GUEST EDITORIAL by Ernst L. Wynder, *M.D.* [1] *and* Gio B. Gori, *Ph.D.* [2]

Contribution of the Environment to Cancer Incidence: An Epidemiologic Exercise

Most cancers today appear to be induced by elements originating in man's environment rather than as a result of purely genetic or viral factors. While mechanistic interpretations generated by classic observations on cancer etiology vary, they agree on the extent of environmental influence on the development of certain forms of cancer. During the past two decades epidemiologic studies have elaborated on this concept and suggest that cancer may not be an inevitable consequence of aging.

Doll (*1*) and Higginson (*2*) have argued that the lowest reported cancer rates represent "baseline" or "natural" rates. Generally any increases from these baseline data can be attributed to environmental influences. Based on comparisons of high- and low-incidence ratios in different regions, Higginson (*2*) concluded that 90% of human cancer incidences can be ascribed to environmental factors. Boyland (*3*) claims that this same percentage is due to chemical components and attributes the remaining 10% of cancer incidence to genetic, viral, and radiation factors. We have defined environmental elements influencing cancer incidence as those originating wholly or largely outside the host's body. These include carcinogens, cocarcinogens, promoters, procarcinogens, and other modifying agents. In many instances, an insufficient amount of hard data exists to make definitive statements concerning cancer incidence and causative factors. Therefore, we have attempted to estimate the extent that cancer incidence and mortality may be related to certain suspect causative factors. Hopefully, such an analysis will stimulate further meaningful studies that will permit formulation of more definitive statements on cancer causation.

To determine more precisely the influence of individual causative factors, the evidence related to specific environmental elements has been examined. Differences between population groups, sex ratios, time trends, and demographic and socioeconomic variables have been investigated. We have assumed that environmental factors do not affect all population groups equally. Although no group is untouched by environmental influences, in general the populations with the lowest rates would have the least contact with specific causative factors. Therefore, examination of the extremes of cancer rate differences by site constitutes a plausible basis for inferences on environmental causes.

BASIS FOR ESTIMATES

Intercountry and Intracountry Comparisons

Mortality and incidence rates for major cancer types show significant differences among countries (*4–6*). The distribution of extremely high and low death rates has been calculated. The percent difference between rates for U.S. whites and low-risk countries and the differences between the high- and low-risk countries are presented in tables 1 through 4. These differences represent the percentage of cancers in excess of a baseline or natural rate.

The worldwide distribution of mortality rates for males (table 1) illustrates the environmental influences on all cancer sites. The ratio between high- and low-risk rates is greater than 2.0 for all forms of cancer. Except for leukemia, the same is true for female mortality ratios. The proportion of incidence rates for both men and women related to environmental elements is indicated in tables 3 and 4. Data have been standardized by age, and the observed variations cannot be explained by this variable. Obviously, it is necessary to consider differences in the quality of vital statistics relative to the reportability of the various cancers, the accuracy of population estimates, and the accuracy of disease diagnoses. In some of the less developed countries, for example, it is likely that mortality and incidence data are underestimated; however, data from select cancer registries that may be regarded as more accurate also indicate comparable large differences between high- and low-risk populations. For example, the United States and Japan have high standards for recording vital statistics, and the large variation in incidence rates is apparent between these countries (tables 5, 6).

The effect of environmental factors on the incidence of cancer can also be evaluated by the comparison of rates within a given country. Perhaps the most striking example is the percent excess of skin cancer rates. This disease is related directly to the intensity and length of exposure to sunlight. A similar, though less distinctive, excess difference has been found in the incidence of melanoma between the northern and southern regions of the United States (*8*). This relationship between incidence of melanoma and exposure to sunlight has been demonstrated in Israel as well (*9*).

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Editor's note: Periodically, the Journal publishes solicited guest editorials as a means of transmitting to investigators in cancer research the essence of current work in a special field of study. The Board of Editors welcomes suggestions for future editorials that succinctly summarize current work toward a clearly defined hypothesis regarding the causes or cure of cancer.

TABLE 1.—*Age-adjusted male mortality ratios for high- and low-risk populations and for U.S. whites by cancer site, 1966–67*[a]

Cancer risk	Low-risk country	U.S. white[b]	High-risk country[c]	
Trachea, bronchus, lung	Portugal	3.6	7.1	Scotland
Stomach	United States (for whites)	—	7.8	Japan
Prostate	Japan	6.9	12.4	United States (for non-whites)
Intestine except rectum	Japan	3.9	4.3	Scotland
Esophagus	Norway	1.3	5.9	France
Larynx	Sweden	3.8	19.8	France
Rectum	Chile	2.4	4.8	Denmark
Buccal cavity, pharynx	Israel	3.1	7.2	France
Pancreas	Italy	1.9	2.3	United States (for non-whites)
Bladder	Japan	2.1	3.3	S. Africa
Skin	Japan	3.4	5.5	Australia
Liver, biliary passage	Norway	1.6	5.3	Japan
Thyroid	New Zealand	1.4	5.5	Switzerland
Leukemia	Japan	2.0	2.1	Denmark

[a] *See* (*5*).
[b] U.S. mortality rate/low-sk country mortality rate.
[c] High-risk country mortality rate/low-risk country mortality rate.

TABLE 2.—*Age-adjusted female mortality ratios for high- and low-risk populations and for U.S. whites by cancer site, 1966–70*[a]

Cancer risk	Low-risk country	U.S. white[b]	High-risk country[b]	
Stomach	United States (for whites)	—	7.8	Japan
Breast	Japan	5.5	6.6	Netherlands
Uterus (all parts)	Israel	1.9	4.7	United States (for non-whites)
Intestine, except rectum	Japan	3.7	4.3	Scotland
Trachea, bronchus, lung	Portugal	2.4	4.2	Scotland
Rectum	Chile	1.6	3.3	Denmark
Pancreas	Italy	1.9	2.4	United States (for non-whites)
Esophagus	Austria	1.0	6.9	Chile
Bladder	Japan	1.5	2.4	United States (for non-whites)
Skin	Japan	2.5	4.2	Australia
Buccal cavity, pharynx	Federal Republic of Germany	2.4	3.8	N. Ireland
Larynx	Norway	4.4	16.8	Ireland
Liver, biliary passage	New Zealand, Federal Republic of Germany	1.6	4.1	Federal Republic of Germany
Ovary, fallopian tube, broad ligament	Japan	3.9	5.9	Denmark
Thyroid	Australia	1.1	4.0	Austria
Leukemia	Japan	1.6	1.9	Israel

[a] *See* (*5*).
[b] *See* footnotes *b* and *c*, table 1.

A survey by Hoover et al. (*10*) showed differences in rates for various types of cancer among counties within the United States. The cancer rates were higher in certain industrial counties than in nonindustrial centers, especially for bladder and lung cancer. However, standardization of data by smoking habits for some cancers is necessary before etiologic factors can be determined.

Intracountry differences for stomach cancer usually involve higher incidence rates in northern regions than in southern regions. In Yugoslavia, for example, gastric cancer is far more common in the north than in the south (*11*), and similar, though not as extreme, differences exist in the United States (*10*). Reasons for these geographic differences remain unclear but appear related to dietary practices.

Population groups such as Seventh Day Adventists and Mormons provide well-documented evidence of the influence of environmental factors, notably diet and smoking habits, on cancer incidence (*12, 13*). Racial and ethnic differences within a country also provide insights into probable environmental influence on cancer risk. For instance, Jews have a low rate of cancer of the upper alimentary tract, related to their low intake of alcohol. Cervical cancer among this ethnic group is one-tenth that of the general population (*14, 15*). In France, the incidence rate of esophageal cancer is significantly higher in Brittany than in other provinces; this is consistent with data on the intake of alcoholic beverages peculiar to this area. Racial differences are illustrated in the significantly greater incidence of prostate and cervi-

TABLE 3.—*Age-adjusted incidence ratios for high- and low-risk populations and for U.S. whites by cancer site: Males*[a]

Cancer site	Low-risk country	U.S. white[b]	High-risk country[b]	
Lung, bronchus, trachea	Nigeria	4.7	72.1	United Kingdom
Stomach	Nigeria	9.5	79.4	Japan
Prostate	Israel	12.8	14.0	United States (Hawaii)
Colon	Rhodesia	50.0	60.0	Canada
Bladder	New Zealand	19.7	21.4	United States (Hawaii)
Rectum	Rhodesia	136.0	136.0	Canada
Esophagus	Israel	36.0	361.0	Rhodesia
Pancreas	Nigeria	6.6	14.7	New Zealand
Kidney	Nigeria	7.8	9.4	Sweden
Larynx	S. Africa	16.7	34.5	India
Nasopharynx	S. Africa	7.0	104.0	United States (Hawaii)
Skin, melanoma	Japan	42.0	62.0	New Zealand
Small intestine	Rhodesia	10.0	11.0	Canada
Liver	Poland	23.0	475.0	Rhodesia
Thyroid	S. Africa	20.0	57.0	United States (Hawaii)
Leukemia	Rhodesia	5.2	7.0	United States (Hawaii)
Lip	S. Africa	141.0	286.0	Canada
Tongue	United States (Hawaii)	26.0	140.0	India
Pharynx	Canada	20.0	160.0	India

[a] *See* (*6*) and (*7*), adjusted to standard world population.
[b] *See* footnotes *b* and *c*, table 1.

TABLE 4.—*Age-adjusted incidence ratios for high- and low-risk populations and for U.S. whites by cancer site: Females*[a]

Cancer site	Low-risk country	U.S. white[b]	High-risk country[b]	
Breast	Israel	7.9	7.9	United States (for whites)
Stomach	United States (Hawaii)	3.3	30.4	Japan
Cervix	Israel	5.1	29.6	Rhodesia
Colon	Rhodesia	44.0	55.0	United States (Hawaii)
Lung, bronchus, trachea	Nigeria	12.1	37.7	New Zealand
Uterus	Japan	13.7	18.3	United States (Hawaii)
Rectum	Rhodesia	83.0	136.0	Canada
Bladder	United States (Hawaii)	44.0	569.0	Rhodesia
Skin, melanoma	United States (Hawaii)	40.0	91.0	New Zealand
Kidney	Nigeria	33.0	60.0	Sweden
Pancreas	Nigeria	6.1	15.3	United States (Hawaii)
Esophagus	Israel	11.0	361.0	Rhodesia
Nasopharynx	Colombia (Cali)	2.0	46.0	United States (Hawaii)
Larynx	S. Africa	8.0	28.0	India
Small intestine	Canada	6.0	11.0	Canada
Liver	India	11.0	342.0	Rhodesia
Ovary	Japan	6.4	8.7	United States (Hawaii)
Thyroid	Hungary	7.1	29.5	United States (Hawaii)
Leukemia	S. Africa	9.0	84.8	Rhodesia
Lip	Japan	2.0	19.0	S. Africa
Tongue	Rhodesia	9.0	30.0	S. Africa
Pharynx	Hungary	5.0	44.0	India

[a] *See* (*6*) and (*7*), adjusted to standard world population.
[b] *See* footnotes *b* and *c*, table 1.

TABLE 5.—*Age-adjusted incidence per 100,000 population of selected cancer sites for males in the United States (Connecticut) and Japan (Miyagi)*[a]

Site	United States	Japan	Incidence ratio[b]
Bronchus, trachea	44.0	15.6	2.8
Prostate	33.0	3.2	10.3
Colon	26.7	4.1	6.5
Bladder	19.9	4.7	4.2
Rectum	16.3	4.8	3.4
Stomach	14.7	95.3	0.1
Pancreas	8.1	6.7	1.2
Kidney	7.6	1.8	4.2
Larynx	7.5	2.4	3.1
Esophagus	5.7	14.5	0.3
Mouth	4.0	1.1	3.6

[a] Adjusted to world population. Data from (*6*).
[b] Represents U.S. incidence/Japan incidence.

cal cancer observed in blacks as compared to whites in the United States (*8*).

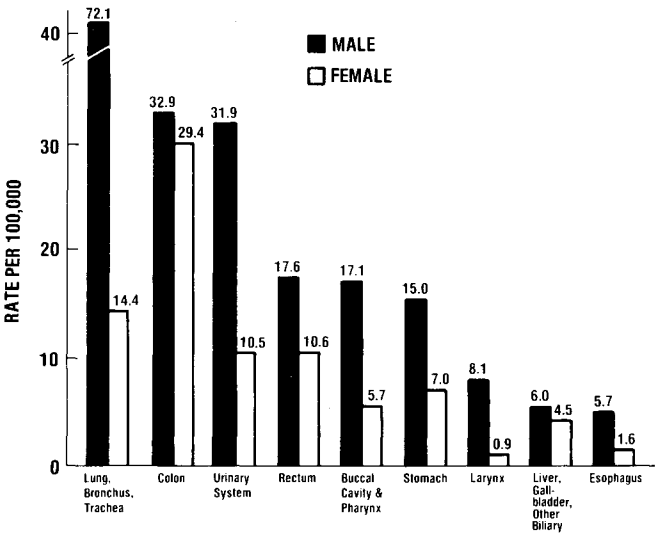
Sex Differences

The effect of environmental factors is also indicated by the different rates for males and females of certain primarily "non-sex-linked" types of cancer (i.e., those not likely to be dependent on specific sex hormones). As expected, these differences are largest among the to-

TABLE 6.—*Age-adjusted incidence per 100,000 population of selected cancer sites in females in the United States (Connecticut) and Japan (Miyagi)*[a]

Site	United States	Japan	Incidence ratio[b]
Breast	62.3	11.0	5.6
Colon	26.7	4.0	6.6
Corpus uteri	15.3	1.3	11.7
Ovary	11.3	1.9	5.9
Rectum	10.7	5.0	2.1
Bronchus, trachea	7.8	6.0	1.3
Stomach	6.8	44.7	0.1
Bladder	5.9	1.6	3.6
Pancreas	4.3	3.8	1.1
Kidney	3.5	0.7	5.0
Esophagus	1.4	4.9	0.2
Mouth	1.4	0.6	2.3
Larynx	0.8	0.3	2.6

[a] Adjusted to world population. Data from (*6*).
[b] Represents U.S. incidence/Japan incidence.

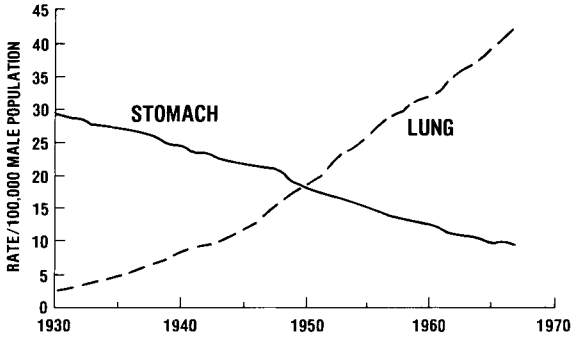


TEXT-FIGURE 1.—Average annual age-adjusted (1970 standard) incidence rates per 100,000 population, by primary site and sex for non-sex-linked cancer sites, in the United States for 1969–71 (*7*).

bacco-related cancers (text-fig. 1). Some of the observed differences are decreasing, and this trend is expected to continue as women are exposed increasingly to the work, social, and recreational environment of men. For example, three decades ago there was approximately 90% difference in lung cancer rates between males and females. This difference diminished considerably as more women began smoking cigarettes. Thus, as environmental exposure for women increases, similar incidence rates of non-sex-linked cancers can be expected for males and females.

Time Trends

Another useful approach in determining the role of environmental factors in carcinogenesis is the investigation of the change in cancer rates within a specified period of time. Lung and stomach cancer death rates for U.S. men serve as prime examples (text-fig. 2). Since 1930 there has been a steep and steady increase in lung



TEXT-FIGURE 2.—Male cancer death rates in the United States from 1930 to 1967 (age-adjusted by site).

cancer; this is consistent with increased cigarette smoking in the general population during this period. The sharp decrease in stomach cancer, however, suggests a decrease in some environmental element or the introduction of a dietary protective factor(s).

Case-Control Studies

Retrospective and prospective epidemiologic studies can contribute not only to an understanding of the incidence of cancer in the presence of a given etiologic factor but also to an increased knowledge of the etiology of such cancer. Such studies depend on reliable reporting and registration of data.

When specific etiologic agents are suspected and can be readily identified (e.g., tobacco, alcohol, and industrial materials), case-control studies are of value in estimating death rates in the presence of such agents and in determining their etiologic role.

Retrospective and prospective studies implicating tobacco smoking in the etiology of lung cancer support available vital statistics. Data from these studies indicate that risk for this cancer and cancers of the oral cavity and larynx are low (1–4/100,000) in the absence of smoking (*16–19*). In addition, about 30–50% of the mortality in males from cancer of the esophagus, kidney, bladder, and pancreas has been shown to be related to tobacco usage, especially in the form of cigarettes (*16–23*). The lower rate for these cancers in females is consistent with the patterns of tobacco usage among women.

SELECT ENVIRONMENTAL FACTORS

Tobacco Use

Epidemiologic evidence for the contribution of tobacco usage to development of cancer is overwhelming (*16–23*).

Prospective studies have determined specific rates of lung cancer in smoking and nonsmoking populations (*16*). These studies have shown that the more definitive the diagnosis of lung cancer (especially in terms of squamous or oat cell cancer), the lower the rate of lung cancer in nonsmokers. Hammond (*16*) showed a rate of 3.4/100,000 for nonsmoking males with histologically proven squamous or oat cell lung cancer. Doll and Hill (*17*) showed a death rate among nonsmoking British male physicians of only 0.7/100,000. Prospective studies of the occurrence of histologically established lung cancer in nonsmoking populations is the best way to determine baseline rates of lung cancer among nonsmokers.

Increases in cancer of the lung have been steady since the 1930's, when the mortality rate in the United States was reported to be less than 4/100,000 (text-fig. 2). This correlates with a steady increase in cigarette smoking during this same period. The increases are more evident for males than females, which is consistent with the fact that less smoking is engaged in by women than by men of comparable age.

Lung cancer rates of populations such as the Seventh Day Adventists, who are nearly all nonsmokers, are more than 80% lower than the rates of the U.S. population in general (*24*).

A reduction of risk has also been noted among long-term filter cigarette smokers as compared to nonfilter cigarette smokers (*16*). In addition, smoking cessation has led to a gradual reduction in the rate of lung cancer to the level of a nonsmoker.

Nutrition

An extensive amount of data relating nutrition to cancer was recently presented in (*22*). This relationship is complex and sometimes perplexing to those who view carcinogenesis principally in terms of a "specific carcinogen." We believe that specific carcinogens play a minimal role in the relationship between nutrition and the development of cancer: Rather, nutritional deficiencies and/or excesses are of great importance as sources of procarcinogens and modifying factors.

The evidence linking diet to cancer is obtained by the comparison of nutritional habits and specific cancer incidence rates among different countries or population groups. Comparisons among countries indicate that "overnutrition" is an etiologic factor for certain types of cancer. Such indications are supported by studies which indicate that cancer patterns of migrant populations tend to change and approach the level prevalent in the host country (*23, 24*). Change in risk patterns for gastric cancer has been linked to diets high in carbohydrates and/or nitrate and low in fat and/or fruit and vegetables. In general, the role of nutrition in cancer etiology is strongly supported by the many epidemiologic studies conducted (*25–41*). Present knowledge provides provoking clues implicating such dietary factors as fat and meat intake, excess caloric intake, and nutritional habits that affect the hormonal and metabolic balances. Additional studies are necessary to elucidate the precise role of specific dietary components.

Dietary elements and nonincorporated contaminants are most likely the responsible factors in cancer rates. This view is supported by data from migrant studies (*23, 25*) and from intracountry studies of population groups living in the same environment (*8, 12–15*). Other data have linked a decline in gastric cancer incidence to an improved dietary experience (*24*).

Several examples suggesting diet rather than contaminants as a causative factor are readily brought to mind. For example, air pollution conditions between the United States and Japan are similar; however, the diets are different and, as illustrated in tables 5 and 6, the cancer incidence rates for diet-related sites are dissimi-

lar. The diets of population groups such as Seventh Day Adventist, Jewish, and black populations vary greatly from those of the general U.S. population and these differences are reflected in their cancer rates (*8, 12, 14, 15*). It has been noted that, as countries improve their dietary experience, gastric cancer rates decline (*27*). Smokers inhale excessive amounts of tobacco-type carcinogens, but their risk of diet-related cancers is not significantly different from that of nonsmokers; this suggests that air contaminants are not causative factors for these particular cancers. There are no epidemiologic data that identify food additives or contaminants such as DDT[3] as etiologic factors (*42, 43*). Long-term studies by Armstrong and Doll (*44, 45*) have shown that the rate of bladder cancer in diabetic patients is not higher than rates for the general population.

Air and Water Pollution

Considerable attention has been paid to air pollution as a causative factor in a variety of cancers, such as those of the lung, stomach, and prostate (*46–48*). Studies have concentrated on the effects of pollution through exposure via direct inhalation of polluted air and ingestion of matter deposited on various vegetables and fruits. However, variables such as cigarette smoking and socioeconomic factors tend to complicate an analysis of air pollution and cancer risk.

Fraumeni's study (*49*), which encompassed 44 states, indicated no differences in lung cancer rates when data were standardized for cigarette smoking. Similarly, Buell and Dunn (*46*) found no differences when different levels of air pollution were studied in California. However, the more recent study of Pike et al. (*48*) has linked polycyclic hydrocarbons in air to lung cancer risks.

Hammond's review (*50*) emphasizes the difficulty of accurately measuring the amount and degree of air pollutant exposure encountered by an individual. Hammond has analyzed the American Cancer Society's prospective data on males living 10 years or more in their present area. No significant difference was found in mortality from lung cancer in relation to either residence or size of residential environment. Furthermore, when occupational exposures were excluded and data standardized by age and tobacco consumption, general urban pollution elements were not found to be etiologic factors in lung cancer risks. These data support the earlier work of Doll and Hill (*51*). Further investigation is needed to understand the complex epidemiologic issues involved in air pollution and cancer.

A recent study of the drinking water in New Orleans suggests that chlorinated hydrocarbons could present a potential carcinogenic hazard for man (*52*). Future studies are needed to determine hazardous dose levels of water contaminants.

Occupational Exposure

There is no question that certain occupational exposures increase risk for particular cancers. Specific agents are listed in table 7. Some of these agents, particularly asbestos and uranium dust, exhibit synergistic effects with cigarette smoke, thus increasing a smoker's risk of lung cancer. Both uranium dust and asbestos exposure can lead to cancer incidences in the absence of smoking. Other agents in table 7 are also independently carcinogenic.

Generally, the data reported on occupation-related cancers do not permit annual incidence estimates, since the cases reported usually represent a sample accumulated over several years, rather than those for a specific year. Data on polyvinyl chloride lend themselves more readily to estimates because a rare tumor is involved. Thus far a direct association between exposure to polyvinyl chloride and death from angiosarcoma of the liver has been reported in 38 cases (*53, 54*). The effect of *bis*-chloromethyl ether has been determined on the basis of number and duration of workers exposed, the number of lung cancers reported, and the increase in risk for this cancer among exposed workers compared to the

TABLE 7.—*Occupations conveying an increased risk of developing cancer*[a]

Site	Agents	Occupations
Liver	Arsenic Vinyl chloride	Tanners; smelters; vintners; plastic workers
Nasal cavity, sinuses	Chromium Isopropyl oil Nickel Wood and leather dusts	Glass, pottery, and linoleum workers; battery makers; nickel smelters, mixers, and roasters; electrolysis workers; wood, leather, and shoe workers
Lung	Arsenic Asbestos Chromium Coal products Dusts Iron oxide Mustard gas Nickel Petroleum Ionizing radiation *Bis*-chloromethyl ether	Vintners; miners; asbestos users; textile users; insulation workers; tanners; smelters; glass and pottery workers; coal tar and pitch workers; electrolysis workers; retortmen; radiologists; radium dial painters; chemical workers
Bladder	Coal products Aromatic amines	Asphalt, coal tar, and pitch workers; gas stokers; still cleaners; dyestuff users; rubber workers; textile dyers; paint manufacturers; leather and shoe workers
Bone	Ionizing radiation	Radium dial painters
Bone marrow	Benzene Ionizing radiation	Benzene, explosives, and rubber cement workers; distillers; dye users; painters, radiologists; radium dial painters
Skin	Arsenic Sun	Insecticide makers and sprayers; oil refiners; vintners; smelters; farmers

[a] *See* King H: Cancer risk and life style, presented at the meeting of the American Association for the Advancement of Science, Boston, Massachusetts, in February 1976.

[3] DDT = 1,1,1-trichloro-2,2-bis(*p*-chlorophenyl)ethane.

general population (*55*). Although the increase in risk is considerable, the total number of excess cases is small because of the relatively small number of workers involved.

The data presently available are, at best, educated estimates of the relationship between specific cancers and specific occupational groups. Cole et al. (*56*) suggested that 20% of bladder cancers occurring in males in the Boston area are related to occupational exposure. In certain counties of New Jersey, the increased risk for this cancer appeared to be high among workers in certain chemical industries. Bailar (personal communication) estimated that the occupational contribution to total cancer incidence in males lies between 1 and 5%, and a similar estimate was made by Nelson (personal communication). General estimates of the percentage of all human cancers related to occupational exposure range between 1 and 10%. However, identification of specific high-risk groups, hazardous exposure levels, and related cancer incidence rates is yet to be determined.

Drugs

Various drugs have been linked to cancer risk (*57*), but there are insufficient data to determine the precise relationship involved. It seems clear that the risk of reticulum cell sarcoma is relatively high in patients receiving immunosuppressive drugs, although the total number of cases thus far reported is small (*58*). The early data on reserpine have recently been disputed in terms of the alleged influence of this drug on breast cancer (*59–61*). Premarin appears to increase the risk of cancer of the endometrium, but again the number of cases is in question (*62, 63*). Because of the widespread use of the hormone and reported increases in the rate of this relatively common tumor, careful attention is warranted. With the exception of inducing benign liver tumors (*64, 65*), the use of oral contraceptives is not linked to increased cancer incidence (*66*). Definitive conclusions in this regard, however, should be postponed until the long-term effect can be analyzed.

EPIDEMIOLOGIC CONSIDERATIONS

Mortality and incidence rates in certain low-risk countries may not reflect the true rate for the area. In some of the developing countries, there may be an underreporting of cases because of a lack of sufficient facilities, a lack of standardized definitions of diagnoses, and cultural mores which prohibit attention to specific diseases or parts of the body. Also, migratory populations may not typically reflect the population from which they originated. Although such inaccuracies may exist, particularly in mortality statistics, the consistency with which certain types of cancers appear to be "missing" in particular settings, in conjunction with the verified failure to find suspected carcinogenic stimuli in these areas, gives credence to the reported low rates. These low rates, however, do not preclude the exposure of some individuals to carcinogenic factors, although at lower rates than individuals in high-risk and high-rate countries.

International comparisons of morbidity and mortality rates indicate that most cancers are related to man's lifestyle, including excessive smoking, alcohol consumption, "overnutrition," and industrial exposures. This lifestyle is a relatively recent occurrence and parallels the development of industrial societies. Such phenomena were unknown in more primitive societies and hardly known to animals at all. Although this latter point is often ignored, it is important to recognize that most of the cancers common in man are exceedingly rare in feral animals.

CONCLUDING REMARKS

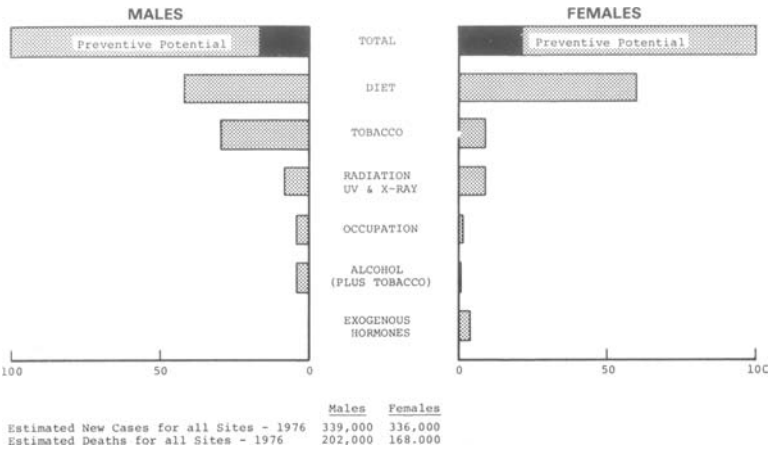
Environmental carcinogens, either established or suspected, may be categorized as being related either to personal lifestyle (tobacco, alcohol, sunlight, occupational exposure, and nutritional imbalances) or to general environmental factors (air and water pollution, drugs, and food additives as contaminants). Some are derived through individual choices; others are imposed by society.

Individuals tend to ignore their own responsibilities and blame harmful occurrences, including carcinogenic exposure, on outside forces. Therefore the general environmental elements receive the most attention rather than factors resulting from personal lifestyles. Individuals cannot deal with some of these issues by themselves; thus public action is required and should be provided. To the extent that industry can reduce carcinogens, cocarcinogens, or procarcinogens (e.g., in the area of tobacco, alcohol, and nutrition) and to the extent that government can control the production or use of products containing such agents (including those of industrial origin), preventive measures should be introduced to protect the individual and society at large.

Personal lifestyle, however, also plays an important role in environmental carcinogenesis. Thus public education campaigns and other services must be provided to help people modify habits that are detrimental to health. Then research and public health efforts must follow to reduce man-made and preventable cancers.

The estimates shown in text-figure 3 represent the relative effects of environmental factors on cancer incidence. We estimated the total percent of site-specific cancer attributable to all environmental factors (depicted as "Preventive Potential") by calculating the percent difference between U.S. mortality rates and the lowest reported worldwide mortality rates for each site and by considering specific case–control studies. Our estimates with regard to such variables as radiation, exogenous hormones, and occupation are based on data in the literature that reflect the increased risk involved with a given exposure and the total number of people exposed.

We hope that text-figure 3 will stimulate research to indicate that a reduction of certain causative variables would indeed result in a decrease in specific cancer incidences. To accomplish this, there must be closer collaboration among epidemiologists throughout the world. With better disease case histories, it should be possible to explain further the vast differences in cancer



TEXT-FIGURE 3.—Percent of cancer incidence in the United States attributable to specific environmental factors.

incidence among countries.

In conclusion, our estimates of the role of environmental factors in cancer incidence concur with earlier data of Doll (*1*), Higginson (*2*), and Boyland (*3*). These estimates are supported by epidemiologic evidence including intercountry and intracountry differences, incidence differences between men and women, and time trends. The data presented here support the basic assumption that cancer is a disease produced by environmental factors. Where disputes may arise, however, is in the relative importance of the general environmental factors versus the personal lifestyle contributions to cancer incidence rates.

This presentation should stimulate investigations of the etiologic aspects of specific environmental factors in total cancer incidence and in the incidence of particular types of cancers. Although it is mandatory that attempts are made to remove every factor in the environment demonstrated to increase the risk of cancer, from both a budgetary and public health point of view, it is equally important that sufficient attention is applied to those elements involved in most cancers. With the increasing number of news reports regarding hazardous components, the average citizen considers himself immersed in an uncontrollable sea of carcinogens. Although society must and can play an important role in the reduction of those environmental factors that contribute to cancer incidence, we have shown that an individual can significantly limit his own risk by appropriately altering his lifestyle.

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