A Healthy Life on a Healthy Planet

A Healthy Life on a Healthy Planet:

What We, as Individuals, Can Do to Make It Happen

By

Danielle Méthot

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TABLE OF CONTENTS

LIST OF TABLES

CHAPTER ONE

OUR HEALTH

What is our health status?

The media are broadcasting that we are polluting our environment, our planet is going through a climate change, animals and plants species are disappearing, and – worst of all – the rate of certain types of cancer is increasing. Should we worry? Is it really true? And do we know the reasons why this is happening?

To answer these questions, we must look closely at the available data and then determine whether we should be concerned.

My first concern, and this is also probably true for most of us, is my health. We want to live long lives without cancer. So, what is the situation today? If we look at the statistics from the U.S. National Cancer Institute, we find that there are four major cancers which constitute 50% of all existing cancers. Those cancers are lung, breast, colorectal and prostate cancers. Since the 1990s, these cancers have been slowly decreasing. In fact, the incidence rate of these cancers is lower today than it was 10 years ago.

That, however, is not the complete picture. The incidence rate for the four major cancers increased from 1975 to the 1990s. Then in the early 1990s, the cancer rate started to decrease. It reached a maximum peak in 1985 for colorectal cancer, in 1992 for lung, bronchus and prostate cancer, and in 1999 for breast cancer; however, except for colorectal cancer, the cancer rate is higher today than it was in 1975. Today, there are more cancer cases per 100,000 persons than in 1975.

Undoubtedly, we should be concerned when looking at Table 1-1. It is true that the number of these cancers is lower than in the 1990s; however, it is still higher than in 1975. In addition, other types of cancer, such as brain, liver, kidney, esophagus, thyroid, testicular, non-Hodgkin lymphoma (cancer of the immune system) and melanoma skin cancer have steadily augmented since 1975. From 1975 to 2014, for example, the incidence rate for males has increased by 146% for thyroid cancer, by 226% for liver cancer, by 103% for kidney cancer, and worst of all, by 273% for melanoma skin cancer.

Table 1-1: Incidence of Cancer Rate (Cases per 100,000 persons)

	1975	2014	Peak cancer rate	Increase since 1975 (%)
Lung and bronchus	52	52	69[a]	0
Colorectal	59	38	66[b]	-36
Breast	105	130	141[c]	24
Prostate	94	99	237[a]	6

(a) in 1992; (b) in 1985; (c) in 1999
Source: U.S. National Cancer Institute (www. cancer.gov)

The most alarming and most troublesome fact, however, is that the rate of cancer among children under 20 years of age has increased by 40% from 1975 to 2014. Leukemia, brain and central nervous system are the cancers that have increased the most and are accounting for more than half of children's cancers.

What are the causes of this increase in cancer rates? This is a difficult question since the human body is a complex machine and is part of a complex environment, thus making it very difficult to understand the interactions between the two of them.

The prerequisites to determine without a doubt the cause of cancer would be to fully understand the workings of a human cell, which is not possible today, or to test the suspected cancerous substance on a human being, which is not an option due to ethical reasons. These restrictions leave the scientist with indirect investigative methods: one is to experiment on the suspected factors on animals or human cells in a laboratory, and another is to conduct population studies, which consist of observing a group of individuals in the population who are in contact with the suspected cancerous substances. These two options have their limitations, and they will be covered in more detail in Chapter Two. In any case, these two options require years of investigation, and in the end scientists may find a factor that is linked to cancer; however, since human beings are in contact with several factors simultaneously, it is difficult to isolate a specific one without the shadow of a doubt. In the end, scientists may associate a factor with cancer due to its constant presence when a person develops a cancer. In fact, based on the repeatability, quality and quantity of data, the scientific community will rely on its judgment to determine a factor as being a cause of cancer.

The certitude of a factor being the cause of a cancer will thus only be possible once the scientific community fully understands the human body and its interaction with the environment, which, by the way, may be hundreds of years away; consequently, the scientific community never appears certain. They use words such as “probable cause”, “possible cause”, “increased chance”, “associated with”, “health hazard”, “significant factor”, “reasonably anticipated”, or “weight of evidence” to describe the possibility that a factor is a cause of cancer, which makes it very difficult to convince a government, an industry or a population to accept the results of a study and change their behavior.

The best example is the story of smoking and lung cancer. It all started in 1913 when cigarettes were first mass produced. In 1939, a German scientist named Franz H. Müller noticed an increase of lung cancer in autopsies of adult males between 1918 and 1937, which prompted him to conduct a population-based study which established a link between lung cancer and smoking. Subsequently, in the 1940s and 1950s, the U.S.’s and other countries’ scientific communities also conducted population-based studies and reached the same conclusion: that lung cancer was linked to smoking.

Based on the overwhelming accumulation of evidence from studies, the American Cancer Society and the American Heart Society in the 1950s declared that smoking was an important health hazard, particularly with respect to lung cancer and cardiovascular disease. This seems not to have been sufficient for government and public awareness, so in 1962 the surgeon general, Luther L. Terry, proposed the creation of a committee of experts to review the studies. The results were released to the U.S. public in 1964 in a press conference. The report “Smoking and Health: report of the advisory committee to the surgeon general of the public health service” stated that cigarette smoking was causally related to lung cancer.[1] It also declared that cigarette smoking causes emphysema, chronic bronchitis and larynx cancer and may be a cause of cardiovascular disease, and these health issues were linked to cigarette smoke. This became a turning point in increasing the awareness of the damage to health caused by cigarette smoking and its consequences on the health of the general public. The government reacted by passing a law in 1965 that forced cigarette companies to print a health warning on the cigarette packs; this was followed in 1970 by a ban on cigarette advertising on television and radio. It took 21 years (1918 to 1939) before scientists noticed a link between cigarette smoking and cancer, another 24 years (1940 to 1964) before the general public became aware of the damaging effects on their health, and another 30 years (1965 to 1995) for cigarette smokers to drop below 25% of the U.S. population, down from 42.4% in 1965.[2] Despite the decrease in cigarette smokers, cigarette smoke is still responsible for approximately one in five deaths in the United States.[3]

Up to now, 70 years after the first population-based study, it is still not well understood which substance or substances in the smoke and its mechanism causes lung cancer in the human body. At any rate, what we need to remember is that identifying the causes of cancer is not a precise science, and if there is enough information available to pinpoint a possible factor chances are that it is a cause of cancer and we should as individuals take the studies seriously. In Table 1-2, I list a summary from the American Cancer Society's web site of some possible risk factors of the most common cancers. This list will evolve with time as new study results become available.

Table 1-2: List of the Risk Factors of the Four Most Common Cancers

Cancer Type	Risk Factors
Lung	Tobacco smoke; air pollution; radon gas; asbestos fibers; inhaled chemicals or minerals, such as arsenic; beryllium; cadmium; vinyl chloride; nickel compounds; chromium compounds; coal products; mustard gas; chloromethyl ethers; and diesel exhaust; smokers who have taken beta carotene supplements; contact with radioactive ores or radiation therapy to the chest; and previous lung cancer.
Breast	Being a woman; being white; being older than 55 years of age; genetic mutations; close blood relatives who had cancer (sister, mother, father or brother); previous breast cancer; more menstrual cycles than average (i.e. began menstruation before 12 years of age or had menopause after 55 years of age); radiation therapy to the chest area; dense breast tissues; having taken or mother having taken DES (diethylstilbestrol); being childless or having had children late in life (after 30 years of age); using birth control pills; using postmenopausal hormone therapy (PHT) for a long period; drinking alcohol; being overweight or obese; not exercising.
Colorectal	Being older than 50 years of age; having a personal history of inflammatory bowel disease and adenomatous polyps, or colorectal cancer; having close blood relatives who had colorectal cancer; genetic mutations; a diet high in red meats and processed meats; eating meat cooked at very high temperatures (frying, broiling, or grilling); being overweight or obese; smoking; heavy use of alcohol; having type 2 diabetes; being of African American or Eastern European Jewish descent (Ashkenazi Jews); not exercising.
Prostate	Being older than 50 years of age; genetic mutations; having close blood relatives who had cancer (brother or father); a diet high in red meat or high-fat dairy products; being an African-American man.

Source: American Cancer Society (www.cancer.org)

Now back to our question: Why is the cancer rate for the majority of cancers higher today than in 1975? First, we must ask ourselves: what is cancer? The medical community defines cancer as a gradual change of cellular functions which allows the cells to grow excessively and invade other tissues in the body. What is important to remember is that cell dysfunction does not appear suddenly; once in contact with the risk factors, it can take 10 to 40 years for the human body to develop a cancer. With this information in mind, we need to also determine the events that permitted a regression of the rate of the four major cancers between 1985 and 1999. Granted, the rate of cancer is still higher today than in 1975; however, something occurred that allowed a slowdown of its pace.

It all started on July 26, 1943 when smog in Los Angeles was so dense that its population was unable to see more than three blocks away and experienced unbearable eye and throat irritation. Later on, in December 1952, a fog in London, which lasted five days, caused 4,000 deaths. These two events triggered public awareness of the harmful effect of air pollution and led to the passing in 1963 of the Clean Air Act. The Act established emission standards for stationary sources (any building that emits air pollutants, such as power plants and steel mills), and it also opened the door for possible intervention by the federal government. Then, in 1965, the U.S. government regulated the emissions for automobiles, and in 1970 an agency called the Environmental Protection Agency (EPA) was created. Its mission: to develop and enforce regulations to protect the general public from exposure to airborne contaminants, the ones known to be hazardous to human health. In addition, the Clean Air Act Extension of 1970 established national levels for ambient air quality called National Ambient Air Quality Standards for six specific pollutants: hydrocarbons (HC), total suspended particulate (TSP), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO) and photochemical oxidants. Subsequently, the list of six pollutants was modified: in 1976 lead (Pb) was added; in 1979 the ozone (O_3) replaced photochemical oxidants; in 1983 HC was removed and TSP was changed to PM_{10}; and, finally, in 1997 $PM_{2.5}$ was added. The six pollutants are now, therefore, the following: SO_2, NO_2, CO, Pb, particulate matter (PM_{10} and $PM_{2.5}$) and O_3.[4]

The National Ambient Air Quality Standards are the maximum allowable concentration levels of the six pollutants in the ambient air, while the emission standards are the maximum rate levels of a variety of pollutants from mobile and stationary sources that are emitted in the air. These levels are set in order to protect human health and are based on the latest medical studies and on the latest available technology. Because our knowledge increases every day, the levels are updated regularly and may be different for each type of mobile and stationary sources.

Presently, the six common air pollutants from the National Ambient Air Quality Standards are monitored in several locations, and their concentration has decreased by at least 30% between 1980 and 2015.[5] As a result of the Clean Air Act, there was a major improvement of air quality in the U.S. for the six measured pollutants.[6]

The Clean Air Act was one of the factors that improved air quality. Another one was that the public became aware of the health hazard of cigarette smoking. Slowly, cigarette smoking was banned in public places and in the workplace (in 1973, Arizona was the first state to designate separate smoking areas in public places), resulting in a smoke-free environment for 81% of the workers in 2013 compared to 46.5% in 1992, which means a substantial reduction of second-hand smoke exposure for non-smokers.[7] The reduction of smoke exposure is supported by the fact that the proportion of non-smokers with cotinine (smoke derivative) in their blood was reduced by more than half since 1988.

In summary, three major actions took place to improve air quality since the 1970s: The federal government passed the Clean Air Act, which improved air quality; a large proportion of the population stopped smoking; and an increased number of public places and workplaces became smoke-free. These three actions could explain the decrease of the rate of the four major cancers between 1985 and 1999. Let us imagine that these actions had not occurred. The lung cancer rate would have probably continued to increase and today there would be approximately 96 new cases per 100,000 people instead of 52. This is good, but it is still at the same incidence level of cancer in 1975, which was at 52 per 100,000 people. It is true that we may not have reaped the full benefit of the improvements in air quality yet, since the change in cancer rate always lags behind, but it remains that the number of cancers-all the body sites are still 8% higher than in 1975 – and remember that some types of cancers have been increasing steadily since 1975.

The air quality does not only depend on six common pollutants (CO, NO_2, PM, SO_2, Pb, O_3). These pollutants have accounted for a large portion of the emitted pollutants, and each individually is still emitted in considerable amounts – 82 million tons for carbon monoxide in 2015;

however, other pollutants that are emitted in smaller quantities may be as harmful to human health. In effect, the Clean Air Act identifies some of them.

The Clean Air Act identifies 188 pollutants called hazardous air pollutants or air toxics that are highly suspected to be harmful to human health. To name a few: perchloroethylene (from dry cleaning), mercury (from coal combustion), methylene chloride (from consumer products such as paint strippers) and benzene (from gasoline). There are, as yet, no fixed maximum ambient concentration levels, and there are approximately 70 monitoring stations in the U.S. that are measuring 177 of the 188 hazardous pollutants, compared to 2310 monitoring stations for the six major pollutants. The main reasons for this are that it is expensive to measure 188 pollutants and that a simple test to measure each of them may not be readily available.

While some hazardous air pollutants come from natural sources such as volcanic eruptions and forest fires, interestingly, most of the hazardous air pollutants originate from human-made sources such as transportation, power plants using combustion, cleaning solvent and pesticides. In fact, one of the major sources of hazardous air pollutants comes from combustion. In Chapters Four, Five and Six, I will describe in more detail the impact of combustion on our health.

Numerous chemical substances classified as Volatile Organic Compounds (VOCs) are part of the hazardous air pollutants list from the Clean Air Act. VOCs do not have a definition that is agreed on worldwide; therefore, for the purposes of this book, I will refer to VOCs as "any volatile compound of carbon, excluding carbon monoxide, carbon dioxide, methane, carbonic acid, metallic carbides or carbonates, and ammonium carbonate". As implied in the name, the VOCs are organic, meaning that they are composed of carbon. Some well-known VOCs are formaldehyde, benzene, naphthalene, acrolein and toluene.

On average, a typical household will have up to 300 VOCs floating in the air, regardless of whether they are living in an industrial or rural area. These chemical substances are very much part of our lives and are found in all aspects of life. To name a few: in our homes, our household products such as air fresheners, cleaning products and aerosol sprays; at our workplaces, permanent markers, correction fluids, and office equipment such as copiers and printers; in our gardens, wood preservatives and pesticides; in our garages, stored fuels, paints and lacquers, paint strippers, glues and adhesives. The troublesome fact is that the concentration levels of VOCs are consistently found to be higher indoors (up to two to five times higher) than outdoors.

Because there are hundreds of VOCs concurrently in the same area, it makes it difficult to conduct scientific population studies that will determine the health effect of each of them on the human body. In addition, their toxicity on the human body may differ depending on the substance and its interactions with other VOCs or pollutants in the ambient air. By itself it may be benign for human health; however, combined with another chemical substance it may become very toxic. Because there are so many of them in relatively small quantities compared to the six major air pollutants, it becomes very difficult to assess their impact on human health. Some studies have determined that a concentration of VOCs as small as 0.000003 ounces per cubic foot of air (3 milligrams per cubic meter) may cause discomfort such as irritation of the eyes, nose and throat, neurological symptoms (e.g. headaches, dizziness and reduced memory), skin irritation, allergic symptoms, and loss of sensitivity to odor and taste.[8] A subgroup of VOCs called Polycyclic Aromatic Hydrocarbons (PAH) is known to be carcinogenic and causes gene mutations. An aspect that makes VOCs insidious is that many of them are invisible to the naked eye and are odorless and tasteless, which makes it difficult for us to be aware of their presence in our everyday lives.

Other elements of the human environment affect our health. The human body does not exist in isolation. In order to survive, it must eat food, breathe air and drink water, which implies that the incidence of cancer must involve the air we breathe, the food we eat and the water that we drink.

The food and the water that we eat and drink come into contact with several chemical substances. One category of these chemical substances is pesticides.

Now, the first step to our food process is to grow fruits, vegetables and cereals, and it is well known that the majority of the agricultural industry uses pesticides to cultivate them. Pesticides include insecticides, herbicides, fungicides, algaecides, rodenticides and nematocides, and their main function is to protect the crops from harmful insects, rodents or nematodes parasites and to prevent the growth of weeds, fungi or algae.

The pesticides are sprayed into the fields and are absorbed by the roots and/or the leaves of the plants. Then the plant vascular tissue system may transport the pesticides throughout the plant, which includes the cereal grain, fruit or vegetable. It should now occur to you that the pesticides are not just on the skin of the fruit, grain or vegetable but they are also within them. The pesticides cannot simply be washed off the fruit, vegetable or grain, since they are also part of their cellular structure.

As for the pesticides that are not absorbed by the plants, they are now part of the soil and with the help of rainfall will slowly reach groundwater and/or run down into a river. The pesticides will thereby be in our drinking water and within the aquatic inhabitants (e.g. fish, plants and frogs).

The second step of the food process is to give the herbs, cereals grains and water that contain pesticides to farm animals. The pesticides within them will be partly absorbed by the animal's digestive system and some will remain in its body until it is eaten by us. As a result, the cereals, the fruits, the vegetables, the fish and the meat that we eat contain pesticides. The water, the colas, the wine and the beer that we drink contain pesticides. We eat and drink pesticides. (In Chapter Two, we will go into more detail regarding the process of absorption of food and water within the human body.)

In 1962, the book *Silent Spring* by Rachel Carson described the danger of pesticides on human health.[9] The public became aware of the possible danger of pesticides and it resulted in the banning or restricting of the usage of one family of insecticides called organochlorines in the 1970s and 1980s. A well-known organochlorine is DDT, which was found to be extremely toxic in the long term.

Public awareness, however, was not sufficient to slow down the use of pesticides. Since 1960, the utilization of pesticides in the U.S. has almost doubled. The latest available statistics from the EPA state that in 2012 the world pesticide consumption was approximately 5.821 billion pounds of active ingredients of pesticides. The total amount of pesticides used in the U.S. was approximately 1.182 billion pounds of active ingredients compared to 637m pounds in 1960. Herbicides accounted for 57% of the pesticides, insecticides for 5% and fungicides for 9%. As expected, the agricultural industry used most of these pesticides (66%), while homes and gardens used 24%.[10]

There are several mechanisms that kill plants, insects or fungi. Each category of pesticides has a different mechanism of action on the pest and individual pesticides may differ within each category. Herbicide kills plants by inhibiting metabolism functions such as their amino acid synthesis and photosynthesis or by modifying their cellular growth regulation. Insecticide acts on the nervous system of the insects. Fungicide alters respiration of the fungus cells' wall structure, DNA synthesis, cellular division, amino acid and protein synthesis.

We must keep in mind that these pesticides also have the potential to modify the biochemistry of our cells. There are several similarities between human, insect and plant cells; for example, the insecticides family called organophosphate, which is widely used, irreversibly inactivates an enzyme called acetylcholinesterase, which is essential to nerve function in insects as well as in humans. Remember that the cell's metabolism is not well understood. The scientific community may broadly understand the mode of action of pesticides but they do not understand the intrinsic details of its action on the cell.

In 1991, the United States Department of Agriculture (USDA) initiated a program called the "Pesticide Data Program", which monitors the amount of pesticides in certain foods and waters. For the year 2015, it measured the amount of pesticides in a sample of fruits, vegetables and peanut butter, of which 76% of the food samples were grown in the U.S. The results were that 85% of the tested food had detectable residues of pesticides. In the food samples, 73% had more than one pesticide. For the year 2013, pesticides were detected in 66% of the butter samples, 0.9% of the salmon samples, 0.6% of the infant formula, soy-based and 51% of the baby food, apple sauce samples while tap water had at least 27 different pesticides.[11]

These findings confirm that pesticides are part of our food and water. It is then easy to extrapolate that they are also within our bodies. In fact, they are. Regularly, the CDC (Center for Disease Control and Prevention) takes blood and urine samples to ensure that certain pesticides are not above a set limit.[12]

We do not only eat and drink pesticides, we also breathe them. We regularly spray our gardens or lawns with pesticides. To make matters worse, not only are we breathing pesticides but we are also breathing VOCs, which are often part of the pesticides.

In the 1940s, the population was in contact with fewer than 30 pesticides; since then, the market has developed much more of them. There are now approximately more than 1,000 active ingredients which are mixed with inert ingredients to manufacture more than 20,000 different products on the market. With several of them used on the same or adjacent fields, they may combine into a toxic substance that is slowly killing us; and because of the sheer number of pesticides, it would be very expensive to determine the health impact of each of them, let alone their combinative effect.

It is known that the agricultural workers who are frequently exposed to pesticides have a higher probability of having leukemia, non-Hodgkin lymphoma, myeloma, and lip, stomach, brain and prostate cancer. So why do we assume that pesticides have a minor or no effect on our health?

Despite this information, as a society we deny to ourselves that the pollution of our air, food and water plays an important role in the condition of our health. Furthermore, its effects may not only include cancer; it may also cause neurological, respiratory and cardiovascular diseases.

Our health issues may be related to pesticides, to hazardous pollutants, or to one of the six major pollutants, or a combination thereof. We should worry because the probability of these elements being harmful to our health is high. There are surely other substances that affect our health, such as hormones, fertilizers and additives in our food; however, for the purposes of this book we will only concentrate on the following pollutants: the six major pollutants, and certain hazardous pollutants and pesticides. As for the other pollutants, such as chemicals released by industries, the additives in our food and our household products, the same reasoning that we will learn in this book should also be applied to them. What we will find out in this book will help us identify and understand the issues at hand and will enable us to make educated decisions that will protect our health and, by the same token, the health of the planet.

In summary, we are surrounded by pollutants that interact with each other. We may decide to ignore them; however, the fact remains that we are in worse shape today than 40 years ago when it comes to cancer, allergies and asthma. Not only may pollutants be a possible cause of cancer, they can also cause neurological, reproductive, developmental and immunological toxicities. We should be concerned with the quality of our air, food and water if we want to live healthy lives. To understand the impact of pollutants, we need to understand the full implication of our actions on the environment.

Now back to our question: Why is the cancer rate of most cancers higher today than in 1975? In order to find an answer to that question, in the next chapters we will dig more deeply into the damaging effects of pesticides and air pollutants on the human body. We will then explore the main sources of major air pollutants and, hopefully, we will have a better understanding of the origin of pollutants and we will therefore be better equipped to comprehend the issues at stake. This will enable us to participate in the actions that will give us better air, water and food quality, and thus a better environment.

CHAPTER TWO

THE WORKINGS OF THE BODY

We do not worry about pollutants, because most of us are unaware of the pollutants that surround us. We do not smell, taste or see the pollutants since, for the majority of us, they were already an intrinsic part of our environment. We were born into them. It does not come into our mind that we could live in an environment that could be different. So we drink water, eat food and breathe air which contains pollutants.

The pollutants come into contact with or enter our bodies through our skin, noses and mouths. The skin serves as a protective membrane that isolates us from most of the contaminants. It does restrict the access to the inside of our bodies; however, it remains permeable. Small amounts of contaminants will pass through our skin, enter our cells and may damage them or – even worse – enter our bloodstream and travel throughout our bodies, damaging several organs when they come into contact with us. Depending on the concentration level of the contaminants, it may take them hours or years to damage our bodies. Unintentionally, we may even apply them on our skin, thinking that we are protecting it. Dibutyl phthalate (DBP), for example, contained in cosmetics, is suspected to be an endocrine disrupter, thus causing development defects.[1] Pollutants in the form of gases may also pass through our skin; for example, carbon dioxide diffuses through our skin.

Furthermore, we cause pollutants in the form of gases, liquid droplets or particles to enter our bodies by breathing, by eating or by drinking them. Our mouths and noses are open doors to our bodies. They allow air pollutants, such as the six common pollutants, hazardous air pollutants and pesticides, to penetrate our respiratory and digestive systems. In order to understand their impact on the body, I will describe the possible paths the pollutants are taking. We will go through the respiratory system and the digestive system and also the cells.

Our respiratory system

The main functions of the respiratory system are to inhale oxygen and exhale carbon dioxide (which, by the way, is a toxic waste from our bodies). The air enters the nose then goes down the throat and into the lungs, which are filled with alveoli. The alveoli are covered with tiny blood vessels called capillaries. The network of blood capillaries is separated from the air by a thin, moist, permeable membrane which allows the passage of oxygen and carbon dioxide in and out of our blood. The membrane has three layers which are called the thin epithelium, the basal lamina and the capillary endothelium. The membrane is very thin, of the order of 0.3 μm (the size of a blood cell is 7 μm). Once the oxygen passes the membrane into the blood capillaries, it is transported by the bloodstream all around the body into our organs, tissues and cells.

Without question, the air pollutants will take the same route. The amount of pollutants absorbed by the respiratory system will depend on the condition of the lungs, whether the breathing occurs from the nose or the mouth, the rate of respiration, and the chemical properties of the pollutants. The absorption of pollutants will also differ from one person to the next.

The pollutants first make contact with the nose, which is covered by a large number of blood vessels. If the pollutants are soluble in water they will be readily absorbed through the lining of the nose into the bloodstream; for example, sulfur dioxide gas is highly soluble and is primarily absorbed in the body through the nose. As for the particulates, they may be stopped in the nose, throat or lungs, depending on their size.

Our air passages have three lines of defense to ensure that pollutants, dust, viruses and bacteria do not enter the lungs. The first line of defense is the cilia in our noses (if breathing from the nose). The cilia filter approximately 75% of the particulates larger than 10 μm in diameter.[2] Even though our noses are efficient in eliminating particulates larger than 10 μm, some of them do reach our lungs, such as the asbestos fibers which are elongated particulates of 40 μm.

The second line of defense is within the throat, up to the bronchioles, where particulates get trapped into mucus. The cilia then move the particulates into our stomachs, or they get evacuated outside by coughing. By the way, smoking reduces the length of the cilia and slows down the movement of the cilia; thus, the throat of a smoker evacuates less particulate than that of a non-smoker.

The third line of defense is the macrophages in the lungs' alveoli. The macrophages (which are cells that can move) will attack the intruder by entrapping and digesting the particulates, bacteria or viruses. The particulates that are indigestible will stay trapped into the macrophage. Once the macrophage dies, it is transported into the lungs, lymphatic system or in our stomachs. This can take more than 700 days.

Sometimes, however, the particulate remains untouched in our lungs because it may be too big to be entrapped by the macrophages or was not detected by it. Consequently, our lines of defense in our respiratory systems are not perfect. If that were the case, our lungs would stay pink when we get older; however, as it was observed, the lungs of a child are pink while those of adults are gray. This darkening is especially marked in city dwellers who are exposed to smoke and to air pollution.

Once the pollutants have reached our lungs, they will come into contact with the alveoli of the lungs. Depending on the size of the gas molecule or particulates, they may pass through the membrane separating the alveoli and the blood capillaries by diffusion (the passage from a high to low pressure concentration area) into the bloodstream, free to harm the entire body. There is evidence that inhaled ultrafine carbon particles similar to the ones in the exhaust of cars can pass through the lung into the bloodstream.

In summary, the pollutants may be spread throughout the body by the bloodstream and lymphatic system or remain permanently in our lungs. This may lead to a decrease in the functionality of our lungs, such as emphysema, chronic bronchitis or lung cancer. The good news is that the air quality has improved since the 1990s and, likewise, a decrease of 24% in the rate of lung cancer from 1992 to 2014 was observed. This suggests that the improvement of our air quality has been partially responsible for the reduction in lung cancer.

Our digestive system

The digestive system's main purpose is to transform food into chemical compounds that are small enough to enter the body cells. The digestive system is a 30-foot-long tube (mouth, esophagus, stomach, small intestine, colon and rectum) with glands connected to it (salivary glands, liver and pancreas). The food enters the mouth and gets cut into small pieces, passes the esophagus and gets delivered to the stomach. The hydrochloric acid and the enzymes (complex proteins that induce or speed chemical reactions) in our stomachs break down the food into a liquid paste called chyme, which then gets transferred to the small intestine.

The small intestine is where the food and water are mainly digested and absorbed into the body. The digestion is helped by the sodium bicarbonate and enzymes of the pancreas and also by the bile of the liver. (The pancreas and liver are connected by a small duct to the small intestine.) The chyme gets broken down into molecules small enough to pass directly through (such as water), or must be transported through the cells of the intestine lining into the blood capillaries; as for lipids, they go into the lymph capillaries. The elements of the food that the intestine is unable to break down into small molecules get directed to the colon, which moves them out of the body as feces.

The small intestine is unable to differentiate between the natural compounds and the contaminants contained in the food or water, which means that the pollutants are also passed and transported into the bloodstream. From the capillaries of the small intestine, the blood is directed into the liver while the lipids from the lymph capillaries are directed into one of the main lymphatic vessels called the thoracic duct, which converges to the bloodstream vein near the heart. The blood with the pollutants then travels throughout the whole body, where it enters each organ, tissue and cell. The pollutants, depending on their chemical composition, can be soluble in lipids or water. The ones that are soluble in lipids get stored in our body fat, where they accumulate and remain for many years.

Do we have a defense mechanism against pollutants in our digestive systems and bloodstreams? The body protects itself in three ways. The first one is the macrophages similar to the ones in the lungs, which entrap intruders in the intestine. The second one is the lymphocytes, which are the white blood cells of the immune system that bombard the intruders within our blood. The third one is the hydrochloric acid, or the enzymes in the stomach, that will chemically modify or destroy intruders. Foreign matter, however, causes inflammation, which makes capillaries more permeable. The pollutant that gets recognized will be attacked by the white blood cells or the macrophages, but then it causes an inflammation of the tissues. The blood capillaries become permeable, which then allows other pollutants to enter the body. Keep in mind that these defenses were designed to be especially effective against bacteria and viruses, not pollutants.

Fortunately for us, the body was also designed to clean itself, and it does this principally in the liver and urinary tract system. The liver transforms, metabolizes or degrades the pollutants within the blood, which is then returned to the bloodstream. The kidneys then filter the blood, removing the toxic waste, which gets transported outside the body within urine. You should be aware, however, that the liver may metabolize harmless chemical substances into toxic chemical substances.

Today our food and water contain numerous foreign matters such as pesticides, food colors, chemicals leaking from plastics, hormones, antibiotics, or other chemicals from industries. All these pollutants are in our meats, fishes, fruits, nuts, cereals, vegetables and water. By eating and drinking them, they all end up in our bloodstream. In the last 50 years, the amount of pollutants that our body deals with has increased tremendously. It should not be a surprise, then, that the incidence rate of cancer for individuals below 65 years of age has also increased. Our defense system may be overloaded. In any case, since 1975, the incidence rate of kidney cancer increased by 114%, liver cancer by 221% and non-Hodgkin lymphoma by 80%.[3]

Our cells

The main function of our respiratory and digestive systems is to provide oxygen and nutrients to our cells. Each cell is then able to combine them and produce energy to enable the cell to live. We each have approximately $4x10^{13}$ cells in our bodies, which constitute the basic structure of our organs, tissues and systems. Indeed, the whole body is made up of cells. The cell is a very complex structure, which makes it very difficult to understand. The process that provokes a cell's division, its specialization, its birth and its death are not known, and its working and maintenance are not well understood.

The human body starts with two cells, the ovule and spermatozoid that merge together and become one cell. This cell with its unique DNA will then split into two cells. Each of these cells will contain an exact copy of the first cell's DNA. The cells will then replicate themselves until a complete body is formed. During that process, the cells will specialize to form different organs, tissues or systems. Each cell, therefore, contains all the required instructions that it needs to form an entire body, and the cells can specialize to create approximately 200 different types of cell, including blood cells, skin cells or stomach lining cells.

In order to survive, the cell needs carbohydrates, proteins, lipids, water, certain minerals, and vitamins. These nutrients are supplied by the bloodstream, which is in contact with all the cells in our bodies; however, not all nutrients within the blood diffuse easily through the outer membrane of the cell. It will depend on the nutrient's size, polarity and chemical composition. The molecules that are smaller than 0.8 nm (such as water) or that are soluble in lipids (independently of their size) pass easily through the cellular membrane; meanwhile, the ones that are too big to pass through the membrane, such as proteins and carbohydrates, are transported into the cell by carriers inserted in the cellular membrane. Each cell has a limited number of carriers and each carrier is programmed to recognize specific molecules. Once the nutrients are inside the cell, there are numerous chemical reactions which transform them to synthesize enzymes, hormones or other proteins. In doing so, the cell produces waste and directs it to the bloodstream, which transports it into the urinary system.

Needless to say, the pollutants within our bloodstreams are also in contact with our cells. Depending on their size, their lipid-solubility or their chemical composition, they may diffuse through the cellular membrane or may attach themselves to a carrier, preventing a nutrient from entering the cell. Once inside the cell, the pollutants may change their processes, such as by speeding up, slowing down or inhibiting the chemical reactions, by preventing the absorption of nutrients, by stopping the synthesis of proteins or hormones, by creating new forms of proteins, or by reducing or heightening the protein function. Consequently, the cell may not be able to efficiently perform its functions – or worse, it may destroy itself. Now imagine that the concentration of pollutants is high enough to damage several cells; it may then partially or completely damage an organ.

Another possibility would be that the pollutants damage the cell's DNA permanently. (The DNA is the blueprint of our bodies; it has a whole set of instructions called genes that determine the functions of each cell.) The pollutants may render the cell's enzymes incapable of repairing the

DNA – or worse, the pollutants may cause so much damage to the DNA that the enzymes are only capable of partially repairing it. The damage to the DNA of one cell may or may not be of any consequence. Imagine, however, that the cell is an ovum. All the cells of the embryo would contain an exact copy of the damaged DNA. Subsequently, the child may later develop health problems.

Pollutants may damage only one cell of the body. You may think that is not a big deal; however, some of our cells need to replicate several times in their lifetime. The skin cells and the small intestine, for example, replicate themselves continuously. On average, the entire lining of the small intestine is replaced every five days. The good news is that if the damaged cell dies before replicating itself, everything is fine; let us consider, though, a scenario in which the cell is instructed to replicate itself a specific number of times before it dies and in which these instructions were damaged and the cell can no longer stop replicating. The cell uncontrollably multiplies itself, which is what we call cancer.

Epigenetics

Until recently, it was thought that the instructions of the DNA could only be modified by its mutation. A new development, however, has come along to add new possibilities. This new science is called "epigenetics". Eccleston defines it as follows: "Epigenetics is typically defined as the study of heritable changes in gene expression that are not due to changes in DNA sequence".[4]

It was found that the instructions from DNA could be modified without its alteration. Mechanisms are able to activate or deactivate a gene as if there was an on/off switch on the gene. The mechanisms are not completely understood, but observation and experimentation found that the switch position (on/off) could be modified by environmental factors such as temperature, nutrition, pressure, gravity, chemicals, light and the presence of dangerous conditions (predators or stress).[5]

This discovery is highly important. It tells us that the environment that we live in will affect the outcome of our health and the health of future generations. Think of it: the environment has the capability of modifying the instructions of our DNA. A pollutant, for instance, could switch a gene that is normally "off" to "on". The gene could be the one that instructs the body to form more fat cells, causing the body to store more fat. The opposite is also true; a gene that is normally switched “on” could be switched “off”, shutting down the receptor of an essential hormone. Pollutants could also alter our cellular division. Some genes are critical in regulating cell division (promoting cell division, reducing cell adhesion, preventing cell death), while others put brakes on cell division (increasing cell adhesion).

The fetus is particularly sensitive to the mother’s environment. During its development, what the mother ingests and breathes becomes critical. The chemical compounds could be harmful or beneficial to its development. These substances could damage the DNA or could induce epigenetic modifications (on/off switch of the gene).

The process of epigenetic change does not only happen within the womb. It also occurs with children and with adults. The best evidence of these changes was observed on identical twins. Normally, identical twins start off with identical DNA. It was observed that as time passes, the twins physically change in different ways depending on their habits, their environments, the areas in which they live and their diets. The twins would develop different health issues to the point that one of them could develop cancer while the other is perfectly fine. The pattern of the on/off switch on their genes was found to be different and the differences increase with age. The differences could be explained by epigenetic changes.

There is a hypothesis stating that the epigenetic changes of our genes may cause the development of diabetes, hypertension, heart disease, obesity and cancer. It was observed that humans can become predisposed to tumor formation and hereditary nonpolyposis colorectal cancer by modifying the switch position on the gene MSH2. (This modification was found to last three generations.) There is still a lot of research to be conducted but there is strong evidence that our environment causes these diseases. There are several examples that can be found in nature and also in humans. The biggest difficulty is to accept that the environment has an effect on our health.

It is to our advantage to accept this possibility, since the epigenetic changes not only affect our health but also affect the next generation. The bad news is that the modifications that occurred to you during your childhood or adulthood can be transmitted to your child, and your child may transmit it to their child, even if the pollutant does not exist anymore.

The good news is that it could probably be reversed. In the future, we could probably develop drug therapies that will reset those switches.

Now, does our health depend on the quality of our air, water and food?

Assumptions

There is a report that is frequently mentioned in order to discredit pollutants as a possible cause of cancer. The main purpose of the report, written in 1981 by Doll and Peto, was to determine whether cancer could be avoided by changing our habits.[6] Based on epidemiology studies, they tentatively estimated the possible causes of death due to cancer. They estimated that 30% of deaths were caused by tobacco, 35% by our diet ("highly speculative", as stated by the authors), 2% by pollution, 3% by geophysical factors and 3% by alcohol. According to the authors, the numbers are speculative except for tobacco, alcohol and geophysical factors, where they had sufficient studies to ensure the reliability of the data.

Doll and Peto distinguish pollution from diet; however, it is virtually impossible to find a population that lives in an area without pollutants in their air, food and water. We must face the fact that pollutants are an integral part of our food, beverages and air. Consequently, it is very difficult during a study – next to impossible – to separate the health effects caused by pollutants within the food from the ones caused by the natural constituents of the food. It is therefore questionable whether it is possible to have statistics that separate the diet from the pollutants.

One often hears that a particular diet, such as the Mediterranean diet, is beneficial to one's health because the people living in that particular area are living long healthy lives. To prove their point, they mention that when some of these people move to another country they develop a higher risk of cancer than their counterparts who are still living in the Mediterranean region. That is possibly true, but one has to keep in mind that their environment has also changed. Needless to say, the quantity and types of pollutants with which they are now in contact are different. What we really should retain is that our health is dependent on what we eat, drink and breathe, and pollutants are part of what we eat, breathe and drink.

Unfortunately, 30 years later, people are still using these numbers to determine whether pollutants are of concern, and one must be careful since any statistics stating the cause of cancer are in the domain of uncertainty. We are unable to predict with certainty the causes of cancer since we do not fully understand the functioning of the human body and the mechanisms of cancer. At least half of the processes in our bodies are not understood. We just do not know, so how can we determine which substances are toxic in the long term?

There are four different methods that the scientific community uses to determine the possible health effects of a substance: tests on animals, tests on human cells (in vitro), controlled human exposure and population-based studies (epidemiology). The first three methods are performed in a laboratory in which the subjects are exposed to a controlled environment, and for the fourth one – epidemiology studies – the subjects are in their natural environment. The main advantage of the first three methods is that the tests are performed in a controlled environment where the scientific team has control of the dosage of the substance studied and of the ambient conditions, and they know the health condition of their subject. Conversely, the main advantage of an epidemiology study is that it allows for a large sample of individuals and it can be conducted over a long period of time, which gives the scientific team the opportunity to study the chronic effects of a substance on humans.

None of the four methods are without flaw; each one has its limitations and drawbacks. To illustrate the possible flaws, let us imagine the perfect study: the perfect study would necessarily be performed on a large number of humans, at least thousands of individuals. It would be conducted for at least 30 years. The scientific team would know the history and the health condition of the individuals. The dosage of the substance and the composition and quantity of the other substances in the air, water and food would also be known. In addition, the study would be designed and analyzed without preconceived ideas, or without any political agenda. Finally, the scientific team would be financially independent and would not be influenced by any political groups, activists or industries.

This perfect study, however, is not realistic. This type of study could be immoral, would be expensive, and no human being – including scientists – are free of all influences. It would be immoral because the individuals participating in the study may be exposed to a substance which is toxic, resulting in major health issues in the long term. It would be expensive because a large team of scientists would be required to question the numerous participating individuals and to compile and analyze the data during the 30 years. Consequently, the scientific team would require lots of capital (in the order of several million dollars), which would be funded by a donor. It would then be very difficult for the scientific team not to be influenced by the donor.

For the most part, however, we are faced with the human aspect of the study. No study is completely objective, because of the human factor. Despite our best intentions, we, as humans, have to deal with our emotions, preconceived ideas, previous experiences, needs, emotions and ambitions. It is not possible for a human to be completely objective and rational. In the end, the test results would not be perfect because the study would have been designed by a human, the scientist, who has asked the questions, compiled the data and interpreted the results. Even the best scientists remain subjective. In addition, participants of the study would not have answered the questions exactly and would not have provided all the pertinent information. This would result in a study that would be flawed, in spite of the best of intentions of all the persons involved in the study, simply because we are not perfect.

This does not mean that we should not conduct or believe any studies. The point is that we should be aware of the possible imperfections and limitations of the studies.

In general, most of us assume that some substances or gases are beneficial and some are harmful to our health, although this assumption is erroneous. Any substances or gases will be harmful to us if taken too often and in large enough quantities. The issue is really in which frequencies and quantities they become harmful to our health – what is the acceptable dosage. To complicate matters, the dosage may depend on other substances and gases that we are breathing, eating or drinking.

One important notion is to understand that all substances are harmful if taken in too large quantities. We tend to forget that we are organisms which function with chemicals and electricity. Granted, we are rigorous organisms; nevertheless, all substances and gases that surround us will have an impact on our bodies' functions. Too much or too little will be of consequence to us. In this book, consuming too much of a particular substance will be considered as a toxin or contaminant.

In reality, the goal of any study is to determine at which point a substance or a gas becomes harmful to our health when taken in the short