Fostering Ecological and Human Health

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For the first time in world history the human species is drastically altering the face of the earth and the composition of its atmosphere. Global air and water pollution, accumulation of toxic wastes, destruction of forests, and depletion of the stratospheric ozone layer threaten the health and survival of humans and thousands of other species. Creating healthy conditions for a human population in the future will require a paradigm shift in the relationship of humans to the environment. Reducing population growth in many developing countries, preserving productive ecosystems, conserving resources and preventing pollution and wastes are essential for human health and survival. Physicians must understand the relationship of the environment to human health and be able to relate the practice of medicine to environmentally induced disease. Moreover, physicians must advise policymakers and the public on methods to reduce the risk of environmental hazards and work with other sectors of society for concerted action to protect the environment. The education and training of environmentally literate physicians is essential and will be one of the important challenges for medicine in the decades ahead. [PSRQ 1991;2:77–85]

For the first time in human history the human species is drastically altering the face of the earth and the composition of its atmosphere. These environmental changes threaten the integrity of the earth, its biodiversity, the security of nations, and the health and survival of human beings. The nature and rate of environmental transformation present important challenges for physicians, whose role it is to care for the health of human beings.

The challenges reflect three ideas. First, the physical environment is one of the most important determinants of human health. Second, protection of the environment and preservation of ecosystems are, in public health terms, the most fundamental forms of primary prevention of human illness. And, third,

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physicians should be the health practitioners most knowledgeable about the environmental factors that create health and cause disease, and should be prominent spokespersons in communicating with the public and policymakers about environmental hazards and intervention strategies to prevent disease

THE PHYSICAL ENVIRONMENT AND HUMAN HEALTH

We have known for quite some time that a healthy environment is essential to human existence and health. Humans can live for about 4 minutes without air, 4 days without water, and 4 weeks without food. Plants, animals, and the habitats they occupy provide the food that sustains human life. Moreover, we have known for centuries that contamination of the environment with heavy metals, microorganisms, physical agents, and certain organic compounds can cause serious illness and death. For example, lead poisoning from lead water pipes and wine goblets was a serious health problem among the ruling class of the Roman Empire, possibly contributing to its demise.

Respiratory and intestinal infectious diseases, the major causes of death in the Western world at the turn of the twentieth century, have been virtually eliminated by improved public health practices oriented largely toward environmental conditions. Improved water, food, and milk sanitation; reduction in physical crowding; improved nutrition; and central heating using cleaner fuels were the intervention strategies most responsible for these improvements in public health. These advantages occurred well before the introduction of antibiotics, vaccines, and other medical interventions.

The nature and scope of environmental health problems in the last 20–30 years have changed dramatically. Severe pollution and sanitation problems similar to those in Europe and the U.S. at the turn of the century are widespread and increasing in developing countries, eastern Europe, and the U.S.S.R.

In Shanghai, China, a city of 12 million people, 95% of the sewage is discharged untreated into the Hangpu River, the city's main source of drinking water. Even more distressing, the intake for the water supply is just downstream of the sewage discharge points. In Beijing, inhabitants are experiencing severe air pollution episodes and chronic respiratory disease is endemic. These conditions are degenerating because annual air pollution levels are routinely 5–8 times higher than U.S. health standards. The worst problem is created from the release of excessive amounts of sulfur dioxide and particulate matter—largely from one million homes burning coal for cooking and heating. (Personal communication with Wang Hanshen, Director, Air Pollution Control, National Environmental Protection Agency, People's Republic of China, January 1988.) For most of the year, Mexico City's 20 million inhabitants breathe tropospheric (ground-level) ozone levels more than 50% above World Health Organization (WHO) guidelines [1]. One hundred three cities in the Soviet Union have air quality levels 10 times higher than Soviet air quality standards [2]. Eight of 10 deaths in Lithuania are blamed on pollution [3]. Lettuce and apples grown in southwestern Poland contain 10 times as much lead as WHO guidelines allow for human ingestion. Life expectancy has been dropping every year for a decade in Krakow while lung and breast cancer rates climb; and chronic bronchitis is endemic among children [3,4]. Three quarters of Poland's rivers and 80% of eastern Germany's rivers are too contaminated to use as drinking water. Air pollution levels in some eastern German cities are 50 times WHO guidelines and 6 million people are at risk from environmentally induced disease [3]. These patterns are repeated in many developing countries around the world.

In addition, today's environmental and health concerns include problems that are international and global in scope and cause long-term and often irreversible effects [5]. Over half the population of the U.S. lives in areas where tropospheric ozone (the principal component of smog), which aggravates respiratory illness and causes long-term lung damage, persists at levels harmful to health at various times of the year [6]. Six hundred million people live in cities where sulphur dioxide levels exceed WHO air quality guidelines [7]. Acid rain is causing, separately or in combination, forest, aquatic, health, and material damage on every continent of the world. Depletion of the beneficial stratospheric ozone layer (12–25 miles above the earth's surface), which protects us from the harmful ultraviolet rays of sunlight, and climate changes due to human-made emission of greenhouse gases into the atmo-

sphere are global in scope, affecting virtually every human being, as well as entire ecosystems. These environmental problems are not amenable to quick technological fixes and are more insidious and difficult to solve because their effects often occur many years in the future and are highly uncertain.

Population Growth and Settlement Patterns

For the first time in human history, the cumulative effects of increases in world population and even more rapid industrial growth with attendant pollution and resource depletion are causing global changes on a scale previously only accorded to Mother Nature. We are changing the basic physiology of the planet—the chemical composition of the atmosphere and the cycling of carbon, nitrogen, and phosphorus, the basic elements of life, through the biogeosphere [5]. Tropical forest destruction, soil erosion, withdrawal of water from the hydrologic cycle, and toxic pollution are causing ecological changes that threaten the quality of life and human survival. Destruction of our planet's natural capacity to be a support system will be one of the most important international issues to be faced by society and, specifically, by the public health community in the twenty-first century.

Trends in population and industrialization illustrate some of the roots of these environmental problems and should serve as warnings for the future. For most of the last 10,000 years, the majority of the world's population has lived in small settlements and rural areas. Moreover, world population grew very slowly until the eighteenth century when the exponential nature of the population growth became evident. By 1830, the world's population reached 1 billion; by 1950, the population grew to 2.5 billion. In just 38 years the world's population doubled once more to reach 5 billion in 1988. The World Commission on Environment and Development predicts that the world's population will stabilize at between 8 and 12 billion in the next 40 years [8]. Unfortunately, there seems to be very little understanding of the concept of environmental carrying capacity, the maximum population size that can be supported by the resources of the planet's ecosystems.

Not only is there unprecedented population growth, but the demographics and the patterns of settlement are changing rapidly. At the end of World War II, 40% of the world's population lived in industrialized countries; by the end of this century that figure will be only 20%. Moreover, 90% of the predicted population growth by 2030 will occur in cities in developing countries. This is a radical change in settlement patterns. In 1940, 1 in 100 people in the world lived in cities with a population of more than 1 million. In 1980, this number had increased to 1 in 10; by the year 2020, it will be 1 of every 2 people [9]. For the first time in history, more people will live in urban than in rural areas.

The rural poor will increasingly migrate and be transformed into an urban poor, and environmental health problems will multiply. The urban poor in developing countries are, and will continue to be, subject to intense physical crowding, poor or no sanitation, and high levels of air and water pollution similar to the conditions in industrialized countries at the turn of the century. Moreover, unlike the Western world during its modernization, developing countries will also have to cope with larger quantities of toxic substances and wastes, and the effects of global environmental change.

Effects of Industrialization

Industrialization is proceeding much faster than population growth, and is an even more crucial determinant of environmental transformation and pollution. In the past 100 years, world industrial production increased 100 times [5]. From 1950 to 1985, manufacturing output increased by a factor of 7, electricity output by a factor of 8, the number of automobiles increased by a factor of 7 (from 50 million to 350 million) and synthetic chemicals by several orders of magnitude [10]. The impact on the global environment has been dramatic. In 150 years human activity has increased the atmospheric concentration of carbon dioxide by 25% and doubled the concentration of methane, two potent greenhouse gases. Human-made emissions of sulfur and nitrogen, which lead to acid deposition, now equal or exceed the natural flux of these elements. Human-made emissions of lead, cadmium, and zinc exceed the natural flux 18 times [5].

The Dominant Paradigms

One might ask, "What fundamental belief structures have led to this environmental transformation?" First, we have an anthropocentric view of the world; that is, that humans are the most important of all biological species and should have dominion over nature. Moreover, we believe that any harm

we do can be reversed with ingenuity and technology—we believe we can repair, reclaim, replace, remediate all problems. In the U.S., we will spend $300 billion in the next 30 years to "clean-up" hazardous, chemical, and radioactive waste sites that contaminate groundwater, land, and air, but it is unlikely that we will ever restore the environment to its unpolluted condition.

Second, we believe that our individual and collective impact will result in only imperceptible changes in the environment. Most of us refuse to believe that it is our personal driving of cars or our personal consumption of energy and other resources that is causing environmental damage. Moreover, we have an infinite capacity to believe that apocalyptic events will not really happen, or if they do, that we, as individuals, will not be affected. Witness cigarette smokers who claim to know someone who has smoked four packs of cigarettes per day for 40 years and lived to be 90. Denial is widespread.

Third, we treat our natural resources as free and inexhaustible. There seems to be very little understanding of the concept of environmental limits and the limits of our natural resources. The frontier mentality, especially in the U.S. and the U.S.S.R. with their vast amounts of natural resources, has led to a rapid depletion of these resources. Tropical rain forests, which contain over 50% of the world's biological species, are being cut down at a rate of an acre and a half per second. Every year the world loses an area of rain forest about the size of Austria. Nearly 1.5 billion people are cutting down forests for fuelwood and agriculture at a nonrenewable rate. At the current rate the world will lose 20% of the estimated number of biological species by the year 2000 [10]. No human generation has ever witnessed a mass extinction of biological species on this scale. Since only 90 species of plants are responsible for 25% of all the pharmaceutical drugs in use today, this loss of biological diversity will be very important for future human survival [11].

Much of the depletion of natural resources is irreversible: each year the world loses 24 billion tons of topsoil and millions of acres of grassland because of deforestation, plowing of highly erodible land and marginal land, and overgrazing. Topsoil is critical for agricultural production and can only be regenerated over geological time horizons. We are also overpumping water tables and causing salinization of irrigated land. In the meantime, grain yields per hectare have not changed since 1984 while the world's population grew by 500 million people [10]. Ironically, we are spending ecological capital as income and are running up a far greater natural debt than the financial national debts about which many countries are concerned.

Fourth, we believe that the environment has a nearly infinite capacity to assimilate any environmental discharges or wastes and can adapt to any adverse resulting changes. This belief has led to pollution control strategies such as tall stacks to disperse local sulfur dioxide emissions. This strategy is sometimes referred to as "the solution to pollution is dilution." Unfortunately, tall stacks allow the discharge of sulfur oxides and nitrogen oxides from fossil fuel burning to travel high into the atmosphere and allow long distance transport of pollutants. They then become transformed into acidic substances that adversely affect plants, fish, humans, and materials over large geographic areas such as the northeastern U.S. and eastern Canada. The emission of carbon dioxide from fossil fuels and the burning of forests; the production of methane from anaerobic digestion in cattle and sheep and from anaerobic bacteria associated with rice paddies; nitrous oxides from fertilizers and fuel combustion; and the use of chlorofluorocarbons in aerosols, refrigeration, air conditioning, and foam production are trapping heat in the atmosphere at an unprecedented rate. They are predicted to cause a 1.5°–4.5°C increase in the average world temperature by the year 2050 [12]. This is highly significant since the average temperature difference between glacial and nonglacial periods is about 5°C. These temperature changes are predicted to have sweeping adverse effects such as a sea level rise, which will inundate several heavily populated coastal areas of the world; shifting agricultural production areas (including a major loss in U.S. productivity); and the loss of forests and coastal wetlands, which are essential for fisheries.

Finally, we have concentrated on single, quick, technological fixes to solve environmental problems. These are often impractical, do not work in the long run, and do not deal with the root cause of the problem. When the smog problem was discovered in Los Angeles, one of the first ideas to emerge was to build large fans in the San Bernadino Mountains to blow the polluted air out to sea. We substituted chlorofluorocarbons (CFCs) for sulfur dioxide and ammonia in refrigeration equipment because CFCs

are inert, stable, and nontoxic. Unfortunately, their very nature allows them to drift up to the upper atmosphere and remain there for decades. In the stratosphere they destroy the ozone layer, which protects us from harmful ultraviolet sunlight rays. The U.S. Environmental Protection Agency estimates that the increased ultraviolet-B reaching the earth because of the thinning of the stratospheric ozone layer will lead to 3–15 million new cases of skin cancer, an additional 31,000–126,000 cases of melanoma, and an additional 7,000–30,000 fatalities among U.S. whites before 2075 [13,14].

The principal solution for over half the total air pollution emitted in the U.S. has been to control automobile pollution with emission control devices on individual cars. Today's vehicles emit over 95% fewer hydrocarbons and carbon monoxide and 75% fewer nitrous oxides than 1970 automobiles. Yet we have a lingering ground level ozone problem across the U.S. The reason is that the amount of automobile travel (vehicle miles of travel) has increased by about 140% between 1960 and 1985 [15], and continues to grow 2%–3% per year, while the number of cars on the road and vehicle mix continues to increase. When patients with a medical problem visit a physician they want a prescription drug or a simple medical procedure to solve the problem and are usually not interested in changing their lifestyle or eating habits. In the same way, very little serious thought has been given to alternative means of transportation (e.g., mass transit) or to developing less polluting energy sources as possible solutions to urban air pollution problems.

Meeting future needs and desires while utilizing strategies that employ the present belief structures cannot be sustained. By the time population growth stabilizes in the next century, a 5- to 7-fold increase in consumption of energy and goods will be needed just to raise the consumption level in the developing world to that in the industrialized world [8].

TOWARD AN ENVIRONMENTALLY SUSTAINABLE AND HEALTHY FUTURE

Given these trends and fundamental beliefs, how can we help create health and minimize disease and illness throughout the world? A first step is to change the relationship of humans to the environment by preventing further environmental transformation, pollution, and degradation as we strive to meet human needs and desires. This will require four major social policy shifts.

Stabilize Population Growth

First, we must stabilize population at levels which will allow the human needs of all members of society to be met in a continuing, sustainable manner. This will require reducing population growth rates in developing countries to achieve the United Nations goal for fertility rates of 2.7 children per woman by years 2000–2005 and 1.9 by years 2020–2025. This goal is ambitious but clearly possible. Cuba, China, and the Republic of Korea have achieved these goals in half this time span and fertility rates for all developing countries have dropped from 6.0 in 1960–1965 to 3.9 today. These achievements were made possible by increasing the education and social status of women, family planning assistance, and access to contraceptives, which has reached an estimated prevalence level of 50% in 1990. To achieve these goals, international population and family planning assistance must be doubled by 2000 to about nine billion dollars annually as recommended by the United Nations sponsored International Forum on Population in the Twenty-first Century, which met in Amsterdam in 1989 [16].

Clean Technology and Resource Conservation

Second, we must change our philosophy from controlling pollution once it is created, or repairing the damage, or both, to preventing the pollution in the first place. Economic development and industrial strategies that reduce the consumption of resources, the use of toxic substances, and the production of wastes are essential to prevent further environmental degradation and to protect human health, and are less expensive in the long run. Changing products and industrial processes; substituting less toxic materials and less polluting fuels; increasing energy and water efficiency; conserving natural resources; and recycling and reuse of "waste" products will be essential to protecting health and improving the quality of life in the decades ahead. For example, some art material manufacturers are now substituting water-based paints for more toxic oil-based paints reducing exposure of artists, teachers, and children to toxic solvents. Ultrasonic cleaning devices are being substituted for organic solvents harmful to workers in some electronic component

manufacturing. Substituting natural gas for coal is one of the best strategies for reducing acid rain and the greenhouse gases. Finding alternatives to CFCs is the only effective strategy that will protect the stratospheric ozone layer. Strategies to reduce the use of pesticides and fertilizers, such as integrated pest management and organic farming, are essential to reduce direct health risks to agricultural workers and consumers from pesticides and to protect groundwater from contamination. Such waste reduction and pollution prevention strategies are proved and cost-effective. Conservation spurred by the high cost of oil kept energy consumption level from 1973 to 1985 in the U.S., while the gross national product grew 40%. The U.S. economy therefore saved 160 billion dollars in annual energy costs while continuing enormous growth [17]. The 3M Company cut the amount of pollution and waste generated from its manufacturing operations from 1975 to 1985 by 50%. Its "Pollution Prevention Pays" program is credited with saving the company 350 million dollars per year during that time [18].

Acting Like a Global Family

A third policy thrust must be in the relationship of the developed countries to the developing countries. Industrialized countries will have to develop new strategies for transfer of technology, for training and education, and to provide financial assistance to developing countries. These strategies must deal with stabilizing population, the international debt problem, and promoting economic development strategies that minimize the destruction and depletion of natural resources and the generation of pollution and wastes, while improving the quality of life. Such strategies must emphasize long-term growth that is sustainable for future as well as current generations. Called "sustainable development" by the World Commission on Environment and Development, such strategies are now being hotly debated in international circles while many entrepreneurial projects are being tried. Examples are debt-for-nature swaps and the planting of trees in Guatemala to offset the carbon dioxide emissions from a new power plant being built in Connecticut.

Environmental Literacy

The fourth policy thrust is the development of short- and long-term educational strategies that will change the mindset of individuals and institutions to protect the environment and health as they carry out their personal and professional lives. Future leaders of the twenty-first century must understand that humans are part of the natural environment, virtually every human activity affects the health and welfare of the planet, and that the air, water, land, plant, and animal life provide the basic support for human existence.

Physicians, engineers, business people, scientists, economists, architects, veterinarians, diplomats, and all other professional disciplines must understand population and environmental issues and their relationship to health and the quality of life and must have individual and collective responsibility for stewardship of the world's resources. At Tufts University we call this educational concept *environmental literacy*. Shifting our way of thinking will require incorporation of these concepts into the curriculum and educational experience of all disciplines at the undergraduate and professional education levels. This educational approach is built on the premise that such fundamental shifts in awareness and understanding will come only with broad, continuing, and repetitive exposure throughout the educational experience. The integration of these concepts through a broad array of courses and experiences, with an emphasis on expansion of curriculum in existing courses, is the best method of achieving the goal of environmental literacy.

PRACTICING MEDICINE ON A SMALL PLANET

Physician Education

Practicing medicine in a world that is linked ecologically and is subject to extreme pressures from population and industrialization will require some reorientation and expansion of physician education. Currently, most physician education and training is designed around the medical model of "finding and fixing" a health problem. We must reorient our thinking to creating health, not just curing disease. Dr. William Hendee of the American Medical Association believes this will require a shift from the bioengineering model to the ecological model of medicine [19]. Human beings owe their existence to the natural environment and cannot be completely isolated from infectious and toxic agents transmitted

through the environment. All physicians (especially primary care physicians) should understand the relationship of environment to health. They should be able to detect, diagnose, and treat environmentally related disease, know how to obtain information about environmental hazards, advise patients on intervention strategies to reduce exposure to environmental hazards, and also be able to refer patients to environmental and occupational medicine specialists. This will require basic training in epidemiology and biostatistics, biological, chemical, and radiation toxicology, human activities that cause environmental hazards, pathways of human exposure to environmental agents, strategies for elimination and reduction of exposure to environmental agents, treatment of environmentally induced diseases, and nutrition. Physicians should also have basic understanding of how natural ecosystems function and provide resources essential for life, human activities that stress natural resources, ecological principles such as the ability of an ecosystem to support human populations on a sustainable basis, and strategies for managing population growth.

Unfortunately, such medical training is rare and there is an acute shortage of occupational and environmental medicine specialists. According to a survey by Dr. Barry Levy in 1985, two-thirds of the U.S. medical schools require occupational health training. However, the median time is 4 hours in 4 years and there is no training on the effects of exposure to environmental hazards in the outdoor environment, in the home, or during recreation [20]. In addition, there is no ecologically based training.

In August 1989, the Committee on Enhancing the Practice of Occupational and Environmental Medicine of the Institute of Medicine (IOM) sponsored a workshop on the shortage of environmental and occupational medicine physicians. The workshop focused on ways to increase the number of specialists in environmental and occupational medicine. The U.S. has about 1,000 occupational medicine specialists and needs about 6,000 by the mid-1990s. Only 20 medical schools have clinical occupational medicine training, and there are only 37 full-time occupational medicine faculty in the U.S. There is a lack of funding for education, research, and residency training.

IOM is working on a strategy to alleviate these shortages and to provide support for the incorporation of environmental issues into physician education. This is extremely important since physicians are the eyes and ears of the health care system and are often the first to recognize disease patterns. For example, the excess rate of leukemia in children living in Woburn, Massachusetts during the 1970s was brought to public light by Dr. John Truman of Massachusetts General Hospital in Boston and by citizens of Woburn. Public health concerns have been the major driving force behind most societal programs to prevent environmental pollution. Moreover, physicians are well respected health professionals who are authoritative sources of information on a variety of health-related matters for both the public and policymakers in government and industry. Unfortunately, physicians do not have the training or information to play this role in a large way. A recent survey of 3,100 people by the Georgetown University Medical School found that physicians are the most respected informants on environmental health hazards. However, only one person in five obtained environmental health information from physicians, and physicians were the last professionals to be contacted for such information after industry, environmental groups, and state and federal government [21].

Given the pressures on medical school curriculum, reorienting and expanding the training of physicians will require some creative strategies. An effective strategy, which does not threaten the current educational programs, is to integrate environmental perspectives and issues into the regular medical curriculum as examples, contexts, and problems. This will, however, require strategies that involve nonmedical specialists to develop the capability of medical school faculty to teach about environmental and population issues.

At Tufts University, we have begun some of this integration through problem-based learning. We are hiring a full-time environmental medicine physician to develop an environmental health program at the medical school, which we intend will encompass training of all physicians in environmental health issues. This is part of a larger university-wide faculty development strategy to incorporate environmental literacy in all the schools and disciplines of the university throughout the Tufts Environmental Literacy Institute. Our long term plan is to offer this program to faculty from other universities and medical schools.

Finally, it is time for physicians and other public health specialists to forge new relationships with environmental and family-planning specialists and advocates in order to promote the health and well-being of the population. With the birth of the modern environmental movement in the late 1960s, public health and environmental specialists separated professionally as new departments of environmental protection were created, often out of units of public health departments.

Public health interests and environmental interests have often been perceived to be at odds, as public health specialists attempted to protect workers and the general public from toxic pollutants; and many environmental specialists have focused on the protection of land, nature, and wildlife. It is important for these professionals to reconnect and mutually support each other because basic protection of our ecosystems is essential to the protection of public health. As history illustrates, we have been somewhat receptive to this way of thinking in past times, for example, canaries were used in coal mines to alert miners of unsafe pollution levels. Today we know that DDT can cause reproductive problems in falcons at far lower concentrations than we would ever have predicted to cause damage in humans.

Examples abound of connections between the two ways of thinking. People with good nutrition, for example, are much less susceptible to a variety of diseases: vitamin E increases resistance to the pulmonary effects of exposure to ground level ozone. And good nutrition is largely dependent on preserving the ecosystems that supply food. The harmful effects of ultraviolet radiation due to depletion of the stratospheric ozone layer, which can cause skin cancer, cataracts, and depression of the immune system in humans, may also cause damage to highly vulnerable oceanic phytoplankton, which represent the beginning of the food chain for all aquatic animal life [14]. Coastal pollution affects the viability and the safety of food from fisheries. When pesticides and fertilizer contaminate fields and underground water supplies, the food and water from these sources become a health threat to those who consume them. Tropical forests are key to providing the biological resources for the life-saving drugs necessary for modern medicine. For example, the rosy periwinkle, Catharanthus roseus, found in Madagascar, yields vinblastine and vincristine, two alkaloids that are effective against Hodgkins disease and acute lymphocytic leukemia [11]. Cooperation between environmental and public health interests is also a politically smart strategy since the more constituencies that can be brought to bear on societal policies the more likely changes are to occur.

Physicians must think of themselves not only as specialists concerned about the direct effects of environmental problems on human health, but as advocates for the ecological health of our planet. This professional responsibility is based on the public health model of medicine, which has developed robustly since the mid-nineteenth century, and has helped secure many of the major advances in the health status of populations in the industrialized world [22]. Physicians and other members of the public health community must develop a better understanding of how the earth's ecosystems support both human existence and good health, and take actions that will stabilize human population levels, prevent illness of current and future human generations, and sustain the viability of all biological species. ❧

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