gree of invariance and, on the other, the factors which tend to break up firm structures and thereby create the degree of variability which is the prerequisite of all further gaining of information, in other words, of all new adaptation.

All this is obviously true of human culture as well as of any other living system whose life-span exceeds that of the individual, for example, of any species of bacteria, plants, or animals. It is, therefore, legitimate to search for the mechanisms which, in their harmonious antagonism of preserving and dismantling structures, achieve the task of keeping a culture adapted to its ever-changing environment. In my latest book *Die Rückseite des Spiegels*, I have tried to demonstrate these two antagonistic sets of mechanisms in human culture.

The preservation of the necessary invariance is achieved by procedures curiously reminiscent of genetic inheritance. In much the same manner as the new nucleotides are arranged along the old half of a double helix, so as to produce a copy of it, the invariant structures of a culture are passed on, from one generation to the next, by a process in which the young generation makes a copy of the cultural knowledge possessed by the old. Sheer imitation, respect for a father figure, identification with it, force of habit, love of old ritualized customs, and, last but not least, the conservativism of "magical thinking" and superstition—which as we have seen influences even the construction of railway carriages—contributes to invest cultural tradition with that degree of invariance which is necessary to make it inheritable at all.

Opposed to these invariance-preserving mechanisms, there is the specifically human urge to curiosity and freedom of thought which, with some of us, persists until senescence puts a stop to it. However, the age of puberty is typically the phase in our ontogeny during which we tend to rebel against tradition, to doubt the wisdom of traditional knowledge and to cast about for new causes to embrace, for new ideals.

In a paper which I read a few years ago—at a Nobel symposium on "The place of value in a world of facts"—I tried to analyze certain malfunctions of the antagonistic mechanisms and the dangers of an enmity between the generations arising from these disturbances. I tried to convince my audience that the question whether conservativism is "good" or "bad," or whether the rebellion of youth is "good" or "bad," is just as inane as the question whether some endocrine function, for instance that of the thyroid gland, is "good" or "bad." Excesses as well as deficiency of any such function cause illness. Excess of thyroid function causes Basedow's disease, deficiency myxedema. Excess of conservativism produces living fossils which will not go on living for long, and excess of viability results in the appearance of monsters which are not viable at all.

Between the conservative representatives of the "establishment" on the one hand and rebelling youth on the other, there has arisen a certain enmity which makes it difficult for each of the antagonists to recognize the fact that the endeavours of both are equally indispensable for the survival of our culture. If and when this enmity escalates into actual hate, the antagonists cease to interact in the normal way and begin to treat each other as different, hostile cultures; in fact they begin to indulge in activities closely akin to tribal warfare. This represents a great danger to our culture, inasmuch as it may result in a complete disruption of its traditions.

NEWS AND COMMENT

Sahelian Drought: No Victory for Western Aid

The famine that struck the six Sahelian zone countries of West Africa last year is thought to have killed some 100,000 people and left 7 million others dependent on foreigners' food handouts. The same or worse may happen again this year. The essence of the tragedy is that the famine was caused not by dry weather or some putative climatic change but, primarily, by man himself. Could not Western skills, applied in time, have saved the primitive nomads and slash-and-burn farmers from destroying their own land? Western intervention in the Sahel, Western science and technology, and the best intentioned efforts of donor agencies and governments over the last several decades, have in fact made a principal contribution to the destruction.

"One of the basic factors in the situation is overpopulation, both human and bovine, brought about by the application of modern science," says a former Food and Agricultural Organization (FAO) sociologist. According to a recent in-house report on the Sahel prepared by the Agency for International Development (AID), "To a large extent the deterioration of the subsistence base is directly attributable to the fact that man's interventions in the delicately balanced ecological zones bordering desert areas have usually been narrowly conceived and poorly implemented." "Too many of our projects have been singularly unproductive and . . . we have tediously reintroduced projects which ought never to have been attempted in the first place," says Michael M. Horowitz, a State University of New York anthropologist who has studied the nomad peoples of Niger. And, to quote the AID report again, "It must be recognized that assistance agencies have ignored the principles [of effective resource management], and the consequence of indiscriminate support has produced negative results or, on occasion, disaster."

The symptoms of distress in the Sahel are easier to percieve than the underlying causes of the disaster. The six countries concerned—Senegal, Mauritania, Mali, Upper Volta, Niger, and Chad—are former French colonies that stretch along the southern edge of the Sahara desert. The land is mostly semidesert that enjoys only 4 months of rainfall a year. But the grasses are sufficient to support the herds of cattle tended by the nomads, and in the southern regions millet and sorghum are grown, together with cash crops such as peanuts and cotton. By 1970, just before the collapse, the fragile steppe and savannah ecology of the six countries was supporting some 24 million people and about the same number of animals. This burden amounted to roughly a third more people and twice as many animals as the land was carrying 40 years ago.

The agent of collapse was a drought

—the third of such severity this century—which began in 1968 and cannot yet be said to have ended. The grasslands started turning to desert, the rivers dwindled to a trickle, and by 1972, the fifth year of the drought, people, cattle, and crops began to die. "Our country is already half desert and our arable lands left are extremely reduced," the director of Chad's water and forestry resources told the FAO. By last year, Lake Chad had in places receded 15 miles from its former shorelines and split into three smaller lakes. The ancient cultural center of Timbuktu, a port fed by an inlet of the Niger river, was completely cut off and boats lay in the caked mud of its harbor. The nomads, forced to sell the surviving cattle that afforded their only means of subsistence, were reduced to the status of aimless refugees in camps around the major cities. Probably 5 million cattle perished, the staple grain crops produced low harvests, and nearly a third of the population faced a severe food shortage which, but for a massive infusion of relief supplies from the United States and other donors, would have ended in widespread famine.

Drought has clearly been the precipitating cause of the ecological breakdown in the Sahel, but attempts to blame the desiccation of the land wholly on the dry weather, or a supposed southward movement of the Sahara desert, do not quite hold water. A global weather change may indeed have squeezed the Sahel's usual rain belts southward, as climatologists such as H. H. Lamb argue, or, as others believe, the drought may be no more than an extreme expression of the Sahel's notoriously variable climate. The Sahara desert may indeed appear to be advancing downward into the Sahel—at the rate of 30 miles a year, according to a widely quoted estimate (which works out at 18 feet per hour). But the primary cause of the desertification is man, and the desert in the Sahel is not so much a natural expansion of the Sahara but is being formed *in situ* under the impact of human activity. "The desertification is man-caused, exacerbated by many years of lower rainfall," says Edward C. Fei, head of AID's Special Task Force on Sahelian Planning. According to the French hydrologist Marcel Roche, "The phenomenon of desertification, if it exists at all, is perhaps due to the process of human and animal occupation, certainly not to climatic changes."

Perhaps the most graphic proof of man's part in the desertification of the Sahel has come from a curiously shaped green pentagon discovered in a NASA satellite photograph by Norman H. MacLeod, an agronomist at American University, Washington. D.C. MacLeod found on a visit to the site of the pentagon that the difference between it and the surrounding desert was nothing more than a barbed-wire fence. Within was a 250,000-acre ranch, divided into five sectors with the cattle allowed to graze one sector a year. Although the ranch was started only 5 years ago, at the same time as the drought began, the simple protection afforded the land was enough to make the difference between pasture and desert.

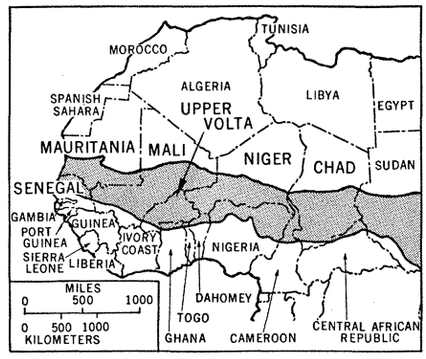

Fig. 1. Sahelian zone countries. (The Sahel also extends into Sudan and Ethiopia.) [Map by Eleanor Warner]

The physical destruction of the Sahel was not an overnight process. Its beginning can be traced to the French colonization of the late 19th century, when the Sahelian peoples lost with their political power the control over their range and wells which was vital to the proper management of their resources.

The Sahel—a term derived from the Arabic word for border—was once one of the most important areas of Africa. In the middle ages it was the home of the legendary trading empires of Ghana, Mali, and Songhai.

The key to the Sahelian way of life was a remarkably efficient adaptation to the semidesert environment. Although the nomads' life-style may seem enviably free to those who dwell in cities, there is nothing random about their migrations. The dry season finds them as far south as they can go without venturing within the range of the tsetse fly. Between the nomads and the sedentary farmers who also inhabit this area there is a symbiotic arrangement: The nomads' cattle graze the stubble of the crops and at the same time manure the fields. In exchange for manure the nomads receive millet from the farmers. With the first rains, the grass springs up and the herds move northward. The rains also move north and the cattle follow behind in search of new grass. According to Lloyd Clyburn of AID, "The migration continues as long as the grass ahead looks greener than that at hand, until the northern edge of the Sahelian rain belt is reached. When that grass is eaten off, the return to the south begins. This time the cattle are grazing a crop of grass that grew up behind them on their way north, and they are drinking standing water remaining from the rainy season." Back in their dry-season range the cattle find a crop of mature grass that will carry them for 8 or 9 months to the next growing season.

The traditional migration routes followed by the herds, and the amount of time a herd of given size might spend at a particular well, were governed by rules worked out by tribal chiefs. In this way overpasturage was avoided. The timing of the movement of animals was carefully calculated so as to provide feed and water with the least danger from disease and conflict with other tribal groups.

By virtue of what one writer has called "the essential ecological rationality of the nomadic pastoral regime," the herders made probably the best possible use of the land. The settled part of the population, the farmers, had an equally capable understanding of their environment. They knew to let the land lie fallow for long periods—up to 20 years—before recropping, and they developed an extraordinary number of varieties of their main staples, millet and sorghum, each adapted to different growing seasons and situations. Within the limits of their environment and technology, the peoples of the Sahel have, over the past centuries, demonstrated what University of London anthropologist Nicholas David calls "an impressive record of innovation . . . which is quite at variance with the common negative criticism of the African as unduly conservative." In fact, when the Sahelian peoples have been conservative and resisted changes advocated by Western experts, it has often been with reason.

It would be absurd to blame the collapse of this intricate social and ecological system solely on Western interference, and yet rather few Western interventions in the Sahel, when considered over the long term, have worked in the inhabitants' favor. Those

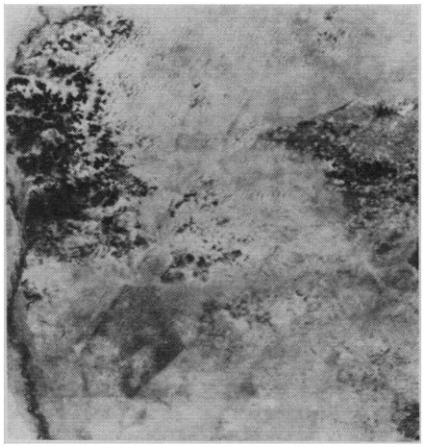

Fig. 2. Satellite picture shows patch of green (lower left) in Sahel. [NASA photo]

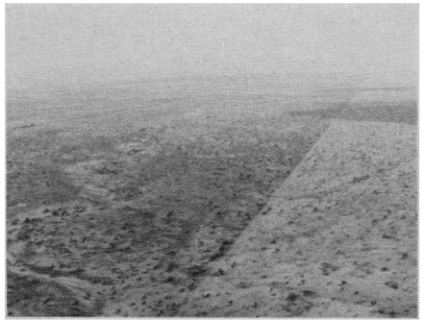

Fig. 3. The green patch is the Ekrafane ranch (left), bordered by desert (right). [Aerial photo by N. H. MacLeod]

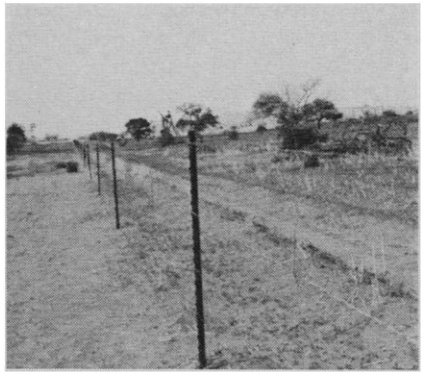

Fig. 4. Ground level: the desert is kept out by just a fence—and limited grazing inside. [Photo by N. H. MacLeod]

who have studied the farmers' and herders' traditional methods, says an FAO report on the Sahel, believe that the destructive practices that are now frequent are due to the cumulative effects of "over-population, deterioration of the climatic conditions and, above all, the impact of the Western economic and social system."

Western intervention has made itself felt in many ways, some inadvertent, some deliberate. Introduction of a cash economy had profound effects on the traditional system. The French colonial division of the Sahel into separate states has faced the nomad tribes with national governments which have tried to settle them, tax them, and reduce their freedom of movement by preventing passage across state boundaries. Curiously, however, it has been the West's deliberate attempts to do good that seem to have caused the most harm. The West in this case means the French, up until 1960, when the Sahelian countries were granted independence, and the French, Americans, and others thereafter. The French should probably not be held particularly to blame; they were only following conventional wisdom, and there is little reason to believe that other donor countries would have handled the situation very differently.

The salient impact is of course the increase in human and animal population that followed the application of Western medicine. The people of the Sahel are increasing at a rate of 2.5 percent a year, one of the highest rates of population increase in the world. If the nomads could have been persuaded to kill more of their cattle for market, the animal population might have been kept within bounds. Not foreseen was the fact that cattle are the nomads' only means of saving, and it in fact makes good sense—on an individual basis—for a nomad to keep as many cattle on the hoof as he can.

As a result herd numbers increased hand over fist in the decade following independence, aided by 7 years of unusually heavy rains. According to the FAO, the number of cattle grew from about 18 to 25 million between 1960 and 1971. The optimum number, according to the World Bank, is 15 million.

While the herders were overtaxing the pastures, the farmers were doing the same to the arable land. Population increase led to more and more people trying to farm the land. An even sharper pressure was the introduction by the French of cash crops to earn foreign exchange. With the best lands given up to the cultivation of cotton and peanuts, people had to bring the more marginal lands into use to grow their own food crops. In many cases these ecologically fragile zones could not take the strain of intensive agriculture. The usual process is that the fallow periods of 15 to 20 years are reduced to five or even one. Fertility declines, slowly at first, and then in a vicious spiral. Poor crops leave the soil exposed to sun and wind. The soil starts to lose its structure. The rain, when it falls, is not absorbed but runs off uselessly in gulleys. Desertification has begun. "Let us be under no illusion," President Leopold Sedar Senghor of Senegal told a symposium on the African drought held in London last year, "the process of desertification had been precipitated since the conquest of Senegal [by the French], since the introduction of growing peanuts without either fallow or crop rotation."

What cash crops have done for the Sahelian farmland, deep borehole wells have done for the pasture. A thousand feet or more beneath the Sahel lie vast reservoirs of water that can be tapped by deep wells. Thousands of these boreholes, costing up to $200,000 apiece, have been drilled across the Sahel by well-intentioned donors. The effect of the boreholes was simply to make pasture instead of water the limiting factor on cattle numbers, so that the inevitable population collapse, when it came, was all the more ferocious. "Few sights were more appalling at the height of the drought last summer," according to environmental writer Claire Sterling in a recent article in *The Atlantic*, "than the thousands upon thousands of dead and dying cows clustered around Sahelian boreholes. Indescribably emaciated, the dying would stagger away from the water with bloated bellies and struggle to fight free of the churned mud at the water's edge until they keeled over. . . . Enormous herds, converging upon the new boreholes from hundreds of miles away, so ravaged the surrounding land by trampling and overgrazing that each borehole quickly became the center of its own little desert forty or fifty miles square."

Overgrazing of the Sahelian pasturelands was a consequence of too many cattle having too little place to go. As the farmers spreading out from the towns took more land under cultivation, they tended to squeeze the nomads and their herds into a smaller strip of space. Moreover, the nomads' ability to manage their own resources was slowly slipping away. Government interference reduced their freedom of movement, and the boreholes threw into chaos the traditional system of pasture use based on agreements among tribal chieftains. With all the old safeguards in abeyance, the cattle numbers began to chew up the ecology across the whole face of the Sahel. First the perennial grasses went. These usually

grow up to 6 feet tall and put down roots as deep. If the plant is heavily grazed, its roots make a shallower penetration and, in dry periods, may fail to strike water. The perennial grasses are replaced by coarse annual grasses, but these, under heavy grazing and trampling, give way to leguminous plants that dry up quickly and cannot hold the soil together. Pulverized by the cattles' hooves, the earth is eroded by the wind, and the finer particles collect and are washed by rains to the bottom of slopes where they dry out into an impermeable cement.

Desertification has been hastened by the heavy cutting of trees for firewood. Trees recycle nutrients from deep in the soil and hold the soil together. Slash-and-burn techniques—the only practical method available to the poor farmer for clearing land—are the cause of numerous fires which, according to a World Bank estimate, kill off 50 percent of the range grass each year.

Under these abuses, the Sahel by the end of the 1960's was gripped by a massive land sickness which left it without the resilience to resist the drought. A whole vast area which might with appropriate management have become a breadbasket providing beef for half of Africa instead became a basket case needing more than $100 million worth of imported food just to survive.

The future prospects for the Sahel and its people are not very bright. Sahelian governments and the various donors have not reached any kind of agreement on long-term strategy for rehabilitation. Some donors—AID excepted—are still digging boreholes. Most of the development projects now under consideration were drawn up before the drought struck and are based on the unlikely assumption that when the rains return everything can go on as before. (A recent meeting of American climatologists concluded that planners should assume drought conditions in 2 years out of every 3.)

Much of the development money for the Sahel will have to come from the United States and France, but there seems to be little coordination or exchange of ideas between the two countries. Nor is there any general agreement on how the Sahel can be restored to self-sufficiency. Optimists, such as William W. Seifert of MIT, who heads a $1 million long-term development study for AID, believe that the Sahel could support its present human population provided that cattle numbers were reduced by a half or more. Unfortunately, there is no way, short of a major social upheaval, that the nomads will consent to reduce their herds. Projects involving controlled grazing, such as in the Ekrafane ranch, are impractical because there is not enough land to go around. AID plans to open up the lands to the south of the Sahel by clearing them of tsetse fly, but this would benefit only 10 percent of the population. Others are not so hopeful. "I don't think there is much optimism that significant improvements can be expected in the short term. All you can do is to try to increase their margin for survival and hope that something turns up," says an agricultural specialist conversant with both the AID and MIT development plans.

"Neither the leverage of modern science and technology," concludes an in-house AID report on the Sahel, "nor the talents and resources of large numbers of individuals and institutions currently being applied to relevant problems has occasioned more than minor progress in combatting the natural resource problems and exploiting the undeveloped potential." Which is another way of saying that Western ideas for developing the Sahel have not proved to be a spectacular success. Its ecological fragility and the vagaries of its climate make the Sahel a special case. But there are many other areas in the world where unchecked populations are overloading environments of limited resilience. The Sahel may have come to grief so soon only because mistakes made there show up quickly. Other Western development strategies, such as the Green Revolution, are, one may hope, more soundly based in ecological and social realities. If not, the message of the Sahel is that the penalty for error is the same Malthusian check which it is the purpose of development to avoid, except that the crash is from a greater height.

—NICHOLAS WADE

U.S.—Soviet Summit: Make Science, Not War

It was a summit of modest expectations, and it more or less lived down to its prior billing. Six days of meetings between President Nixon and Soviet leaders produced an aura of restrained diplomatic camaraderie and several small, though not trivial, movements in relatively noncritical areas of arms control that added up to the minimum progress U.S. officials had hoped to achieve.

There were also small elaborations of science and technology agreements signed in the two previous summits in 1972 and 1973. Along with a bundle of similar but less specific accords reached by the President on his June swing through the Middle East, these agreements seemed to reaffirm what has evolved as an unwritten tenet of Nixonian summitry: Science and technology are the handiest instruments of détente.

Following is a summary of arms control and research agreements reached from 27 June to 3 July, and earlier in June in the Middle East.

Threshold Nuclear Test Treaty. As expected, the two sides agreed to limit the size of nuclear weapons tests underground, but the limitation agreed upon was significantly less restrictive than anticipated (*Science*, 17 May). The treaty, subject to ratification by the Senate, would ban weapons tests larger than 150 kilotons and would take effect on 31 March 1976. In the meantime, the two sides would agree to hold the number of weapons tests to an unspecified "minimum."

Testing in the atmosphere, in space, and undersea is already prohibited by the 1963 Limited Test Ban Treaty.

The agreement marks an important precedent: Under a separate protocol, the United States and the Soviet Union will exchange detailed geophysical information about their respective nuclear test sites and about the explosive yield, date, time, and depth of two nuclear "calibration" shots in the test