William W. Ballard

Horsemen of the Apocalypse

THEY WERE ALL GOOD, all superlatively clever steps: the development of language and of tools, the taming of fire, the cultivation of crops, the winning of freedom from the forces of natural selection, the establishment of science and technology, the building of machines and application of non-human power to them, the exploitation of fossil fuels to feed an expanding population. But now we know how badly we have fouled our nest, how much we are in danger of making the world uninhabitable for ourselves. A horrid picture from my childhood shows the four horsemen of the Apocalypse in the symbolic dress of famine, disease, war, and death. Modern apocalyptic writers need a larger number: eight perhaps.

I choose to ignore the possibility of atomic war because of its uniqueness, its finality. There is no peril so desperate, so oppressively near. None of the other disasters to be discussed can happen totally this evening, or totally tomorrow. They can be seen coming. There is time, if not to turn them aside, at least to blunt their impact. Let us, for the moment, consider only these others.

1. Growth of the Human Population

The population *growth rate* is usually given as the number of births minus the number of deaths per year per thousand. It may be a positive number, a negative number, or zero. It is important to note that any given growth rate may be produced in a region with a very high birth

This essay is excerpted from a series of lectures for the Dartmouth Alumni College, and appeared, in somewhat different form, in the *Dartmouth Alumni Magazine*, March 1970. The first lecture, not here included, described life on earth as a blanket of self-regulating ecosystems, each evolving through interdependent efforts of countless ephemeral species of plants, animals and decomposers, which are all eventually replaced because of inadequacy or arrogance. Its account of the recent swift rise of Man as one such species, unique but not free, led to the following inventory.

rate or a very low one, depending on the death rate. Also, in predicting from current growth rates it is essential to examine the age structure of the population: the proportions of immature, presumably fertile, and post-mature individuals. A high growth rate is vastly more ominous in a population with 50% of its members under the age of fifteen than in one with relatively few children and old people. Demography has its intricacies.

In looking to the future, the principal matter for concern is the time required for a given population to double in numbers. This can be figured out from the growth rate by a compound interest formula, making what seem like reasonable assumptions about the age and sex distribution in the population, and future birth and death rates. Of course, all of these figures are actually subject to change. Here is a sample result of such calculations:

Growth Rate	*Doubling Time*
0.5% per year	139 years
1.0	70
1.5	47
2.0	35
3.0	23
4.0	18

These doubling times usually do not give accurate predictions beyond the first or second decade because of changing values of the factors in the calculation. For this reason the experts usually make high and low predictions on the basis of a reasonable range of the unpredictable variables.

Rates of growth in many parts of the world, and in previous centuries, are based on unreliable or incomplete estimates, so that serious discrepancies are readily found in the figures of different authorities. This is a minor point. They all point to the same sort of acceleration in human population growth today.[1]

From the year 1000 to 1650 the world population probably doubled. The next doubling, by 1825, took not 650 years but 175, and the next, by 1905, took only 80 years. World population is now assumed to be growing at the rate of 2% per year, with an expected doubling rate of 35 years. A child born today with life expectancy of 70 years might

[1] L. H. Day and A. T. Day, 1964, *Too Many Americans.*

thus see world population increase from the present 3½ billion to about 15 billion unless something changes drastically. The growth rate in the United States has been gliding down for a few years, and headline writers have made false cheer from each new report. It hovers now at 1% but students of our population structure expect it to go up again. President Nixon's way of dramatizing the prediction from this "low" figure was to say we would have to produce the equivalent of a new city the size of Dayton, Tulsa or Jersey City every 30 days for the next 30 years to accommodate the population expected in the year 2000.

I shall make only two observations about the population explosion. The first is that it cannot go on indefinitely. A continued logarithmic growth of any sort eventually approaches infinity at an unimaginable speed. Luten calculates that the present world population, continuing to grow at 2%, would reach standing-room-only in about 800 years, i.e., one person per five square feet, *land and sea*.[2] A 2% growth rate since the time of Christ would have given us a population twenty million times larger than what we now have, stacked up 100 people per square foot. Such a crush being obviously impossible, it follows that something must occur rather soon to rein in this terrible horseman. What happens could be hideous beyond comprehension (war, famine, plague . . .) or it could be a planned cooperative intelligent effort.

My other observation is that, in spite of the fact that the technology of birth control is already quite adequate to solve this problem, and faint signs of progress are in sight, we are not going to rescue ourselves in this sensible humane way. Even the Planned Parenthood groups, who are leaders in this almost hopeless effort, merely concentrate on preventing the conception of unwanted babies. The American problem and the worldwide problem is that parents *want* too many babies.

Kingsley Davis[3] has pointed out that no country in the world has yet developed a population control policy, and that planned parenthood and the voluntary practice of contraception will have no significant effect on solving the problem. Bernard Berelson recently reviewed the policies that might work if they were adopted, but concluded that none of them is universally or even generally acceptable. Even if every community

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[2] D. B. Luten, 1964, *Sierra Club Bulletin* 49: 43. Numbers Against Wilderness.

[3] K. Davis, 1967, *Science* 158: 730. Population Policy: Will Current Programs Succeed? B. Berelson, 1969, *Science* 163: 533. Beyond Family Planning.

in the world became overnight dedicated to the goal of *zero growth* (an average of two children per family) there would continue to be a very large population growth well into the 21st century, because in the world today adults of fertile age are greatly outnumbered by children.

Meanwhile, the 1969 United States budget for population problems was $116 million but we had earmarked 35 times that for space programs, and nearly 700 times that for military programs. And President Nixon said, "Clearly, in no circumstances will the activities associated with our pursuit of this goal (population control) be allowed to infringe upon the religious convictions or personal wishes and freedom of any individual, nor will they be allowed to impair the absolute right of all individuals to have such matters of conscience respected by public authorities."

It is good, and indeed remarkable, that President Nixon has reached out a finger and pointed to our population problem, but the urgency of his concern disappears in his flatulent peroration: "If we now begin our work in an appropriate manner, and if we continue to devote a considerable amount of attention and energy to this problem, then mankind will be able to surmount this challenge as it has surmounted so many during the long march of civilization. . . . Let us act in such a way that those who come after us—even as they lift their eyes beyond earth's bounds—can do so with pride in the planet on which they live, with gratitude to those who lived on it in the past, and with continuing confidence in its future."[4]

It is reasonable to suppose that if a hundred million people were expected to crowd in upon us in the next thirty years by parachute or border infiltration, our leaders would rally us with a different choice of words and a recommended program.

The rest of the problems on my list arise because there are too many people now, herded in the wrong places, asking too much of the earth.

2. *Famine*

President Johnson once said, "Man's greatest problem is the fearful race between food and population. If we lose that race our hopes for the future will turn to ashes." Food production increases by simple interest, but the population increases by compound interest, as Malthus first ob-

[4] Message to Congress, July 19, 1969.

served. His "dismal theorem of economics" was that if the only deterrent to expansion of the population is starvation and misery, then the normal state of affairs will be a starved and miserable population. To this the economist Kenneth Boulding has added an "utterly dismal theorem," that the end result of any technological improvement will be to permit more people to reach the same state of misery and starvation.

The widespread shortage of food in the world today and the practical certainty that Mr. Johnson's fearful race cannot be won even to the extent of properly feeding the present world population or of preventing the situation from sharp deterioration in the near future have been many times documented. Recently, however, new genetic strains of wheat, rice and corn have been introduced in a number of hungry lands. The great jump in productivity, where multiple cropping can be practiced and sufficient water, fertilizer and heavy machinery can be furnished, has been widely hailed as a "green revolution."[5] At the moment it seems a major technological achievement but the warnings are already out that predictions based on it may be blasted in the next decade or two for a great variety of governmental, economic, sociological and biological reasons. Already one side effect is appearing: the rich are getting richer, the poor poorer. In just these lands, the populations are growing so as to double in 25 or 30 years. If the food supply does not continue to double in less than the same period, the net accomplishment will be utterly dismal.

This in fact is the thesis of the Paddock brothers.[6] Their conclusion is that the United States must be prepared in the next century to decide in its own self-interest which are the starving countries that we should favor with our food surpluses, and which are so firmly caught in the Malthusian trap, or so relatively useless to us, that we should abandon them to the great famines that surely must come soon.

3. *Exhaustion of Non-Renewable Resources*

The non-renewable resources of fossil fuels and metals, and the very slowly renewable resource of agricultural soil, are being used up at rates which are quite well known, but for obvious reasons the dates when they will become inadequate cannot be calculated. All we know is that

[5] C. R. Wharton, 1969, *Foreign Affairs,* April. The Green Revolution: Cornucopia or Pandora's Box?

[6] W. and P. Paddock, 1967, *Famine 1975!*

the earth cannot continue indefinitely to support the human species in the style to which some of us have suddenly become accustomed.

On the average, each American now consumes as much of the world's resources as 25 to 30 residents of India. With 7% of the world's population we are now absorbing more than 60% of the world's mineral production. Our own affluence is increasingly dependent on imports from other countries. Park[7] estimates that if the rest of the world reached the level of affluence of the United States by the year 2000, the then doubled population would need to be processing 11 times as much copper per year, 12 times as much iron, 16 times as much lead. Plastic or other synthetic substitutes for metals are expensive in fossil fuels, which are also non-renewable.

It has been estimated that half the coal ever burned by man has been burned in the last 31 years, and half the oil in the last 16. Lamont Cole points out that modern agriculture, which raises more food on less land with fewer laborers, is not really a triumph of efficiency. It is essentially a device for exchanging the calories of fossil fuel for food calories. He reaches this conclusion by taking the calorie value of the food we produce and deducting from it the fossil fuel calories used by the farmer's machines, those used to build and deliver the machinery to him, and those to mine the necessary raw materials. Also those used to manufacture, process, transport and apply fertilizers and pesticides, to collect and deliver the water, and to process and distribute the food.

With vastly more effective prospecting methods, the rate of expansion of proved resources in fossil fuel, particularly oil, is still encouraging, but the demand for power is on a steep climb too. It is foolish to predict when we will run out of these resources, but to deny that the time will come is to deny that they are non-renewable. When that time comes, another enormous source of energy must be available or the human species will have to drop back to the agriculture of the hoe and the horse, with primitive transportation and little reliance on chemical fertilizers and pesticides. Under these conditions the earth might still comfortably support a human population like that of the 1600's.

The rate of burning of fossil fuels is increasing very rapidly, and already we are releasing six billion tons or so of carbon dioxide per year into the atmosphere. Green plants decompose some of this, and the oceans can very slowly absorb it, but the CO_2 level in the air is appar-

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[7] C. F. Park, 1968, *Affluence in Jeopardy*; Minerals and the Political Economy.

ently increasing. This is being monitored with some concern, since it has been suggested that it interferes with the loss of earth heat to outer space. If so, it could produce a "greenhouse effect" that might eventually result in the melting of the polar ice caps and the flooding out of most of the large cities and inhabited lands of the earth. On the other hand we are polluting the atmosphere with dust and soot at an accelerating rate, which is reflecting sunlight away from the ground, and this may be pushing us to a new ice age. Which way will the balance tip? If neither way, will the living be better than now, or worse?

4. *Atomic Energy*

It is quite clear that we are damned if we don't develop new sources of energy before it becomes economically impossible to recover the last traces of fossil fuel, and the question is whether we are also damned if we do. At the moment, the prospects are not exactly bright that controlled fusion of hydrogen to helium will become possible. Even if this problem were solved tomorrow, no benefits would be likely to accrue before world population has doubled again. However, the age of power from atomic fission is beginning. There were a dozen or so such power plants running in this country in 1968 and scores more are under construction or contemplated. They are all designed to use uranium-235, which is in alarmingly short supply; therefore, they must promptly be replaced by breeder reactors, which are still only in experimental design but will surely be more dangerous. Only the very large atomic power plants are expected to produce kilowatts competitive in price with conventional generators, which makes it unlikely that they will solve the energy needs of impoverished nations or scattered populations. Also, since they produce electric power, which is applicable to only 20% or so of present American demands for energy, they cannot relieve much of our rising need for fossil fuels without an enormously expensive conversion of household and industrial equipment that is now run by steam or internal combustion engines. This in turn would greatly aggravate the shortage of metals.

But it is already painfully obvious that the reliance upon atomic fission for an energy source brings with it two dangerous and expensive problems. The first is the disposal of the radioactive waste. Fission bombs and fission power plants produce the same atomic by-products. One can disregard the ones that have half-lives of a few seconds or minutes, but others, including some that are very dangerously active in biological processes, have half-lives of hundreds or thousands of years. A rule of thumb is that they should all be kept under close control for at least twenty times their half-lives. For carbon-14 that would be well over a hundred thousand years.

All the control methods now in use are special ways of sweeping the stuff under the rug, whether it is set to cook in million-gallon steel and concrete tanks buried to their necks in some convenient desert, or embedded in glass or ceramic and stashed in old salt mines, or just quietly dropped into the ocean. The material has to be transported in trucks on our crowded highways. How much accidental contamination of the oceans, of the ground water, of the atmosphere, can the living world tolerate? The safety standards and monitoring systems are at present made by people at least obliquely involved in setting up new industries, not by experts solely charged with protecting the general welfare, and there is recurrent criticism of the standards as now defined.

The other problem is heat disposal. The generation of electricity in an atomic fission plant wastes very much more heat than in conventional steam generators, and nothing can be done with waste heat except to disperse it in the environment. It is not lost; it heats the world up a bit. The present concern is with thermal pollution of our rivers and lakes, since the cheap thing to do is to use water as a heat sink. There are engineering estimates that by 1980 from a sixth to a third of all this country's freshwater runoff will be needed as coolant for electric energy generators, and that by 2000 all of it will be needed. Biological estimates of the damage to the ecosystems of our estuaries, lakes and rivers are less than precise, but if the predicted trends are projected into the future they point to rapidly spreading and eventually total disaster. Cooling towers to disperse the heat in the atmosphere or subsoil piping to disperse it under farm land that could then be cropped an extra time or two per year have been suggested, but are more expensive. All of them heat up the world a bit. Recent calculations projecting current rates of increase in power demand, with current rates of heat wastage, have produced the dizzying conclusion that the world climate will be too hot to support human life in less than 150 years, even allowing for the delay in melting the polar ice caps.[8]

[8] L. C. Cole, 1966, *Bioscience* 16: 243. Man's Ecosystem. C. A. Smith and L. C. Cole, 1970, letters in *Bioscience* 20: 72, following L. C. Cole, 1969, *Bioscience* 19: 989. Thermal Pollution. Cf. also S. Novick, 1969, *The Careless Atom.*

5. *Air Pollution*

No city in the world is free now from the health hazard of smog. There is a growing list of instances of multiple deaths from smog corked up in a valley or a city by thermal inversions of the atmosphere. The major sources of airborne poisons are already known, and technology for reducing them is rapidly developing. A good deal of the sulfur in the air comes from fossil fuels. As sulfur dioxide it kills lung cells. Brought down as sulfuric acid in raindrops it dissolves buildings. Much of the carbon monoxide and nearly all of the lead comes from automobile exhaust, which also gives us many of the hydrocarbons and nitrogen oxides that rot rubber and ruin nylon stockings. But then there are also the scattered fine particles from the smokestack plumes of factories, mills, incinerators, and heating plants, coming back down upon us as sootfall and afflicting us with irritability in our productive years and emphysema in later life.

Theoretically, as we all know, this problem can be solved. But the prevailing winds bring one city's smog down upon others, and there are days when even Vermont knows it is downwind from Chicago and Detroit. In fact, the problem cannot be solved locally, or even nationally. Meanwhile, more and more of the population is concentrating in the cities where the problem is worst. We double and redouble the sums we spend to keep the air from being soiled and poisoned, and those in charge of the work tell us we are losing ground.

6. *Water Pollution, Water Shortage*

Most of our other troubles generate water troubles. The most intimate and obvious problem is pollution from raw sewage and industrial wastes. If we can give ourselves a merely passing grade in the matter of protecting ourselves from our own sewage, we do far less well with the comparable tonnage of excreta from our concentrations of farm animals. The food processing industries also turn out sewage in a tonnage not much less than what people produce. Oxygen-demanding dispersed organic waste has altered, or ruined, the original ecology of more brooks, rivers, ponds, and lakes than even most active conservationists know, since we keep no records on most of these resources. When the warning comes through the nose, it is usually too late.

Much more subtle are the problems of enrichment of the streams and ponds with the molecular and ionic materials that are still present in processed sewage and foster the growth of algae and other microscopic life. Half the enrichment comes from fertilizer run-off rather than from raw sewage. The switch from soaps to detergents has extended the pollution with phosphates. All this encourages a population explosion among the microorganisms whose support would normally be limited by the recycling of materials already present in the ecosystem. The visible effect of the enrichment is an alga "bloom" just below the surface of the water. The billions of algae, dying when their time comes, sink and disintegrate, exhausting the oxygen in the deeper waters, suffocating fish and ordinary plankton, leaving only stinking mats and floating wads of nameless and unlovely organic material.

Most of the fresh waters of the settled parts of the world are in serious trouble, from gasoline and oil pollution and over-enrichment and poisoning. It is the same from Lake Champlain to Lake Tahoe. The long-lived pesticides have not only produced mammoth fish-kills in the Mississippi and the Rhine, but also thousands of smaller ones.

The actual shortage of usable fresh water is still a novelty to eastern Americans, but the trouble zones are spreading. Ground water is a reserve accumulated during Pleistocene times. First tapped, it seems free and inexhaustible, but used at a rate in excess of the annual input from rain and seepage, it becomes increasingly expensive and hard to get, until finally fewer people can live off it. To supply a periodically doubling population of individuals, each requiring more hundreds of thousands of gallons of water per year, at some point becomes impossible. Leading toward that distant time will be a long history of regional squabbles crossing state and national lines, leaping mountain ranges and river basins, about who has the right to what water sources. The water troubles in our southwestern states are nothing compared with those along the Jordan, the Nile, the Indus.[9]

7. *Runaway Technology*

This may be a riderless horse. We have no technology for reining in technology. It has been the western way of life to exploit natural resources by the newest and cheapest methods so as to maximize private profit. Hidden costs are passed on to the public at some later date and by the time we become aware of the size of the mess to be cleaned up the harm has been done.

[9] G. Borgstrom, 1969, *Too Many*.

The conservation movement was born of the shock of this realization. Nobody reckoned who would pay for the houses and streets in towns built over coal mines when the mines were abandoned and started to collapse or burn. No plans were made to restore to usefulness the land covered by the tailings of strip mines, or left to erode after the virgin forests were skinned off. No one thought what would have to be done by whom when the lakes became cesspools. We knew why we went all out with DDT, and perhaps we can deliver ourselves from serious damage by it to ourselves, but some of its destruction can never be repaired. We learned new ways to make paper more cheaply, at the cost of ruining rivers, which now need to be salvaged.

We developed machinery that made profits for the plantation owners but forced their tenants into misery and exile in the cities, leaving the costs to be picked up by quite other, quite surprised, quite unwilling people. There was nothing fundamentally wrong with our railroads, but somebody offered us private automobiles and now we have to travel more dangerously and inconveniently on highways that pave over some of our best farmland and violate our parks and sanctuaries. It began to look as though some of our uniquely beautiful valleys were being dammed and flooded-out by silt-catching basins only because we had set up a bureaucracy that knew how, and had to keep busy. What other reason than the military one is there for building monster jet planes that will take a few people across oceans faster than they need to go, shattering the nerves of vastly more people with sonic booms?

The military one. We hire R & D technicians to invent and build weapons that then produce undesired but predictable responses in other countries, thus determining our defense strategy and our foreign policy for us. More clearly than anything else, the atomic missiles race shows that we are in the grip of forces that have a self-generating momentum beyond the control even of our statesmen. And where can we honestly put the blame? The horse has no rider.

8. Plague

We think we have freed ourselves from natural selection, from the old-fashioned biological balancing and reorienting forces, and so we have for the time being. We have exterminated the sabertooth and the cave bear, we can remain discreetly out of reach of the remaining wolves and grizzlies and tigers, and with reasonable precautions we can be free of tapeworms, liver flukes, and ringworms. But waiting in the background are the microbial and viral diseases, many of them transmitted by polluted water, or by contact in crowds, or carried by insects only temporarily held in check. If population growth is not arrested almost at once, if the predicted century of great famines is not averted, if the worldwide deterioration of the environment is not arrested, if our slap-happy tendency to put our big money and our great technology at the service of wrong causes is not corrected, then the world is surely approaching a time of political instability, social disorganization, and economic breakdown vastly more serious than any yet known. The last pandemic of the bubonic plague occurred in a time of peace and reasonable prosperity within this century, and it killed 14 million people. It is now established as an endemic in all the continents and lurks ready to strike again. The same is true of most of the great killing diseases. What an epidemic of smallpox could sweep through the world if our guard went down in major areas for ten years! Total chaos, developing in the overpopulated, impoverished, famine-swept countries, will undoubtedly spawn epidemics of a size and intensity never before seen. What kind of frontier defenses will be adequate?

If the last world war was a time for re-reading Thucydides, we should begin re-reading accounts of the great plagues of the Middle Ages. The mildest comment is that those times brought out the best and the worst in humanity. Even if we don't get atomized first, there are frightful times ahead.

II

THERE ARE TWO FACETS to this unprecedented crisis for the human species, and they are cause and effect: too many people, and too much demand on the supporting capacity of the earth. Here, a moderately large population at a high level of affluence, there a swarming mass of human beings in abject poverty. In both cases, our ecosystem is intolerably out of balance. Why did this have to happen? A disturbing essay by Lynn White[10] suggests that human individuals have been led astray by inculcation in an ancient Judeo-Christian point of view, that they are commanded to increase and assert their mastery over nature. I think the trouble lies farther back, in a direction taken by the stock of mammals many millions of years ago.

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[10] L. White, 1967, *Science* 155: 1203. The Historical Roots of Our Ecologic Crisis.

To maximize the amount of life that can be supported in a given ecosystem, a large number of species of plants, animals and decomposers are brought into balance, each occupying its own niche and following its own instructions to make the best of the things available to it while contributing to the flow of energy and the recycling of materials. If one species in the ecosystem gets out of balance the whole community develops an instability that may either result in an irreversible change in its character, or in the control or rejection of the destabilizing element.

The human species has been manipulating its environment since the invention of agriculture, favoring the plants and animals that serve it for food, repressing or even exterminating others. Where this was overdone—e.g., Mesopotamia, the Near East, Yucatan—ghost cities and records of dead cultures remain to show how powerfully nature can strike back. Quite recently we have begun to use the treasure trove of fossil fuels to grow the food to satisfy the multiplying demands of our own population, and we congratulate ourselves on having temporarily freed ourselves from the normal restrictions of the natural world. It is a dangerous game we are playing.

No good asking why the human *species* takes these risks. A species is an invention of the mind, a generalization. Only human *individuals* actually walk and breathe and make decisions and it is the collection of individuals who have been doing what I say the species has been doing. What went wrong with human individuals, that they have gotten their species and their environment into such a mess? The other face of this question is, what is an individual supposed to be doing, and within what limits is he supposed to be held?

The Primary Computer. To simplify, I shall restrict the latter question to animals rather than plants or decomposers. A frog will do. I assume that whatever a frog does, any choice that it makes, is determined by its inherited computer system. It receives from its ancestors a scanning mechanism which reports what all the circumstances around and inside it are at the moment. This information is checked against an inherited memory encoded in its central nervous system. The computer then not only orders up the strategy and tactics that had met that sort of situation successfully before, but directs what every cell, what every organ, what the whole frog must be doing to contribute to that response.

The Secondary Computer. There is such an inherited program in the human individual, but there is much more. The baby does not really learn to walk, he develops the inherited capacity to walk; but then he can learn a dance that no man has ever danced before, he can paint a picture with a brush clasped between his toes. During late fetal life and his first six or eight years he gradually matures a second computer system superimposed on, controlling and almost completely masking the ancient frog-type computer. The evolutionary history of this new device is traceable back to, and in some respects beyond, the time of origin of the modern mammals 70 million or more years ago. It has progressed farthest in particular mammalian orders—the carnivores, hoofed animals, bats, whales and primates, and least in the egg-laying mammals and marsupials.

The new trend has worked certain real advantages, and has been kept under reasonable control, in the higher mammals, but it is my strong suspicion that its overdevelopment in man is the root of our trouble. Like the dinosaurs, we contain in our own structure the reason why we will have to go. Robinson Jeffers[11] said it: "We have minds like the fangs of those forgotten tigers, hypertrophied and terrible."

Up to a point, the development of brain and spinal cord follows the same course in frog and man. Sense organs, cranial and spinal nerves, principal subdivisions of the brain, basic fiber tract systems, all form in strictly comparable fashion in both. But the adult human brain is a far different thing from the adult frog brain. It continues the multiplication and interconnection of neurons during a far longer growth period, and adds to the elementary or frog-type apparatus two principal complicating tissues that far overshadow the earlier developments. One is often called reticular substance, the other is the cerebral cortex.

The reticular substance is so called because it is an interweaving of small centers of gray substance with short bundles and interspersed mats of axons (the white substance), quite different from the simple contrast between gray and white substance seen in primitive animals and in early embryos. The frog brain is not without this sort of tissue, but in the brains of advanced vertebrates like the teleost fishes, the reptiles and the birds, it becomes indescribably complex. The modern mammals push this development to still higher orders of magnitude.

Although neurological science is not yet ready with answers to most specific questions about what happens where in the central nervous system, the new techniques of exploration within the brain suggest that in and through the reticular substance the connections for integrating

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[11] R. Jeffers, "Passenger Pigeons," in *The Beginning and the End.*

sensory information with the devices for evaluation and for making decisions and coordinated responses are multiplied exponentially.

Thus, an electrode planted within a single neuron in the reticular substance of the hindbrain can give startling evidence that this one cell is receiving and reacting to sensations reported from widely scattered parts of the body, and sending out coded pulses as a calculated response. Your own brain contains hundreds of millions, probably billions of such cells, every one individually a computer.

The neurologists can now stimulate chosen localized areas through implanted electrodes, either hooked up to wires dangling from the cage ceiling or activated through transmitters healed in under the scalp and controlled by radio transmission. In such experiments, stimuli delivered to many parts of the reticular substance cause the animal to react as though he were flooded with agreeable sensation. If the cat or rat or monkey learns how to deliver the stimulus to himself by pressing a pedal, he will do so repeatedly and rapidly, until he falls asleep exhausted. As soon as he wakes, he goes to pounding the pedal again.

There are other reticular areas which have the reverse effect. If the stimulus comes at rhythmical intervals and the animal discovers that he can forestall it by pressing the pedal, he quickly learns to regulate his life so as to be there and step on it just in time. What kind of sensation such a stimulus produces can only be guessed by the experimenter. One might suppose that these areas of reticular substance which have such opposite effects are there to add into the computer's analysis of the situation at the moment a go signal or a stop signal for particular alternative choices, or a sense of goodness or badness, satisfaction or distress, urgency or caution, danger or relaxation. A value judgment, in other words.

It is not difficult to see the survival value of such a device. No doubt the basic mechanism exists in the brains of fishes and frogs, though I am not aware that experiments have been done to locate it. In the reticular substance of mammals, however, we see it hugely developed. The result of overdoing this might produce an awareness of the good and bad features of so very many facets of a situation as to delay and perplex the individual in calculating his single coordinated response.

Mammals are also conspicuously good at remembering experiences from their own lives as individuals, and these memories are loaded with value judgments. There is still no clear answer as to where or in what coded form these new personal memories are stored. But an animal with all this added to the ancestral memory, enhanced with perhaps casually acquired and unwisely generalized connotations of goodness and badness, might predictably be endowed with excessive individuality, prone to unnecessarily variable behavior chosen more often for self-satisfaction than in the interest of species survival.

The other evolutionary development, the formation of the cerebral cortex, is almost unknown in vertebrates other than mammals, and is feeble in some of these. Cerebral cortex is a tissue of awesome complexity, and our techniques for analyzing what happens in it are highly inadequate. Stimulation of willing human subjects, in chosen spots exposed surgically, or radio stimulation of these areas through permanently installed electrodes operated by healed-in transistor devices, evoke feelings referred to a particular part of the body, or cause normal-appearing localized movements, e.g., the flexion of an arm or a finger, time and again, upon repetition of the signal. Other areas produce more generalized sensory or motor or emotional or physiologic effects. The patient, his brain exposed under local anesthesia, does not know when the stimulus is applied. When the electrode touches a particular spot of his cortex he may report that he is suddenly remembering a scene identifiable as to time and place, but the memory blacks out when the current is off. Stimulation of other areas may elicit emotions of sexual attraction or anxiety or rage graded according to the intensity of the signal.

More wide-ranging experiments with cats, monkeys or barnyard stock, singly or in groups, free to move in large caged areas, show the possibility of turning on and off a great range of complex emotions, behavior, and even personality traits, by local stimulation.[12] The effect produced through a permanently planted electrode is area specific. Though not predictable before the first stimulus is given, the response is repeated with each stimulus, many times a day or over periods of months or years.

In subjective comparison of mammals with greater or less personal individuality one gets the impression that the degrees of freedom of choice, of imaginative recognition of possible ways to react to situations, of storage capacity and retentiveness of memory, and the richness of association, are correlated with the intricacy and amount of the cerebral cortex and reticular substance. Animals highest on both scales include porpoises, elephants, cats and dogs, apes, and people.

[12] J. M. R. Delgado, 1969, *Physical Control of the Mind.*

One cannot underestimate the effects on the human species of other evolutionary trends that came to a climax in us, for instance the development of upright posture that frees the hands, the reshaping of the fingers for grasping and manipulating, the perfection of binocular vision that can bring into focus either the hands or the far distance at will. Far more significant than these was the development of speech, made possible by and controlled in a particular small area of the new cerebral cortex. This expanded the powers of the human secondary computer by orders of magnitude, even in comparison with that of relatives like apes.

We no longer communicate with each other by baring teeth, raising hackles and flaunting rumps, but in symbolic language. We can make abstractions and generalizations and artificial associations. Through speech we can feed into the recording apparatus of each other's secondary computers not only the vast and rather accidental store of individually acquired and long-lasting memories of our own experience, but also the loads of approval or disapproval which we deliberately or unwittingly put upon them. We increasingly remove ourselves into created worlds of our own, calculating our choices by reference to a memory bank of second-hand ghosts of other people's experiences and feelings, prettied up or uglified with value judgments picked up who knows where, by whom, for what reason.

Language gave a fourth dimension to the powers of the secondary computer, and writing a fifth dimension. We can now convince each other that things are good or bad, acceptable or intolerable, merely by agreeing with each other, or by reciting catechisms. With writing we can color the judgments of people unborn, just as our judgments are tailored to the whim of influential teachers in the past.

Symbols have given us the means to attach a value judgment to some abstract noun, some shibboleth, and transfer this by association to any person or situation at will. We invent, we practice, we delight in tricks for saying things indirectly by poetry and figures of speech that might sound false or trite or slanderous or nonsensical if we said them directly. A more normally constructed animal, a porpoise or an elephant, mercifully spared such subtleties, might well look at human beings and see that each one of us has become to some degree insane, out of touch with the actual world, pursuing a mad course of options in the imagined interest of self rather than of species.

The primary computer is still there, programmed in the interest of species survival. With his new powers, man should do better than any other animal at understanding the present crisis and generating an appropriate strategy and tactics. Instead, the effort is drowned out in the noise, the flicker-bicker, the chattering flood of directives from the personalized secondary computer. In pursuit of his own comfort and his own pleasure, man wars against his fellows and against the good earth.

The frame of each person is like a racing shell with two oarsmen in it, back to back, rowing in opposite directions. One represents the ancient computer system, comparing the personal situation of the moment with an inherited value system and driving the person to perform in such a way that the species will survive, irrespective of how absurd his own expendable life may be. The other represents the secondary computer system, probably located in reticular substance and cerebral cortex, surveying chiefly memories of childhood and adult life, and of how to act according to the value-loaded store of personal experience.

It is this runaway evolutionary development of our superimposed second computer that has produced our inventors, our artists, our saints and heroes, our poets, our thinkers. Our love and hate, ecstasy and despair. The infinite variety of human personalities. It has also atomized the species into a cloud of ungovernable individuals. We split our elections 48 to 52, make laws to break them, and either ignore community priorities or establish them by political blind-man's-buff in frivolous disregard of real emergencies. Six experts will come violently to six different decisions on how to meet a crisis because their personal histories lead them to weight the same data differently. Each of us can see bad logic and conflicts of interest affecting the judgment of most of our associates; it is more difficult to detect them in ourselves. Our individual prejudices have been built into our secondary computers.

The California biologist Garrett Hardin, in a famous essay called "The Tragedy of the Commons," showed that this ungovernable power of the human individual, the essence of our humanity, accounts for practically all the facets of our apocalyptic crisis, from the population explosion to runaway technology.[13] He is referring to the community pasture where anyone may feed his animals. Overgrazing will bring erosion and irreversible deterioration in it. Each herdsman, calculating the advantage to himself, adds another animal in his own interest, and another, and another. All do, and all lose together. The tragedy is the inescapable disaster when each herdsman pursues his own advantage without limit, in a limited commons. This is the tragedy that leaves us

[13] G. Hardin, 1968, *Science* 162: 1243. The Tragedy of the Commons.

with too many human mouths to feed, soil impoverished and washed or blown away, forests skinned, lakes ruined, bottles and cans scattered over the countryside, rivers clogged with dead fish, bilge oil on public waters, streets and highways obscene with advertisements. It gives us choking smog, the stink and corruption below mills and slaughter houses, the draining of one well by another in a falling water table, the sneaking of radioactive wastes into the air and ocean.

All these, Hardin makes clear, are problems with *no technological solution*. To be sure, the technology stands ready, but the trouble starts with some individual, you, me, whose response to a situation is to give highest priority to his personal chance of profit, or his family's, or his country's. He has a vivid sense of the value to himself of his own freedom, but not of the total effects of all such freedoms on the species and on the natural world which supports it.

Some of these problems can be brought under control by compacts, treaties, and other agreements between willing groups, or by laws imposed by the majority upon a minority. Hardin, however, finds the population problem the worst example of the worst class of problems, in which all of us must restrict the freedom of all of us, when none of us wants to. He is properly skeptical of conscience or altruism for uniting the community when nearly all of us are still daring to gamble on the continued capacity of the commons to withstand collapse. He says a fundamental extension of morality is needed.

I agree by saying that human nature is our chief enemy because the species-preserving function of our primary computer has not yet been built into the secondary computer which generates our human nature. It is by now clear that our nature is not so much inherited as learned, as babies grow into people, in and from their individual, accidental and culture-bound experiences. We need to incorporate into the decision-making apparatus that will really control them a new survival morality, a system of values whose principal axiom is that anything which threatens the welfare of the species is bad, anything that serves to bring the species into harmony with its environment is good. We must each, because of this inner drive, regulate our numbers and our selfish wants as rigorously as the forces of natural selection would have done had we not learned how to set them aside.

Do we know how to create a human nature that can keep the species going without undue sacrifice of the privilege and joy of being human? How much freedom must we give up? Do we want to? Is there time?