of inheritance and contain the power of reproduction and evolution. In the long run, the fire of life leads to the same end as the fire in a fireplace or a forest fire—namely heat, the end of the degradation process of energy. But this very degradation process allows a man to climb a mountain. It drives the eddy of evolution from amoebas to Leonardo da Vinci to Goethe, Beethoven, Gandhi, Schweitzer, Einstein and Martin Luther King Jr. Important is not the final doom. Important is what happens between beginning and end. Man, who has conquered time by language creating science and technology by which he conquers space, man has developed his brain power so that he can increase the wonderful eddy in the stream of energy degradation, increase order from chaos, increase beauty, increase life, and the quality of life.

When we are aware of this great promise, we feel like joining gratefully a jubilant chorus in the **Ode to Joy**, or repeat Hutten's victorious call during the Renaissance: "The arts are blooming, science is growing, it is a joy to be alive!"

Food and Population

We don't have to worry yet about the entropic doom but about starvation. We began with man's energy requirement.

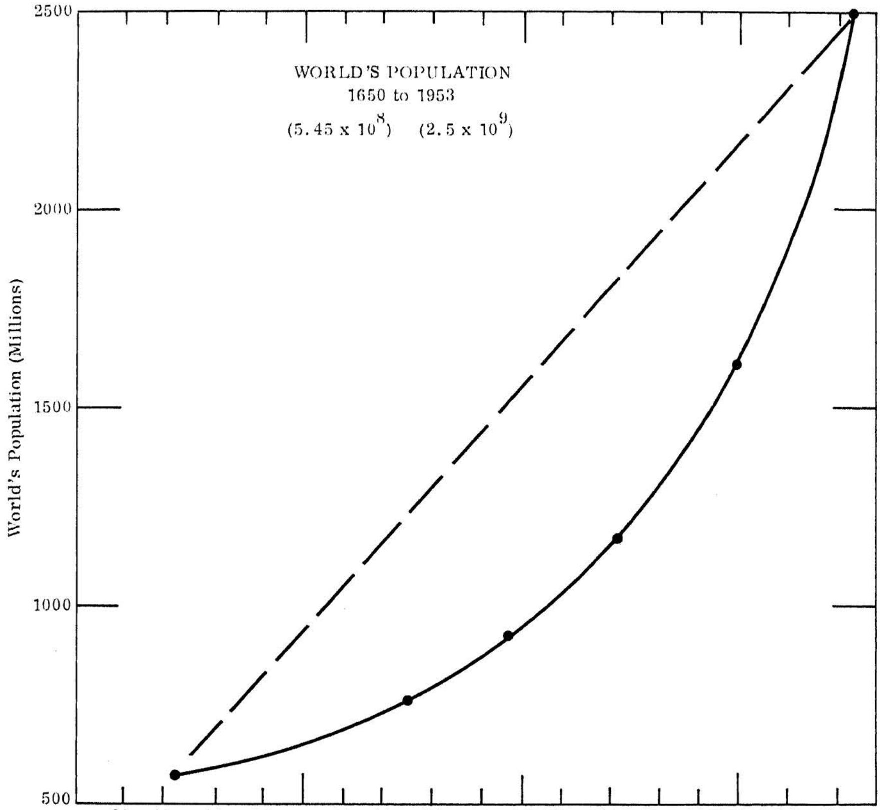
To measure the fuel requirement of man's fire of life we can measure his basal metabolic rate; or since this has been measured many times, we can calculate it. A reasonably close approximation may be based on the result for various animals that metabolic rate of homeotherms is on the average $70 \times W^{3/4}$ Kcal/day where W is the body weight in Kg. If we want to be more specific, we can express the basal metabolic rate of men as a function of their body weight showing the effect of sex, age and degree of slimness. For a man of average age and a body weight of 65 Kg we can calculate an average of $70 \times 66^{3/4} = 70 \times 23 = 1600$ Kcal/day. This is for a fasting resting man. We are probably not underestimating his requirement at 3,000 Kcal of food energy per day.

Must Men Starve?

Does the fuel of the fire of life give out? During the early periods of mankind, in fact up to the rather recent times in the development of the human race, this question was hardly asked. When man relied for his food on his skill and luck as a hunter and the good fortune and efficiency of women and children as gatherers of wild fruits and roots, periods of starvation had to be taken as a matter of course. With a small fraction of today's human population the world then was overpopulated. In these times tribal wars for hunting grounds were a natural struggle for survival. To eat your killed enemy was sensible. It not only removed a competitor, but at the same time, increased the supply of high quality food. That certainly made more sense than the later wanton destruction of entire populations with wasting of their substance just because these populations were ruled by governments who proclaimed the highest aim of man is worship of either a three-fold or a one-fold God or Capitalism or Communism.

In these early epochs of humanity, killing of newly born children and weak, old people may have been a horrible but necessary means to keep the tribe alive during periods of severe food shortage. This method used by some Eskimos not long ago is no longer followed. Man, or maybe woman, learned to cultivate plants instead of just gathering what happened to be there. He learned to domesticate and breed animals instead of hunting them. Man learned to anticipate lean years (Joseph's interpretation of Pharaoh's dream in Egypt[6]) and to conserve and store food in years of plenty.

Figure 2



[6]Bible: Genesis 41: "that food shall be a reserve for the land against the seven years of famine."

Yet, even now, according to Fairfield Osborn[7], only 1/5 of the human population eat enough, 4/5 are undernourished. Is this necessary, **Must Men Starve?** as Jacob Oser called his illuminating book[8].

There are still two opposed views on that question. One was expressed most clearly at the start of the 19th century by an alumnus of Jesus College at Cambridge, England, the Reverend Thomas Robert Malthus (1766-1834), professor in the East India Company's college. Malthus theorized that the human population could increase in a geometric progression, that is, add each year a given percentage of population, whereas the food supply at best could increase only in an arithmetic progression, that is, add only a given constant amount each year. Starvation, therefore, according to Malthus, is the result of a law of nature. More than that, poverty and misery are the natural punishment for the lower class for their lack of restraint in multiplication. There must be no government relief for the poor, nothing to alleviate the horrible conditions in the English factories at Malthus' time. Malthus opposed free trade in wheat which would have lowered the cost of bread. He advocated, instead, bounties on export which raised the cost of bread, starved the poor and enriched the rent-collecting landlords.

Oser cites Malthus as follows: (p. 24)

> "A man who is born into a world already possessed, if he cannot get substance from his parents on whom he has a just demand, and if the society do not want his labour, he has no claim of right to the smallest portion of food and, in fact, has no business to be where he is. At nature's mighty feast there is no vacant cover for him. She tells him to be gone, and will quickly execute her own orders. If these guests get up and make room for him, other intruders immediately appear demanding the same favour ... The order and harmony of the feast is disturbed, the plenty that before reigned is changed into scarcity."

Oser remarks (p. 26): "How soothing this doctrine was to those wealthy people who were reluctant to contribute to private charity or to public relief through taxation!"

And Malthus gave the poor no chance. He accused the poor of too great a rate of reproduction but he rejected birth control.[9]

> "Indeed I should always particularly reprobate any artificial and unnatural modes of checking population, both on account of their immorality and their tendency to remove a necessary stimulus to industry. If it were possible for each married couple to limit by a wish the number of their children, there is certainly reason to fear that the indolence of the human race would be greatly increased and that neither the population of individual countries, nor of the whole earth would ever reach its natural and proper extent."

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[7]Fairfield Osborn. **The Limits of the Earth.** Little, Brown, & Co., Boston (1953) p. 211.

[8]Jacob Oser. **Must Men Starve?** Abelard Schuman, New York (1957) p. 23.

[9]As quoted by Jacob Oser, p. 21

When Darwin explained evolution by the survival of the fittest, Malthus' masochistic theory seemed to acquire the dignity of a natural law, cruel and gloomy.[10]

Malthus' Advice

> "To act consistently therefore we should facilitate instead of foolishly and vainly endeavoring to impede, the operations of nature in producing this mortality; and if we dread the too frequent visitation of the horrid form of famine, we should sedulously encourage the other forms of destruction, which we compell nature to use. Instead of recommending cleanliness to the poor, we should encourage contrary habits. In our towns we should make the streets narrower, crowd more people into the houses, and court the return of the plague. In the country, we should build our villages near stagnant pools, and particularly encourage settlements in all marshy and unwholesome situations. But above all we should reprobate specific remedies for ravaging diseases and those benevolent, but much mistaken men, who have thought they were doing a service to mankind by projecting schemes for the total extirpation of particular disorders. If by these and similar means the annual mortality were increased, then we might probably every one of us marry at the age of puberty and yet few be absolutely starved."

Darwin writes that in 1838 he read **Malthus on Population** for amusement. (This indicates that Darwin had a rather strong stomach for amusement.) He then credits Malthus of having furnished him with a theory to explain the mass of data which he had collected in his research on the origin of the species. What we usually feel as good, especially the behavior advocated, among others, by Jesus of Nazareth, according to Malthus goes against nature. Not brotherly love but fight with tooth and claw, or with money and law, for survival seemed the proper and natural behavior. Do not help the needy and weak, but help nature to destroy the unsuccessful so that the "harmony of the feast" of the rich and mighty is not disturbed! That is the message of the reverend alumnus of Jesus College.

Kropotkin

This view was challenged by Peter Kropotkin. He was born (1842) as a Russian Prince. He developed to a successful scientist and then was shocked by the condition of the peasants and workers in Russia. He became a revolutionist, a socialist, but he disliked Marxian regimentation. He loved freedom and indi-

[10] F. Darwin. **The Life and Letters of Charles Darwin,** vol. I, p. 68 (1899) (Cited by T. Hollway, Introduction to Research, Boston (1956) p. 11).

viduality and classified himself as an anarchist. (His memoirs which are as exciting as best fiction have been published by the Atlantic Monthly.)[11]

Peter Kropotkin asked—What are the characteristics of the fittest, in natural selection, what are the particular features of those that survive in the struggle? He answered—not the best fighters (not the saber tooth tiger) but those animals have survived which learned to cooperate in groups (including man). One is almost tempted to cite with Kropotkin's book:[12] "Mutual aid in animals and man," the passage of the Bible "the meek shall inherit the earth." The instinct to serve in a group rather than the instinct to grab for oneself has the greater survival value for the species.

Food Problem Today

How do we stand today with respect to population and food supply? It seems that in America we are more plagued by surplus than by scarcity. We burn corn, we destroy wheat to keep the prices up. We slaughter piglets to reduce the supply of pork, we pay farmers for not raising crops, and punish those that produce more than others—punish professional achievement.

"The Progressive" of April 1969 p. 5 reports that Senator James Eastland received in 1967 (from the U. S. tax payers on top of his senatorial salary) the sum of $157,936 for not growing cotton on his Mississippi estate. Similar subsidies ranging from $50,000 to more than one million dollars each were paid that year to 1698 farm operators for not growing food and fiber.

In Vietnam our armed forces systematically destroy not only the people's food but also their plants on which their life depends. So far they have defoliated 5 million acres[13]—the equivalent of the yearly food of 15 million people (assuming the productivity of grain). In comparison with this outrage against humanity the equally degrading bloody massacre at Mylai shrinks to a minor incident.

In his book **Our Depleted Society** (1965) Seymour Melman reports a speech by George McGovern of South Dakota in the U.S. Senate on Aug. 2, 1963. The Senator said that America and Russia have piled up nuclear weapons with an explosive power of 60 billion tons of TNT, enough to put a ten ton bomb at the head of every human being on our planet.

At 3.6 Kcal per gram of TNT a 10 ton bomb represents a heat of combustion of 3.6×10^{10} cal (36 billion cal)—the food requirement of a man amounts

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[11]Peter Kropotkin. **Memoirs of a Revolutionist.** Houghton Mifflin Co., Boston and New York (1930).

[12]Peter Kropotkin. **Mutual Aid - A Factor of Evolution.** McClure Phillips, New York (1904).

[13]KPFA Broadcast, Berkeley, California, February 5, 1970.

to one billion cal per year. The explosive energy in the nuclear stockpile transformed to food energy would thus be sufficient to feed every human being on earth for 36 years. That was in 1963. According to William Winters Comments 1, October, 1968, this would now be the nuclear store of the U.S. alone.

When people starve today anywhere in the world, it is not because there are more people on this earth than can be fed. The problem is not one of production potential of food, it is one of distribution, of economics, of buying power.[14]

There is more profit in the manufacturing of atom bombs and constructing foreign bases for missiles than in the feeding of hungry people. That is why people starve today.

But what about the future? To speculate on that we have to investigate growth of population and food further.

Growth of Population

Figure 2 illustrates the increase in number of human beings for the last three centuries. There is no doubt that the mass of humanity has been growing at an accelerated rate. The yearly increase in population itself grows. From 1650 to 1750, the world's population increased from 545 million to 728 million, an increase of 183 million in a century; from 1850 to 1953, humanity grew from 1,171 million living souls to 2,492, this is an increase of 1,321 million in 103 years, or 1,283 million per century, seven times as much as the increase from 1650 to 1750! What will the population be in the year 2,000 or 10,000?

Growth as a geometric progression.

When we want to predict the future from our knowledge of the past, we deduce from our experience rules or laws. To extrapolate population to a future time we can express its growth as a geometric progression as indeed Malthus suggested. This means that the yearly increase is not constant (as in an arithmetic progression) but is a given part of what at any time is present. We may then formulate generally[15]

$$P = P_0 r^y$$

Where P = population at y years after start
r = yearly growth quotient
y = years from start of observation
P_0 = population at start of observation

[14]See Jacob Oser. **Must Men Starve** (1957) and John D. Black. **Food Enough.** Jaques Cattrell Press, Lancaster (1943).

[15]See Charles Darwin. **Population Problems.** Bull. Atomic Scientists 14:323, Oct. (1958).

Figure 3

Growth Ratios for Population and Food

$$P_y = P_o \cdot r^y$$

	years	r.
World's human population	1650-1750	1.003
World's human population	1900-1953	1.008
Corn yield per acre	1905-1952	1.007
Potato yield per acre	1905-1952	1.021
Milk yield per cow	1910-1952	1.008
Eggs per hen	1910-1952	1.018

From Max Kleiber, The Fire of Life, Wiley, New York, 1961, p. 334.

Thus, 1650 to 1750 the growth quotient amounted to 1.003. That is, the population grew yearly at a relative growth rate of .3%.

The growth quotient rose to 1.006 between 1850 and 1900, and to 1.008 between 1900 and 1953. Humanity grew faster than in a geometric progression. It outmalthused Malthus.

Our formulation of population as a geometric progression permits the comparison of growth in various regions during the past half century. In Europe and Asia population increased at a ratio of 1.007, that is, .7% was added per year. The African population increased with a relative rate of 1.1% per year. In North America we added 1.5% to our population yearly and our neighbors in Latin America won the multiplication rate with a yearly increase of 1.9% of the population.[16]

During the last 300 years the world's population has increased more rapidly than would correspond to a simple geometric progression. We cannot, with any degree of certainty, predict what the future growth of humanity will be. We can only calculate what the population would be if it were to continue to grow at a given relative growth rate. We can choose, as an example, the mean relative growth rate of the world's population during the first half of this century.

In this case the population will be expressed by the equation

$P = 2.5 \cdot 10^9 \cdot 1.008^y$ or for Latin America $P = 2.5$

where $2.5 \cdot 10^9$ is the population at 1953; y the number of years after 1953. The earth has a surface area of $5 \cdot 10^{14} m^2$—about ⅓ of that area is land. The population today amounts to $2.5 \cdot 10^9$ souls. There is thus 1 human being per 20 hectars or 50 acres of total earth surface. If our population grows as it did between 1900 and 1950, there will be 1 person per hectar in the year 2400 A.D.: 1 person per acre in 2500, and 1 person per 100 m^2 in the year 3000. (See M. Kleiber, Figure 19.2 in **The Fire of Life, an introduction to animal energetics,** Wiley & Sons, New York (1961) p. 336 or Fig 4 from the German translation, 1967.)

Growth of Food Supply

While history justified, or even more than justified, Malthus' contention that population can grow in a geometric progression, it does not at all support his second posit that food supply can increase only in an arithmetic progression. Apparently Malthus failed to consider the impact of science on agriculture which increases the yield per acre and the productivity of farm animals.

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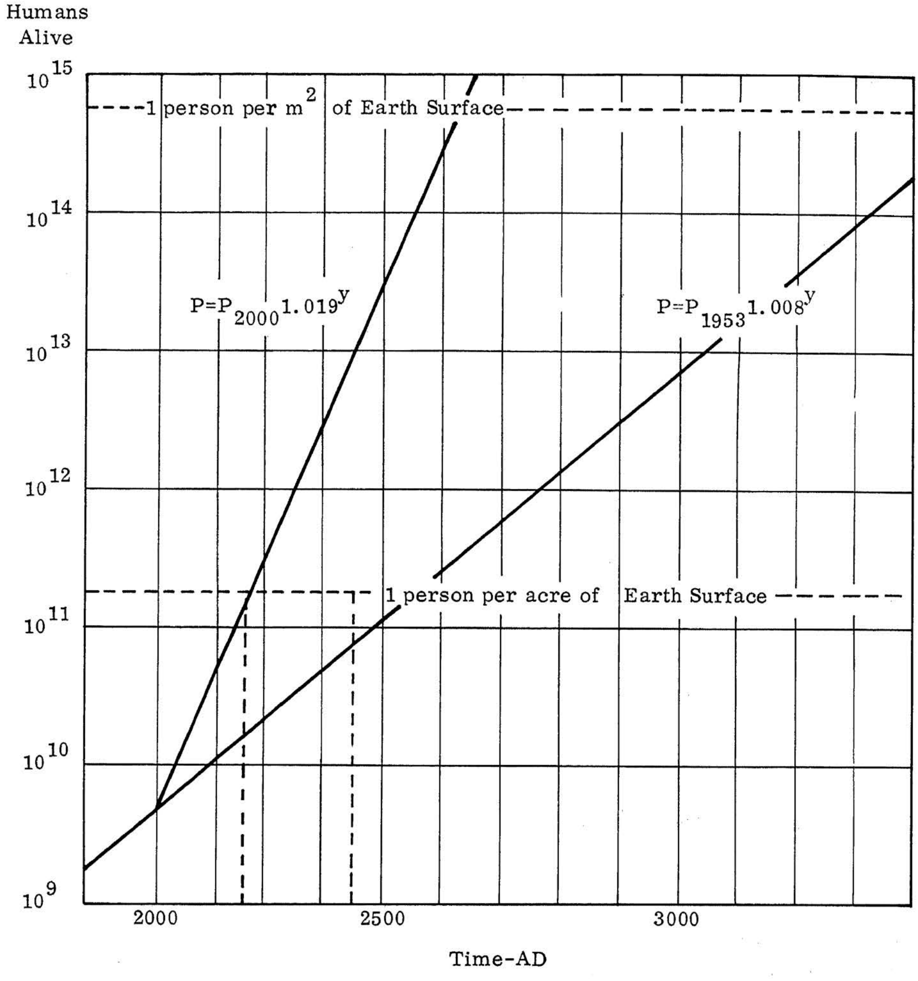
[16]Note that the relative growth rate of the population is the difference between the relative birth rate and the relative death rate. The highest growth quotient of a population does not therefore necessarily indicate the greatest relative birth rate.

Figure 4

Population Explosion



From M. Kleiber, Der Energiehaushalt von Mensch und Haustier. Parey, Hamburg & Berlin, 1967, p. 277.

The average yield of corn increased from 24 bushels per in 1866, to 38 bushels per acre in 1952.[17] The yearly growth quotient calculated in the same way as that for the human population increased from 1.002 at the end of the 19th century to 1.005 between 1900 and 1945, and to 1.016 for the years 1945 to 1952.

William and Paul Paddock, **Famine 1975**, Little, Brown & Co., Boston, 1967, in a diagram on p. 38 repeat Malthus' error of assuming increase of food as an arithmetic progression through increased acreage neglecting influence of science on efficiency of agriculture. The Paddocks may be correct in their prediction of famine in underdeveloped countries, but they fail to consider the effect of the repression of agrarian reforms in order to maintain the profits of colonial exploitation in underdeveloped countries by private enterprize of a rich nation. An example is the CIA directed military invasion of Guatemala which drove a democratic progressive government out and wrecked a promising agrarian reform.

The mean yield of potatoes in 1875 was 84 bushels per acre. In 1952, it amounted to 248 bushels per acre. The yearly growth quotient of potato yield per acre over the entire period is 1.014, a relative rate of increase of 1.4% per year.

The yield per acre of corn and of potatoes outgrew the human population. The increase of food supply thus can be greater than that of the population, especially when one considers the possibility of increasing the area by irrigating deserts by hydroponics or by cultivating algae in places where the soil is unfit for agriculture. So far, the growth rate of agricultural production in the developed countries has outstripped population growth. We could build our productive acreage up by building our houses and streets underground leaving the place in the sun to corn and potatoes and fruit trees. That should please our civil defense enthusiasts like Drs. Kahn and Teller.

But there are limits to our production potential. Obvious among these limits is the energy flux from the sun.

Figure 5

Growth Ratios for Human Population

$$P_y = P_o \cdot r^y$$

years	r
1650-1750	1.003
1750-1800	1.004
1800-1850	1.005
1850-1900	1.006
1900-1953	1.008

[17]Taken from J. Oser. **Must Men Starve**, New Pork (1957) p. 71.

Energy Flux From the Sun

Abbot[18] has made numerous measurements of the intensity of the sun's radiation. He concluded that the sun sends every minute 1.94 cal of radiant energy to each square centimeter of the earth's path. This figure is called the *solar constant.* It indicates a flux of 7 megacalories per square meter of the earthly surface area per day, or 2.8×10^{10} cal per acre per day. Thus the flux of radiant energy represents a power of 1.3 megawatt or 1800 horsepower per acre.

Figure 6 indicates the energy stream from sun to earth per m^2. The greatest part of this energy leaves the earth as heat. In the long run, all goes that way. It leaves the earth at a much lower temperature than it left the sun. It is like the water shooting down with great force from mountains and then sluggishly moving along as a wide stream through the flat land toward the ocean.

But on its way down from sun radiation to earthly heat some of the stream is diverted. A part evaporates water and is then again liberated as heat of condensation. From that part we tap our hydroelectric power.[19] About 2% of the sun's radiation reaches green plants. Of this amount of energy, most is again given off as sensible heat and as heat of evaporation. But what interests us most is that part appearing on the figure as a tiny rivulet, 1%, which the plants transform by photosynthesis to chemical energy and from which some becomes available as fuel for the fire of life of man, about 2 parts per million of the radiant energy of the sun reaching the earth.

Efficiency of Conversion of Sun Energy to Energy of Human Food

When humanity converts all the sun energy to human food it has reached its limit. But we are rather far from that condition as our picture has illustrated.

Figure 7 shows what percent of the radiant energy from the sun appears as chemical energy in various crops.

Figure 8 presents the total efficiency in the utilization of sun energy for the production of milk, pork and eggs as calculated from the efficiency for producing the feed and then from that of feed to animal product.

The area necessary to feed a man per year for various foods is shown in Figure 9.

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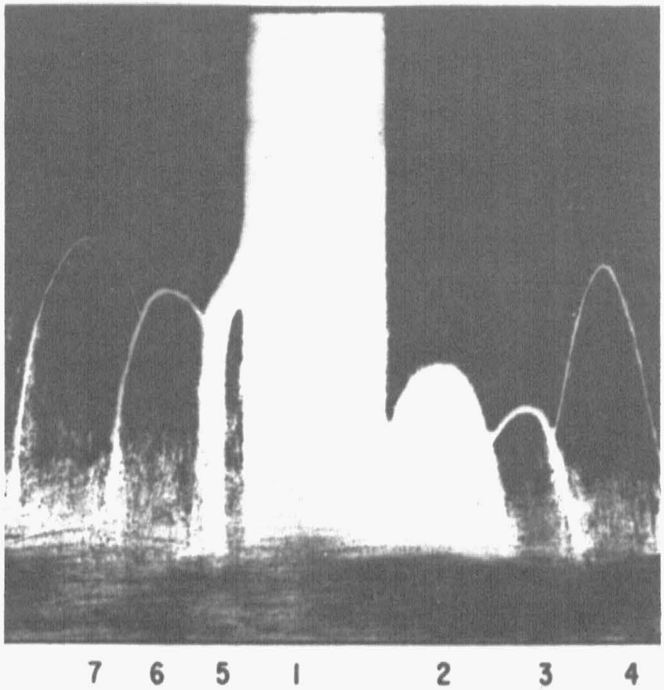
[18] Abbot, Charles G. **The Sun** (1929).

[19] A book on this subject has been written by Hans Thirring. **Energy for Man.** Indiana University Press (1958).

[20] Like the shipwrecked man on Solas y Gomez Island in Chamissos' beautiful poem.

Figure 6

ENERGY FALL FROM SUN TO EARTH



Energy Flux from Sun to Earth

Pro m^2 of Earth Surface, Pro Year

Total : $2.6 \cdot 10^9$ cal

		Direct Fall to Heat cal.	Part. Counter-Current cal.
1.	Heating of Air and Earth Surface	$1.3 \cdot 10^9$	
2.	Latent Heat of Water Evaporation		$1.3 \cdot 10^9$
3.	Mechanical Energy of Running Water		$1.4 \cdot 10^5$
4.	Hydro-Electric Energy		$0.6 \cdot 10^2$
5.	Radiation to Plants		$0.6 \cdot 10^7$
6.	Chem. Energy in Photo Synthes Prod.		$0.6 \cdot 10^5$
7.	Chem. Energy in Human Food (ideal)		$0.5 \cdot 10^3$

From M. Kleiber, Energie Haushalt, 1967, p. 279.

Figure 7

Utilization of Sun Energy

Flux density: 11 x 10^{12} calories

Energy per hectar per year.

Crops	Yearly yield per hectar*		Efficiency %
	tons	thousand mega-calories	
Alfalfa hay	8.4	32	.29
Potatoes	15.0	11	.10
Grapes	9.0	6.6	.06
Grain	2.1	5.5	.05
Prunes (dried)	3.0	4.4	.04
Pears	8.4	2.9	.026
Beans	1.0	1.6	.015

*1 hectar = 2.47 acres
1 acre = 0.405 hectar

Figure 8

Utilization of Sun Energy for Animal Products

	Total Efficiency		
	N/U %	U/S %	N/S %
MILK, 1200 lb. cow fed hay and beets, 20 lb. milk p.d. 35% partial efficiency	16	0.26	0.042
PORK, quick fattening 40 to 22 lbs. in 20 wks; potatoes, concentrates and silage	22	0.07	0.015
EGGS, 50 eggs per 100 hens per day 10 Skand. feed units	4	0.05	0.002

N = energy in animal product available for man

U = energy in animal feed

S = Radiant energy from sun

Figure 9

Area Yielding Food Energy for One Man Per Year

Requirement 10^9 calories per man year
Flux density of sun's radiation in California 1.6×10^9 cal./m^2 yr.

	Efficiency	Area Required	
	%	m^2	Acres
Algae (Warburg)	50	1	0.002
Potatoes	0.10	600	0.15
Grain	0.05	1200	0.30
Prunes	0.04	1500	0.37
Milk	0.04	1500	0.37
Pork	0.015	4000	1.0
Eggs	0.002	30000	7.4

If we insisted on meeting all our fuel needs with eggs[20], we would soon reach the end. With potatoes, we could get by with an area of .15 acres per person, about six persons on every acre! We could feed $.7 \times 10^{12}$ people. If we insist on multiplying the way we have been doing it in the past 50 years, we would reach that number in A.D. 2600. That is pretty soon as human history goes and practically now in terms of the time of development of homo sapiens.

Do We Want as Many People as We Could Feed?

We have no reason to doubt Fairfield Osborn's estimate that ⅘ of today's world population do not get enough to eat. Neither do we have reason to doubt that we can produce enough food for the present world's human population and could produce enough for several times the population of today. Tremendous effort now goes into the production of means for the annihilation of the human race which more and more threatens the security of all men. A fraction of this effort would suffice to produce and to distribute abundant food for all human beings. This would not only satisfy our feeling of solidarity with other fellow men, a feeling cherished in all modern cultures and regarded as the supreme command, especially of Christian ethics, it would be also in harmony with enlightened national politics. John Boyd Orr[21] writes: "In a hungry world people will be more attracted to the country which has the biggest supply of food than to the one with the biggest supply of atomic bombs."

Extrapolating the multiplication rate of the human population to the future, however, we must recognize justification in a statement by Robert C. Cook[22]: "Next to the atom bombs, the most ominous force in the world today is uncontrolled fertility[23]."

With the present efficiency of agronomy we could feed five men per acre, but do we want humanity to multiply to that limit?

Fairfield Osborn[24] rightly claims that the goal of humanitarianism is not quantity but quality.

Control is obviously necessary. Writers with a hate complex like Malthus advocate the decrease of health and other welfare measures in order to increase the death rate. Military men suggest wars as a remedy, but war is very ineffec-

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[21]J. B. Orr **The White Man's Dilemma.** British Book Center, New York (no date).

[22]Robert C. Cook. **Human Fertility.** McLeod, Toronto (1959) p.5.

[23]See also **Unitarian Register,** Fall (1959).

[24]Fairfield Osborn. **The Limits of the Earth** (1953) p. 226.

[25]Dr. Teller's successes may possibly change that.

[26]Chou Pei-Yuan. **Population, Production and Birth Control.** Bull. Atomic Scientists, 14(8):325 (Oct. 1958).

tive. War destroys the means of production more than it decreases population[25]. Thinkers with more friendly feelings toward their fellow human beings and a more lenient attitude toward basic human drives advocate birth control, such as now started in China[26].

Cook[27] cites Clarence Senior as follows:

"Presumably God gave men both sexual organs and intelligence. The latter should be used at least as frequently as the former."

If the clergymen preach what the wisest and most responsible and conscientious members of their churches are doing anyway and if everybody then does what the clergymen preach, then the problem of the population explosion will be solved. Not by population control alone, important as this is and important as it is to read and study the **Population Bomb** by Paul Ehrlich (1968) and the **Famine 1975** by the brothers Paddock (1967) whose conclusions are limited by their political faith, but study also the recent book by Nick Kotz (1969) **Let them Eat Promises, the Politics of Hunger in America.**

Conclusion

Man's Fire of Life does not have to be limited by starvation. Men starve today because the people who govern our national efforts find more profits in war and war preparation than in producing food for hungry people. With the help of scientific research, modern agriculture could feed several times as many people as live on the earth today if governments would be willing to give up war. If the cost of the war in Vietnam alone were channeled into support of agricultural research and efforts for food production, the United States could abolish famine in a few years thus preventing the famine in 1975 predicted by W. and P. Paddock. If the energy stored in the stock pile of H bombs could be utilized for desalting sea water a considerable part of our deserts could be transferred to gardens.

The explosion of the human population should be controlled now, not for fear of starvation, but because crowding would diminish the enjoyment of living even when everybody had abundant food, even when cities were cleared of slums, even when every empty beer can and cigaret carton were removed from sea and lake shores, forests, and mountain tops, even when air and water pollution were overcome by proper engineering. The most reasonable and thus most dignified method of checking overpopulation is birth control. Not starvation should limit the extent of man's fire of life, but reasonable control by the enlightened mind of man guided by the feeling of responsibility for humanity as a whole.

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[27]Robert C. Cook. **Human Fertility.** Willian Sloan, New York, 151, p. 36.