Environmental Health Hazards: How Children Are Different from Adults

Cynthia F. Bearer

Abstract
In policymaking on environmental health, it is often assumed that the entire population is exposed to and reacts to environmental contaminants in a similar manner. However, this assumption is misguided, especially where children are concerned. This article presents the scientific basis for the impacts of the environment on children, showing how children are different from adults in the ways in which they are exposed to environmental contamination and the ways in which they react to it when exposed. Specifically, the article examines the changing physical and biological environments of children. Children at different stages of development have unique physical risk factors for certain types of exposure because of changing location, levels of mobility, oxygen consumption, eating patterns, and behavior. When children are exposed to contaminants, their developing biological makeup—the way in which they absorb, distribute, and metabolize chemicals—will also affect how their bodies deal with the foreign substance. Each of these factors, along with the customs, laws, and regulations that affect the way in which children are exposed to the contaminants, has implications for the well-being of children in the years to come.

As the human population increases, its demands on the earth also increase. Today, the demand for food, potable water, clean air, energy, and manufactured goods; the need for solid and liquid waste disposal; and the requirement for habitable land are all expanding. With this expansion, increasing amounts of pollutants are released into the environment, and more and more people come into contact with polluted environments.

Interaction with polluted environments can have an adverse impact on the health of humans and other living creatures. This impact is felt first among the most vulnerable members of a population. Children, because of their unique physical, biological, and social characteristics, are among the most vulnerable members of our population.

We have become increasingly aware of the dangers posed by the accumulation of pollutants in the environment and have looked to policy
in the form of legislation, regulation, and private, voluntary action for protection. It may, however, be costly to identify and effectively deal with environmental hazards, particularly when there are benefits to be gained from the use of hazardous materials. Under these circumstances, effective policymaking depends on honest and accurate assessment of the risks posed to all members of society, including children. For a variety of reasons, special consideration should be given to protecting children in formulating environmental policies: children are less able than adults to protect themselves, may be more vulnerable to particular toxins, and are not considered responsible for pollution. Crafting environmental policies responsive to the special needs of children requires a thorough consideration of these special needs and an understanding of how these needs may change as children grow and develop.

This article presents the scientific basis for the impacts of the environment on children. It describes the differences between adults and children in physical, biological, and social environments, and highlights why children should not be treated as “little adults” in developing environmental policy.

**Human Environments**

Children exist within three broad types of environments: physical, biological, and social (see Figure 1). Each affects their well-being, is at risk of degradation, and is amenable to policy intervention. The physical environment is anything that comes in contact with the body. Air, for example, is in constant contact with our lungs and skin, and is a large part of our physical environment. To define the physical environment precisely, it may be necessary to divide a large environment into smaller units, called microenvironments. For example, in a room contaminated with radon, the radon will not be evenly dispersed; air near the floor has a higher radon concentration while air near the ceiling has a lower radon concentration. Therefore, the environment of an infant playing on the floor would be much different from that of an adult standing in the room. These microenvironments can differ enormously between adults and children in many situations.

The biological environment consists of the internal physiological workings of the body as it takes up, processes, and interacts with the substances it contacts. The body has specific chemical pathways used to digest, process, and excrete substances found in air, food, and water. The multiple steps by which a toxic hazard may result in adverse health effects help illustrate the complexity of the biological environment. The steps are (1) absorption (how the chemical gets into the body), (2) distribution (once inside the body, how the chemical gets to each of the organs and in what amount), (3) metabolism (how the body processes the chemical), and (4) the toxic action (how the chemical interacts with the biochemistry of the body). Each of these steps depends on the developmental stage of the child because the child’s biological environment changes over time.

The social environment includes the day-to-day circumstances of living in a family or other setting as well as the laws and regulations that affect day-to-day living. Children, because of their continued development and their different physical and biological environments, are a unique group of individuals in relation to toxic hazards. If laws, regulations, policies, and behavior do not reflect this fact, then chil-
Children may be unwittingly exposed to environmental hazards. In time, children may become bodies of evidence that environmental degradation can have severe impacts on the health of societies.

This article concentrates largely on the physical and biological environments of children at various developmental stages. The social environment is discussed in detail in the article by Landrigan and Carlson in this journal issue.

Developmental Stages

A child’s vulnerability to environmental exposures is closely related to his or her developmental stage. Changes in growth, hormonal levels, and biochemical makeup continually occur. Developmental stages are periods in a child’s life characterized by the achievement of certain intellectual and physical milestones. For organizational purposes, this article recognizes five stages: the newborn (from birth to 2 months of age), the infant/toddler (2 months to 2 years of age), the preschool child (2 to 6 years of age), the school-age child (6 to 12 years), and the adolescent (12 to 18 years). The fetus is considered as a single separate stage, although there are multiple critical stages of development for the fetus.1

The Physical Environment

Exposure to an environmental agent is the first step in a sequence of environmentally related health effects. Exposure may occur at any point as people move through several environments during the course of a day. Adult environments include home, work, and errands outside home and work. Infants and children spend time at home, school, day care, and play. Because the environments of children are typically different from those of adults and may vary according to the age of the child, children’s exposure to environmental agents may be different from exposures of adults and may vary with the developmental stage of the child. In addition, different patterns of exposure to a toxin may yield different
health effects. For example, nitrates in well water may cause the hemoglobin in blood to become methemoglobin. If too many nitrates are ingested, this chemical change can cause insufficient oxygen to reach the body tissues. However, if the nitrates are ingested at a rate that is slow enough for the enzymes in the blood to convert the methemoglobin back to hemoglobin, no health effect will occur.

Exposure Before Birth

Exposures that have profound health effects on an individual may occur before birth. Even exposures that occur to women before the conception of a child may have an effect on that child (see Table 1). For example, women who conceived after eating cooking oil contaminated with polychlorinated biphenyls (PCBs) gave birth to infants with a pattern of abnormal physical characteristics called yusho. In another case, a woman inadequately treated for lead poisoning in childhood gave birth to an infant with congenital lead poisoning.

An individual can also be affected by exposures that had direct effects on the ovum and sperm prior to conception. The ovum, formed within the fetus of the future mother, is affected by the exposures both of the grandmother and the future mother. Studies have measured chemicals foreign to the human body in the fluid that bathes the ova prior to ovulation, showing the potential for exposure. Sperm, in contrast, are created only a few hours to a few days prior to conception. Thus, harmful effects to the sperm are most likely the result of the father’s exposure in the period immediately before conception.

In most instances, exposures after conception are dependent on exposures to the mother. Infants may experience the result of exposure to many of the toxins mothers come into contact with during the pregnancy. For example, maternal smoking during pregnancy is associated with reductions in forced expiratory flow rates for the child.

Exposure from Birth to Adolescence

Exposures for newborns, infants and toddlers, preschool children, school-aged children, and adolescents depend on their physical location, breathing zones, oxygen consumption, food consumption, types of foods consumed, and normal behavioral development (see Table 2)—all of which change as the child develops.

### Physical Location

That the physical location of children changes with development has large implications for a child’s exposure. Premature and sick newborn infants are exposed to noise, light, compressed gases, intravenous solutions, and benzyl alcohol, among other things, during their stay in neonatal intensive care. Most newborns, however, are usually near their mothers, so exposures will be similar to those experienced by the mothers. Moreover, a newborn frequently spends prolonged periods of time in a single environment, such as a crib. Infants and toddlers, on the other hand, are frequently placed on the floor, carpet,

<table>
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<th>Table 1</th>
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<tr>
<td><strong>Periconceptual Exposures of Possible Importance</strong></td>
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<tr>
<td><strong>Grandmother</strong></td>
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<td><strong>Father</strong></td>
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<td><strong>Mother</strong></td>
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or grass. They therefore have more exposure to chemicals associated with these surfaces, such as formaldehyde and volatile organic chemicals from synthetic carpets and pesticide residues from flea bombs.

Children who are not yet able to walk or crawl may also experience sustained exposure to noxious agents because they cannot remove themselves from hazardous environments. The infant who is badly sunburned because of his or her inability to escape from the sun is a good example.

Many preschool children spend part of their day in a day-care facility, which can be located anywhere from church buildings to private homes. In addition, preschool children may spend a significant period of time in outdoor environments such as playgrounds and backyards.

School-aged children spend a significant period of time at school, a very different physical environment from a house or an apartment. Schools are sometimes built on relatively undesirable land. School sites may be near highways (resulting in exposure to auto emissions and lead), under power lines (resulting in exposure to electromagnetic fields), or on old industrial sites (resulting in exposure to benzene and arsenic).

Adolescents may not only have a new school environment, but also select for themselves other physical environments in which they misjudge or ignore the risks. Attendance at concerts with damaging sound levels is a relatively benign example of a situation in which adolescents willingly put themselves at risk. Many adolescents also have part-time jobs that place them in physical environments which may be hazardous because of occupational exposures.

**Breathing Zones**

Breathing zones, the places in space where individuals breathe, are also closely related to development. The breathing zone for an adult is typically four to six feet above the floor. However, for a child, it will be closer to the floor. It is within these lower breathing zones that heavier chemicals such as mercury and large breathable particulates settle out and radon accumulates. The presence of mercury in a child’s breathing zone which came from latex house paint accounted for a Michigan child’s case of acrodynia, a form of toxicity from mercury exposure. (See the article by Goldman in this journal issue.)

**Oxygen Consumption**

Because children are physically smaller than adults, their metabolic rate is higher than that of adults and they consume more oxygen relative to their size than do adults. As a result, a child’s exposure to an air pollutant may be greater than an adult’s. For example, if radon is present, a six-month-old child with an average oxygen consumption rate will, over a given period of time, receive twice the exposure to radon as will an adult with an average oxygen consumption rate.

**Quantity and Quality of Food Consumed**

Similar to their need for proportionately more oxygen than adults, children’s higher metabolic rates mean that they need to consume more calories per pound of body weight than adults. Quite simply, the amount of food that children consume per pound of body weight is higher than that of adults. The reason for this difference is that children not only maintain homeostasis, as adults do, but also grow.

Consider the amount of water that an infant who receives formula reconstituted in boiled tap water drinks every day. The average infant consumes six ounces of formula per kilogram of body weight. For the average male adult, this is the equivalent to drinking 35 cans of soda pop a day.
### Table 2

**Environmental Risk Factors for Children at Different Stages of Development**

<table>
<thead>
<tr>
<th>Developmental Stage</th>
<th>Developmental Characteristics</th>
<th>Exposure Pathways (Physical Environment)</th>
<th>Biological Vulnerabilities</th>
<th>Appropriate Responses in the Social Environment</th>
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<tr>
<td><strong>Newborn</strong>&lt;br&gt; (0 to 2 months)</td>
<td>Nonambulatory&lt;br&gt;Restricted environment&lt;br&gt;High calorie/water intake&lt;br&gt;High air intake&lt;br&gt;Highly permeable skin&lt;br&gt;Alkaline gastric secretions&lt;br&gt;(Low gastric acidity)</td>
<td>Food&lt;br&gt;Breast milk&lt;br&gt;Infant formula&lt;br&gt;Indoor air&lt;br&gt;Tap/well water in home</td>
<td>Brain&lt;br&gt;Cell migration&lt;br&gt;Neuron myelination&lt;br&gt;Creation of neuron synapses&lt;br&gt;Lungs&lt;br&gt;Developing alveoli&lt;br&gt;Bones&lt;br&gt;Rapid growth and hardening</td>
<td>Need for newborn-sensitive programs&lt;br&gt;and regulations regarding:&lt;br&gt;Polychlorinated biphenyls (PCBs)&lt;br&gt;Lead in drinking water&lt;br&gt;Environmental tobacco smoke&lt;br&gt;Need to educate parents and policymakers concerning environmental hazards</td>
</tr>
<tr>
<td><strong>Infant/Toddler</strong>&lt;br&gt; (2 months to 2 years)</td>
<td>Beginning to walk&lt;br&gt;Oral exploration&lt;br&gt;Restricted environment&lt;br&gt;Increased time away from parents&lt;br&gt;Minimal variation in diet</td>
<td>Food&lt;br&gt;Baby food&lt;br&gt;Milk and milk products&lt;br&gt;Air&lt;br&gt;Indoor&lt;br&gt;Layering effects&lt;br&gt;Tap/well water in home and day care&lt;br&gt;Surfaces&lt;br&gt;Rugs&lt;br&gt;Floors&lt;br&gt;Lawns</td>
<td>Brain&lt;br&gt;Creation of synapses&lt;br&gt;Lungs&lt;br&gt;Developing alveoli</td>
<td>Need for child-sensitive programs&lt;br&gt;and regulations regarding:&lt;br&gt;Radon in the home&lt;br&gt;Residential pesticide use&lt;br&gt;Lead abatement&lt;br&gt;Environmental tobacco smoke&lt;br&gt;Need to educate parents and policymakers concerning environmental hazards</td>
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<tr>
<td>Developmental Stage</td>
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<tr>
<td><strong>Preschool Child</strong></td>
<td>(2 to 6 years)</td>
<td>Language acquisition Group and individual play Growing independence Increased intake of fruits and vegetables</td>
<td>Food Fruits, vegetables Milk and milk products Air Day care/preschool Outdoor Water Tap/well Water fountains</td>
<td>Brain Dendritic trimming Lungs Developing alveoli Increasing lung volume</td>
</tr>
<tr>
<td><strong>School-Aged Child</strong></td>
<td>(6 to 12 years)</td>
<td>Beginning of school Playground activities Increased involvement in group activities</td>
<td>Food At home and school Air School air Outdoor air Water School water fountains Tap/well Other Arts and crafts supplies</td>
<td>Brain Specific synapse formation Dendritic trimming Lung Volume expansion</td>
</tr>
<tr>
<td><strong>Adolescent</strong></td>
<td>(12 to 18 years)</td>
<td>Development of abstract thinking Puberty Growth spurt</td>
<td>Food Air Water Other Occupation Self-determination</td>
<td>Brain Continued synapse formation Lung Volume expansion Gonad maturation Ova and sperm maturation Breast development</td>
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*Layering effects occur when a particle in the air is distributed in layers in a room. Radon, for example, is more concentrated closer to the floor, where infants and toddlers are likely to be.*
been found in infants with heavy exposure to tap water from reconstituted formula. Adults consuming the same tap water would suffer no adverse health effects because they would ingest much less lead relative to their body weight.

In addition, the types of food children consume differ from those consumed by adults. The diet of many newborns is limited to breast milk, which may contain environmental pollutants including lead, PCBs, and dioxins. The diet of children also contains more milk products, fruits, and vegetables than the typical adult diet, and as a result, children may be exposed to more dangerous levels of pesticides and other chemical residues than adults.

**Normal Behavioral Development**

The normal behavioral development of a child will also influence environmental exposures. Infants and young children may not be able to remove themselves from noxious environments. Normal children pass through a developmental stage of intense oral exploratory behavior from about age six months to two years, when most objects grasped will be placed in the mouth. This behavior is one common cause of lead poisoning in environments with high levels of lead dust, such as houses painted with lead-based paint. It also places the child at risk in environments that have not taken the oral orientation of young children into account. For example, some wood used in playground equipment is treated with arsenic and creosote. In the course of normal play, children will frequently place their mouths on playground equipment, inadvertently exposing themselves to these toxic chemicals.

The ability to walk often places children in play situations that have the potential for dangerous exposures, such as near empty lots, mud puddles, and used containers holding oil or other liquid substances. As children become adolescents, they gain more and more freedom from the parental supervision that might otherwise protect them from some exposures. Their physical strength and stamina are well developed, but they are still acquiring abstract thinking. They do not consider cause and effect, particularly delayed effects, in the same way that adults do. Because of this lack of perception, they often place themselves in situations with greater risk than an adult would willingly face. An example is the higher incidence of farm injuries among adolescents than among adults.

**The Biological Environment**

The biological environment—the internal physiological workings of the body as it takes up, processes, and interacts with the chemicals it contacts—is another important part of a child’s overall environment. The body has specific chemical pathways used to digest, process, and excrete substances found in air, food, and water, which vary at different stages of development. A chemical that comes into contact with the biological systems of a child’s body can produce adverse health effects or be processed into nonharmful substances.

**Absorption**

Absorption is the way a chemical enters the body. Absorption generally occurs in one of four ways: through the placenta, the skin, the respiratory tract, or the digestive tract. Each of these portals of entry is dependent on the developmental stage of the child.

**Through the Placenta**

During the fetal stage, the placenta is a major pathway of absorption. Several classes of compounds readily cross the placenta, including compounds with low molecular weight, those that are fat-soluble, and other specific compounds such as calcium and lead. Carbon monoxide, a poisonous compound of low molecular weight, crosses the placenta readily. When carbon monoxide enters the blood, it binds to hemoglobin, creating carboxyhemoglobin. This bond prevents hemoglobin from binding to oxygen and delivering...
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it to the cells. Because carbon monoxide has a higher affinity for fetal hemoglobin than it does for adult hemoglobin, the concentration of carboxyhemoglobin is higher in the fetus than in the mother. Therefore, the infant may have reduced oxygen delivered to tissues, with subsequent organ damage.

Fat-soluble, or lipophilic, compounds, such as polycyclic aromatic hydrocarbons (found in cigarette smoke) and ethanol (found in alcoholic beverages), readily gain access to the fetal circulation and thereby may cause toxic effects in the fetus. Also, mechanisms in the placenta actively transport specific nutrients and toxins to the fetus. Lead, for example, is found in equal concentrations in the mother and the fetus.

Through the Skin

The skin undergoes enormous changes with development which affect its absorptive properties. Pathways of absorption through the skin are particularly important for fat-soluble compounds. Because the skin is mainly composed of fatty chemicals, fat-soluble chemicals generally cross it more readily than other chemicals.

The outside skin layer of a fetus lacks the rough exterior dead skin layer called keratin and thus is without one of the major barriers of the skin. The acquisition of keratin occurs over the initial three to five days following birth. Therefore, the skin of a newborn is a particularly absorptive surface, and absorption of chemicals through the skin has caused many cases of illness in newborns. For example, hypothyroidism has resulted from iodine in betadine scrub solutions used for sterilization of the skin prior to birth or other skin penetrating procedures, such as obtaining blood or starting intravenous fluids. Neurotoxicity has occurred from hexachlorophene solutions which were used to bathe infants following birth, and hyperbilirubinemia has resulted from a phenolic disinfectant used to clean equipment between use for different patients.

An additional factor in the absorption of these chemicals through the skin is the larger surface-to-volume ratio of newborns compared with older children and adults. This means that for the same amount of skin covered with a chemical, the younger child may receive up to three times the dose received by an adult.

Through the Respiratory Tract

During prenatal life, the fetus makes breathing motions. Although the net flow of fluid is from the lungs out of the tra-
Chea into the amniotic fluid, some chemicals in amniotic fluid may come in contact with the lining of the respiratory tract. Studies on this pathway of exposure to foreign chemicals are limited.

The surface absorptive properties of the lung do not change during development; the lungs continuously absorb airborne chemicals in the same manner. However, from birth to adolescence, the lung continues to develop more alveoli, the terminal air sacs through which humans breathe. The increase in the number of alveoli increases the size of the absorptive area in the lungs. Thus, some airborne chemicals may gain greater access to the body through the lungs as the child ages.

Through the Gastrointestinal Tract

The gastrointestinal (digestive) tract, at all stages of development, provides many opportunities for exposure to environmental toxins. The fetus actively swallows amniotic fluid. Chemicals, including certain pesticides as well as chemicals from tobacco smoke, can be present in amniotic fluid, but it is not known if the fetus absorbs those chemicals by swallowing the fluid. Following birth, stomach acid secretion is relatively low, but it will achieve adult levels by several months of age. As the infant grows, the difference in acidity will markedly affect absorption of chemicals from the stomach.

The small intestine in the newborn can respond to increased nutritional needs by increasing absorption of a particularly needed nutrient. For example, because children’s bones are still growing, they require more calcium than adults. Thus, children absorb more calcium than adults do from the same food sources. However, this enhanced absorption can create problems. Lead, because it is absorbed in place of calcium when it is present, is absorbed to a greater extent in children than in adults. An adult will absorb 10% of ingested lead, whereas a one- to two-year-old child will absorb 50% of ingested lead.

Distribution

The distribution of chemicals, the process by which chemicals get to body organs, varies with the developmental stage of the child. For example, many drugs become more diluted in newborns than they do in adults, spreading out so that more of the body has contact with them at lower levels. In animal models, it has been shown that lead is retained to a larger degree in the infant animal brain than in the adult. Lead also accumulates more rapidly in children’s bones than in adult bones, doubling between infancy and the late teen years.

Metabolism

Metabolism is the way the body processes chemicals using a series of steps, or pathways, to alter chemicals for use as fuel or for waste. It may result in activation or deactivation of the chemical by the body. The metabolism of chemicals depends on the child’s developmental stage, and the end result may either protect or harm the child, depending on the chemical in question.

The activity in each step of a metabolic pathway is determined by developmental stage and the genetic background of each individual. Therefore, some people are more susceptible to adverse effects from certain exposures. There are also large differences in the ways enzymes work in metabolic pathways between developmental stages. The same enzyme may work more or less depending on the age of the individual.

In some instances, the lack of certain pathways can be a protective factor. In the adult, high levels of acetaminophen may cause fatal liver poisoning, because adult metabolism breaks down the drug into subcomponents that are harmful to the liver. However, infants are not as easily hurt by acetaminophen. Infants born to mothers with high acetaminophen levels will also have high acetaminophen levels in the blood, but they will not have liver damage.
The reason for this lack of damage is that the metabolic pathways of the fetus have not yet developed enough to break down the drug into harmful subparts.49

**Target Organ Susceptibility**

Children are also different from adults because their organs are undergoing growth and maturation, a process that may be adversely affected by exposure to harmful chemicals. Responses of children’s bodies to harmful exposures may differ from responses of adults’ bodies to these exposures in both the nature and the severity of the effect. Examples of such outcomes are poor fetal growth, poor growth in childhood, diminished intelligence quotient (IQ), precocious puberty, small head size, and diminished lung capacity.

The body experiences three types of growth: multiplicative, where cells divide; auxelic, where existing cells become larger; and accretionary, where ground substance and nonliving structural components accumulate.50 Multiplicative growth is complete around six months after conception for tissues that do not undergo continual turnover throughout life, such as skin cells. After that point, all growth is accretionary or auxelic.

Cells undergo two further processes to become the adult organism: differentiation and migration. Differentiation occurs when cells take on their individual tasks within the body and lose the ability to divide. The trigger for differentiation may be hormones, so when chemicals mimic hormones they can alter the differentiation of some tissues. Because the organ systems in children, including the reproductive system, are continuing to differentiate, a chemical that mimics a hormone can have drastic effects on the development of those organ systems. Chlorinated insecticides are an example of this mechanism. Studies have shown effects on the adult rat reproductive system from neonatal exposure to chlordcone,51 including abnormal growth of the vagina and sterility.52

Cell migration is necessary for certain cells to reach their destination for function. Neurons, for example, originate in a structure near the center of the brain, then migrate out to a predestined location in one of the many layers of the brain.55 Chemicals such as the ethanol in alcoholic beverages may have a profound effect on this process, as shown in children with fetal alcohol syndrome. Prenatal exposure to ethanol may result in interruption in this process severe enough to cause obvious malformations of the brain.54,55

Some organs continue to develop for several years. The brain and the lungs both have prolonged periods of postnatal development which are not complete until adolescence.39,56 This protracted period of growth and development increases the vulnerability of these organs. For example, brain tumors are frequently treated by radiation therapy in adults, with uncomfortable but reversible side effects. However, in infants, radiation therapy needs to be minimized when possible because of profound and permanent effects on the developing central nervous system.57

Another example of the unique vulnerability of children is the toxic effects of lead on the brain and nervous system. The current blood lead concentration of concern for children is 10 mcg/dl,58 based on studies59 which found that children with blood lead concentrations above that level may have measurable decreases in intelligence quotient. Because of differences in developmental stage, the occupational limit for exposure to lead for adults is six times higher than the limit for children.60

**The Social Environment**

For every developmental stage, there are unique combinations of developmental characteristics, physical environment, and biological environment that place children at special risk of harm. To protect children from the harms caused by exposure to
The regulation of the school environment is of particular concern. The drinking water at the tap in schools should be judged safe for a child’s consumption. Arts and crafts supplies should be designed and purchased keeping in mind a child’s unique way of handling these materials. For adolescents who are beginning to work, child labor laws should be adequate not only to protect them from occupational risks, but also to ensure that their ability to learn in school is not adversely affected.

These are only a few examples of the potential effects of laws and regulations on the environments of children. These social environment effects are discussed more thoroughly in the article by Landrigan and Carlson in this journal issue.

**Conclusion**

There are many reasons children cannot be considered little adults in the area of environmental health. Important differences exist between children and adults in exposures, absorption pathways, tissue distribution, ability to transform and eliminate chemicals, and body response to environmental chemicals and radiation. Each of these differences is dependent on the developmental stage of the child, and all children are not the same during each stage (see Table 2). When considering the health impacts of a particular exposure on the population and potential policies to alleviate those impacts, each of these differences must be heeded.

What can be done to alleviate the harm—both potential and actual—done to children by environmental pollution? Health care providers, policymakers, teachers, community leaders, parents, and children all have roles to play in preventing children’s exposure to harmful agents in their environment and in addressing the consequences for children who are exposed.

Education about the unique vulnerability of children to environmental pollution is one powerful tool for change. Teaching parents and children how to avoid harmful exposures and therefore prevent environmental illnesses is an important piece of prevention, which can occur at many levels and in different settings. However, education can and should go beyond parents and children. Clinicians can be especially helpful when serving as educators, investigators, and advocates for children. Most environmentally caused diseases have been diagnosed by alert, environmentally aware clinicians, and publication of case studies has allowed further education of other clinicians about environmentally mediated diseases. Increased awareness of the effects of environmental hazards on children can influence both exposure and treatment for children.

Community leaders and policymakers can use information presented by parents, clinicians, scientists, and other advo-
cates for children and the environment to take the unique vulnerability of children into account when establishing regulatory policy. To bring about change, policymakers must understand the basis for this unique vulnerability—that children are not little adults.

1. The fetus represents a unique period of time in life when many critical chemical reactions are occurring, the disruption of which can have far-reaching consequences. In addition, the environment of the fetus is unique.


3. This is an example of a threshold effect, where the health effects will not occur until the toxin reaches a particular level in the body.


5. The reason for the linkage of PCBs with birth defects is not completely clear. The most likely explanation is that, when the women were exposed to high levels of the PCBs, their bodies stored them in their fat tissues, where they slowly were released into the bloodstream. When these women became pregnant, the PCBs in the bloodstream crossed the placenta and affected the fetus. Taylor, P.R., Lawrence, C.E., Hwang, H.L., and Paulson, A.S. Polychlorinated biphenyls: Influence on birthweight and gestation. *American Journal of Public Health* (1984) 74:1153–54; Yu, M-L., Chen-Chin, H., Gladen, B.C., and Rogan, W.J. In utero PCB/PCDF exposure: Relation of developmental delay to dysmorphology and dose. *Neurotoxicology and Teratology* (1991) 13:195–202.


7. Storage in the woman’s bones of lead that became mobilized during pregnancy is the most logical explanation for this result, although definitive proof is awaiting further technological advances. Silbergeld, E.K. Lead in bone: Implications for toxicology during pregnancy and lactation. *Environmental Health Perspectives* (1991) 91:63–70.


13. In addition, because the risk of skin cancer is most closely related to the amount of sun damage the skin sustains during the first 18 years of life, an infant’s caregiver determines part of an infant’s personal risk for this disease later in life. Jackson, R.J. Testimony to the U.S. House of Representatives, Select Committee on Children, Youth and Families, 1990.

14. The evidence that exposure to electromagnetic fields is hazardous to children is inconclusive. Several studies have found an association between children’s cancer and exposure to electromagnetic fields, but a causal relationship between exposure and disease has not been established. For further information, see Savitz D. Overview of epidemiologic research on electric and magnetic fields and cancer. *American Industrial Hygiene Association Journal* (April 1993) 54:4:197-204; Hendee, W.R., and Boteler, J.C. The question of health effects from exposure to electromagnetic fields. *Health Physics* (February 1994) 66:2:127–36.


35. Although chemicals have been described in amniotic fluid, the absorption of these compounds through the skin has not been studied. Van Vunakis, H., Longone, J.J., and Milunsky, A. Nicotine and cotinine in the amniotic fluid of smokers in the second trimester of pregnancy. *American Journal of Obstetrics and Gynecology* (1974) 120:64–66.


48. For example, theophylline, a drug commonly prescribed for all age groups by physicians, is metabolized by several different chemical pathways. During the newborn period, these pathways operate at low levels, so theophylline remains in the body unchanged for a long period of time. However, the pathways become increasingly present over the next several months, breaking theophylline down so it is not in the body as long in the same chemical form. To keep the same level in the body, the prescribing physician has to increase the prescribed dose. In adolescence, the metabolic breakdown of theophylline slows again, possibly because steroid hormones are competing for the same pathways. (Levi, P.E. Toxic action. In *A textbook of modern toxicology*, E. Hodgson and P.E. Levi, eds. New York: Elsevier, 1987, p. 152.) To accommodate this change, the dose of the drug must be reduced to avoid overdosing the patient.


52. Tissues undergoing multiplicative growth (by cells dividing) and the final stages of growth and change (differentiation) are particularly susceptible to cancer. (Levi, P.E. Toxic action. In *A textbook of modern toxicology*, E. Hodgson and P.E. Levi, eds. New York: Elsevier, 1987, p. 152.) This increased susceptibility is due to the shortened time period for DNA repair and the multiple changes that are occurring within the DNA as the cell grows. The epidemic of scrotal cancer among the chimney sweeps of Victorian England shows how exposure to chemicals can interfere with these stages of development. (Nethercott, J.R. Occupational skin disorders. In *Occupational medicine*, J. LaDou, ed. San Mateo, CA: Appleton & Lange, 1990, p. 218.) Chimney sweeps were usually adolescent boys with developing secondary sexual characteristics who would climb naked inside chimneys to clean them, exposing their entire bodies to soot. Occupational exposure to cancer-causing chemicals such as soot was common for many occupations at the time, but scrotal tumors were uncommon in groups other than young male chimney sweeps. Thus, it is likely that the scrotum at this stage of development had increased susceptibility to the chemicals in soot.


55. In the brain, two other processes deserve mention: the making of synapses (synaptogenesis) and dendritic trimming. Nerve cells communicate through cellular structures called synapses, which are the basis for the circuitry of the brain. Up to two years of age, the brain makes synapses rapidly. After age two, while specific synapses are formed as learning occurs, formation is much slower. In fact, after age two, the brain begins actively to remove synapses, so that a two-year-old’s brain contains more synapses than it will at any other age. This process, called dendritic trimming, occurs so that the resulting network of neurons will be more specific.


60. At that level, adults do not have brain problems but may have impaired kidney function, decreased fertility, and problems with the peripheral nerves. Royce, S.E., ed. *Case studies in environmental medicine: Lead toxicity*. U.S. Department of Health and Human Services, Agency for Substances and Disease Registry, Washington, DC, 1990, p. 5.