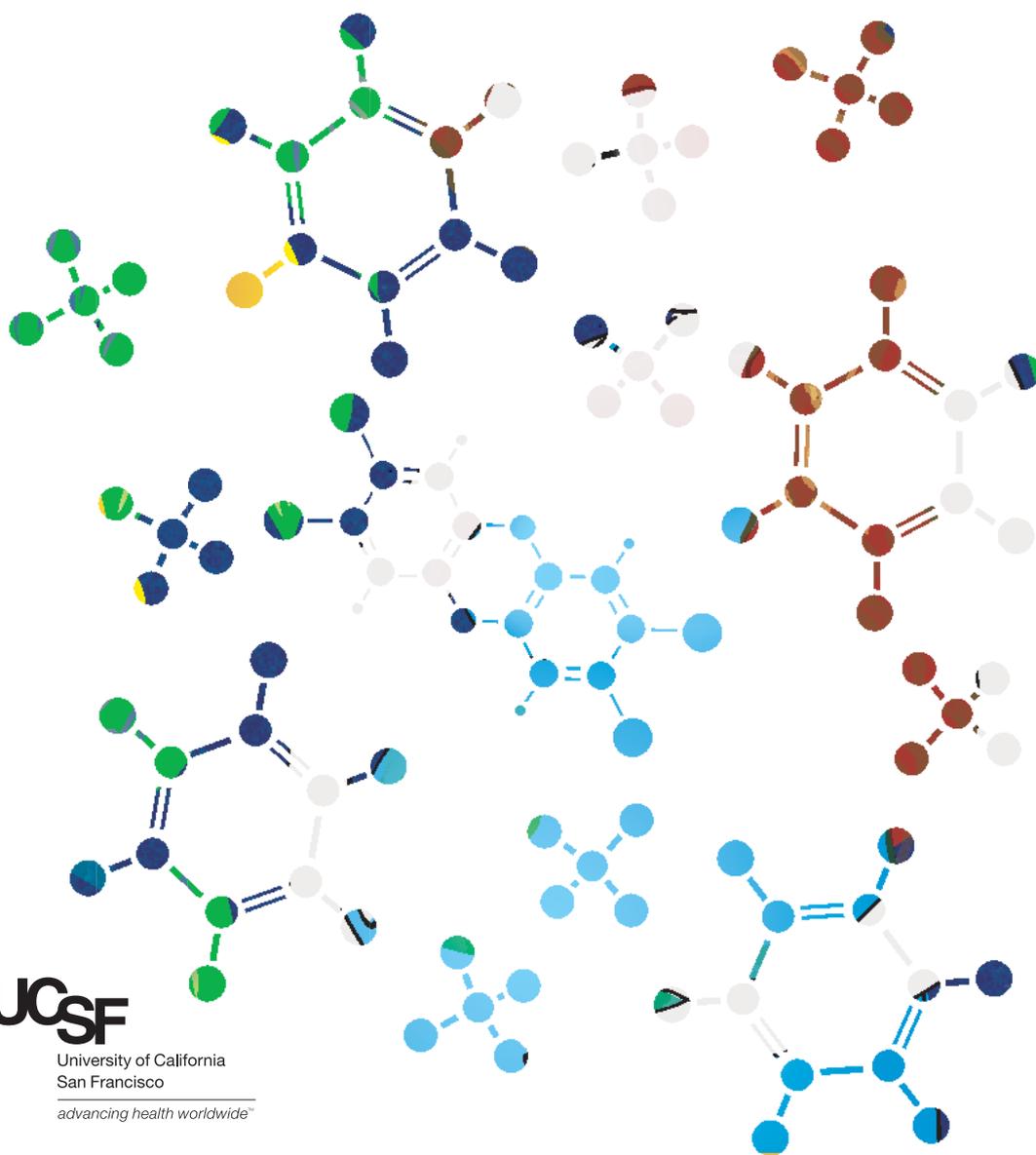


# Shaping Our Legacy: Reproductive Health and the Environment



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**Program on Reproductive Health and the Environment**  
Department of Obstetrics, Gynecology and Reproductive Sciences  
National Center of Excellence in Women's Health







# Shaping Our Legacy: Reproductive Health and the Environment

A report on the *Summit on  
Environmental Challenges to  
Reproductive Health and Fertility*

Convened by the University of California,  
San Francisco and the Collaborative on  
Health and the Environment

A Report by:

**Program on Reproductive Health and the Environment**  
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## About the *Summit on Environmental Challenges to Reproductive Health and Fertility*

The *Summit on Environmental Challenges to Reproductive Health and Fertility* (the *Summit*) was held January 28-30, 2007 and was co-sponsored by the UCSF Department of Obstetrics, Gynecology and Reproductive Sciences and the Collaborative on Health and the Environment (CHE). The goals of the *Summit* were:

- to review the science linking exposure to chemicals with impaired reproductive health and fertility; and
- to discuss new research directions, clinical care approaches, educational tools and policy initiatives to improve fertility, pregnancy outcomes, development and reproductive health.

Research presentations complemented discussions among health professionals, policy makers, government regulators, and patient, community, environmental and reproductive health advocates at work in the field. In addition, over 400 participants from these fields collaborated to form a series of recommendations for advancing the field of environmental reproductive health. More information on the *Summit* is available at [www.prhe.ucsf.edu/prhe/events/ucsfche.html](http://www.prhe.ucsf.edu/prhe/events/ucsfche.html).

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## A note on the terms and chemicals mentioned in this report

This report mentions numerous chemicals that have been studied in relationship to reproductive health. The Chemicals in Our Environment and Our Bodies chapter (page 55) provides more information on these chemicals, including what they are used for and how humans are exposed.

Also, terms that appear in purple are defined at the bottom of the page on which they first appear, or on the following page. They are also defined in the Glossary (page 51).

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# Reproductive Health, Fertility and Our Environment

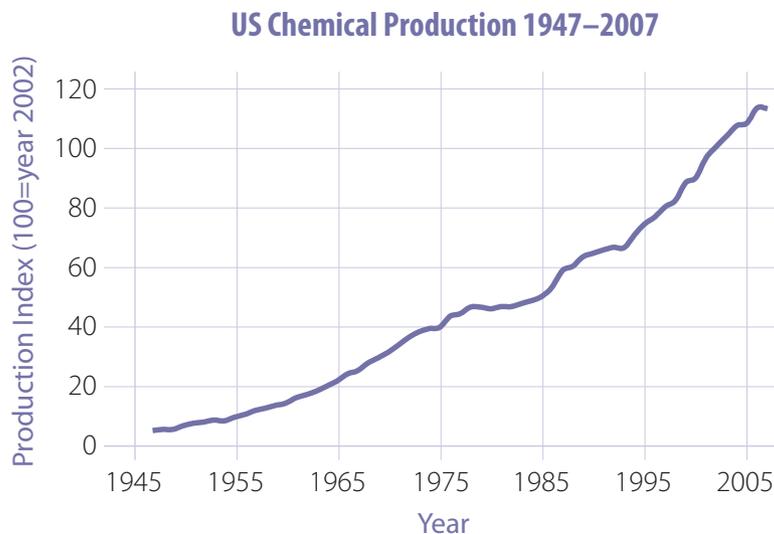
**We have made great strides in some aspects of our of health,** such as increased life expectancy and better cancer treatments, but in other areas we are losing ground. When it comes to our **reproductive health**, we are only about half as well off as our grandparents were. Sperm counts have decreased by 50 percent during the past 50 years in several industrialized regions. More women, particularly those under the age of 25, are reporting difficulty conceiving and maintaining their pregnancies. Compared with 30 years ago, 26 percent more women get breast cancer, 46 percent more men get testicular cancer and 76 percent more men get prostate cancer. Thirty percent more babies are born premature, and, on average, babies are born one week earlier now than they were 15 years ago. The second and third most common birth defects today are malformations of male reproductive organs. For the most part, we don't know exactly why this is happening. But we do have substantial clues that suggest something in our environment is involved.

Since World War II, chemical production in the United States has increased more than twenty-fold and the number of chemicals registered for commercial use has grown by over

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**Reproductive health** refers to the health and healthy functioning of the female and male reproductive systems during all stages of life. Reproductive health means that women and men are capable of conceiving, that a woman is able to maintain a pregnancy to full term and to breastfeed, and that the baby is born healthy and properly developed. Reproductive health also means that children will not develop diseases or disabilities later in life that are caused by exposures they experienced in the womb or during infancy, early childhood or adolescence, and that they will be able to conceive and bear healthy and properly developed children.





30 percent since 1979. Manufactured and mined chemicals are now everywhere in our environment — in our air, water, food, drinks, cosmetics, personal care products and everyday household items. Consequently, they get into our bodies when we breathe, eat, drink and come into skin contact with consumer products. National studies that measure human exposure to chemicals (called **biomonitoring** studies) have been conducted since 1976. These studies show that nearly everyone has measurable amounts of numerous chemicals in their bodies (phthalates, bisphenol A, lead, cadmium, perfluorinated compounds and perchlorate, to name a few). Once inside our bodies, these chemicals can create havoc. Some can kill cells directly. Others can interfere with the way cells, tissues and organ systems operate by mutating (damaging) **genes** or changing the way genes function. Yet others can

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**Biomonitoring** A kind of research that measures the types and amounts of chemicals in people's bodies. Biomonitoring studies collect samples of body fluids (such as blood, urine and breast milk) and measure the types and levels of chemicals or chemical breakdown products in these samples. This information gives us an understanding of human exposures to chemicals that compliments measuring chemicals in the environment (air, water, food, consumer products, etc.).

**Genes** Molecules that contain information and instructions for making proteins and other compounds that are necessary for a living organism to develop, grow and survive. Genes are passed down from parents to children, and are present in every cell in the body. Genes are organized in strands called DNA. DNA, in turn, is organized in structures called chromosomes.

cause damage by scrambling our bodies' communication and regulatory systems. A list of chemicals we are commonly exposed to, including those mentioned throughout this report, is included in *Chemicals in our Environment and Bodies*, which begins on page 55.

We have known that exposure to chemicals can harm human reproduction since Roman times, when lead was first recognized to cause miscarriage and infertility in men and women. In the mid-1950s we learned that the placenta does not protect the fetus from the damaging effects of chemicals, when women who ate mercury-contaminated fish while pregnant gave birth to children with debilitating neurological and reproductive problems. Shortly thereafter, pregnant women who took therapeutic doses of a morning-sickness drug called thalidomide without experiencing any side effects themselves gave birth to babies with severe limb deformities. Through these experiences, we realized that the fetus can be uniquely sensitive to chemical exposures. In the early 1970s, we found out that chemicals can damage the development and health of our offspring in less visible but equally damaging ways: Daughters of women who had taken a miscarriage-prevention drug called DES during pregnancy developed a rare form of cancer that can affect the cervix and the vagina. Soon after, both daughters and sons were discovered to have high rates of reproductive problems and infertility. Over time we discovered that these reproductive problems could be passed on to a third generation, despite the fact that the grandchildren of the women who had taken DES never themselves took the drug (see page 26).

These painful lessons resulted from much higher levels of exposure to chemicals than the average person living in the United States experiences. For years it was assumed that our everyday level of exposure to chemicals would not harm our fertility, reproduction or development.

However, over the past twenty years we have come to realize that this assumption may not be true. Research has demonstrated that the levels of chemicals that an average person is exposed to can prevent genes from functioning normally or interfere with the body's regulation system and, as a result, increase the risk of disease, malfunction and infertility. We have

We know that development is susceptible to disruption by environmental factors. We've proven that. It is not, in fact, a debate.

*Lou Guillette*



also learned that the mixture of chemicals we are exposed to can be much more toxic than exposure to the same chemicals on an individual basis.

We are also surrounded by evidence of declining fertility and reproductive success in animals that inhabit our same environments and that drink the same water, breathe the same air and eat food grown in the same terrain. Chemical pollution in our lakes and rivers is causing problems with sexual development, infertility and decreased survival in amphibians and alligators. Consumption of chemical-contaminated prey is thought to explain, in part, the failure of the Orca whale and Florida panther populations to rebound, despite endangered species protections.

Humans look, think, function and live quite differently from amphibians, alligators, whales, panthers and other animals, but we reproduce in surprisingly similar ways. We have the same reproductive organs, we produce the same hormones that orchestrate our reproduction, and our offspring develop in parallel processes. This commonality means that if a chemical harms an animal's ability to reproduce — either by damaging an organ or by disrupting vital communication between organs — it is likely to do the same to humans. And, when scientists see that a chemical causes similar effects in several types of animals, their concern that humans could also be harmed increases.

The lessons we have learned from science and from observing the fate of animals that share our environment beg two very difficult questions: Are the chemicals we have introduced into our environment and our bodies interfering with our ability to conceive and bear healthy children? And, if so, how do we stop endangering our survival and, instead, start shaping our legacy?

### ***Summit on Environmental Challenges to Reproductive Health and Fertility***

To begin to answer these questions, the UCSF Program on Reproductive Health and the Environment and the Collaborative on Health and the Environment's (CHE) Working Group on Fertility and Early Pregnancy Compromise convened the

*Summit on Environmental Challenges to Reproductive Health and Fertility* (also referred to as the *Summit* in this report). Over 400 key players from the research, health care, environmental justice, advocacy and policy arenas gathered January 28-30, 2007, to share their research and expertise on what information and changes are needed to improve our collective understanding of **environmental reproductive health**. This meeting helped unite an emerging environmental reproductive health movement — an interdisciplinary

effort to understand the effects of chemical exposures on fertility and reproductive health and to leverage this understanding to create healthier environments for reproduction through policy change, improved medical care and public awareness.

This report provides a general overview of the science presented at the *Summit* and outlines the participants' recommendations on ways to create environments that are healthier for fertility and reproduction.

The UCSF **Program on Reproductive Health and the Environment (PRHE)** is a new transdisciplinary program dedicated to advancing scientific inquiry, professional training, citizen education, and health policies that reduce the impact of chemical exposures on fertility and reproductive health. [www.p rhe.ucsf.edu](http://www.p rhe.ucsf.edu)

The **Collaborative on Health and the Environment (CHE)** is a diverse network of over 2,900 individual and organizational partners in 45 countries and 48 states, working collectively to advance knowledge and effective action to address growing concerns about the links between human health and environmental factors. [www.healthandenvironment.org](http://www.healthandenvironment.org)

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**Environmental reproductive health** A collaborative, interdisciplinary effort to understand and reduce the harm that chemical exposures cause to fertility, pregnancy, development, growth and health throughout life. This field includes the work of scientists, researchers, clinicians, policymakers, health-affected groups, community and advocacy groups, and the media.



# The Risks to Reproductive Health and Fertility

## **Conception, pregnancy and fetal development are delicate, complex and highly orchestrated processes.**

For conception to succeed, a sequence of events involving both parents must occur within a narrow time frame. Embryo and fetal development transform one cell into over one trillion cells of more than 300 different types. These cells divide, migrate to different areas of the forming body and specialize into tissues and organs. Systems of communication between these organs are established, and genes in the various types of cells are programmed to perform specific functions.

Many of these events are directed by hormones produced by the father, the mother and the fetus (see page 12). Hormones are vital chemical substances that certain organs, called endocrine glands, make in order to trigger other cells, tissues or organs to function in a particular way. Hormones are secreted by endocrine glands and travel through the bloodstream to the cells whose function they are meant to direct. Through a series of chemical reactions, these hormones activate genes in cells to produce **proteins** that ultimately modify how the organ functions. The **endocrine system** is efficient: The same hormone can trigger many types of responses in different cells of numerous organs. For example, the hormone estrogen communicates with cells in at least 12 tissues and

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**Proteins** Large, complex molecules that the body manufactures based on information stored in genes. (Different genes produce different proteins.) Each cell in the body contains thousands of different proteins and these proteins play many critical roles in the cell and in the body. For example, proteins perform most of the work performed by cells, and they give cells their shape and help them to move. Proteins make up the hormones that transmit signals throughout the body and the antibodies that recognize foreign substances in the body. Proteins also carry important molecules, such as oxygen and hormones, through the bloodstream.



organs, including the brain, bones, heart, lung, uterus and prostate. The endocrine system is also very specific: Hormones come into contact with all of the cells in the body, but they can only alter the function of cells that have been genetically programmed to respond to them. These cells have specific chemical molecules, called hormone receptors, that are capable of bonding chemically with specific hormones. This bond is what triggers the chain of chemical reactions that alter the function of the organ.

Many of the chemicals we are exposed to in our environment and that get into our bodies are structurally and chemically similar to hormones. As a result, these chemicals can interact with hormone receptors in cells and trigger changes in how genes, cells and organs function. They can also interfere with the ability of endocrine glands to produce hormones. These chemicals are called **endocrine disrupting chemicals** because they disrupt the function of the endocrine system. They do this in at least two ways. First, they take away the endocrine system's control. Endocrine glands produce hormones only when a particular response is needed. In contrast, endocrine disrupting chemicals can trigger a response any time they are in the body. Second, they take away the endocrine system's specificity. Because endocrine disrupting chemicals do not have the exact same structure and chemical composition as hormones, they do not react with the exact same set

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**Endocrine system** An integrated system of hormone-producing glands that control body functions that happen slowly, such as reproduction, development, growth, mood, tissue function and metabolism. Endocrine glands include the pituitary, the thyroid, the thymus, the pancreas, the adrenals and the testes (in males) or the ovaries (in females). The endocrine system works in coordination with the nervous system and the immune system to regulate fertility and reproduction.

**Endocrine disrupting chemicals** Chemicals that interfere with the function of the endocrine system (see endocrine system) in one or more ways. Once inside the body, endocrine disrupting chemicals can alter the amount of hormones that are produced or released into the bloodstream, or they can alter the supply of proteins that transport the hormones through the bloodstream. Endocrine disrupting chemicals can interfere with the ability of hormones to react with hormone receptors, thus blocking vital biological messages and responses. These chemicals can also send artificial messages and cause undesirable biological responses. Lastly, endocrine disrupting chemicals can alter the body's supply of hormones by disrupting the process through which hormones are broken down and eliminated from the body.

of receptors and they do not trigger the exact same genetic responses that natural hormones do. For example, the pharmaceutical drug DES turns on 119 out of the 192 genes that natural estrogen activates in the cells of a mouse's uterus, but also signals nearly 200 additional genes that natural estrogen does not affect. Other chemicals can interact with receptors and block a necessary genetic response from occurring. The net effect is that exposure to endocrine disrupting chemicals can cause a series of untimely and nonsensical biological responses that may prevent conception, interfere with fetal development or otherwise damage our reproductive health.

Endocrine disrupting chemicals are typically described in terms of the natural hormone or hormones they most closely mimic or disrupt. For example, DES triggers genes that respond to the hormone estrogen and is therefore described as an estrogenic chemical. The pesticide vinclozolin blocks the signal from the androgen (male) hormone testosterone and is therefore described as an anti-androgen.

In addition to disrupting the function of the endocrine system, exposure to chemicals can harm fertility, fetal development and reproductive health by causing **genetic mutations** or by altering **gene expression**. Genes contain the information and instructions for producing proteins that determine how a cell functions, similar to the way a recipe holds the information on how to prepare a meal. All cells contain the same set of genes, but only a subset of genes are programmed to be expressed, or active, in any given type of cell,

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**Genetic mutation** A permanent change in the information contained in a gene. This change can cause problems with the proteins that the gene produces. For example, the protein may malfunction or may not be produced at all. The consequences of genetic mutation can range from slight to severe and life threatening. Genetic mutations can be inherited from a biological parent (called hereditary mutations) or they can occur during a person's lifetime (called acquired mutations). Acquired mutations are caused by environmental factors, such as radiation or chemical exposure. They can also occur when a cell divides.

**Gene expression** The process by which information stored in a gene is accessed and used to make (in most cases) a protein. Gene expression varies in response to changes in the internal (body) or external environment, so that different amounts and types of proteins are produced over time, depending on the body's needs. Hormones regulate how much and which genes are expressed in cells.

Endocrine disrupting chemicals are not pure hormones. They, in fact, turn on and shut off genes that the body's hormones will never affect. Is this what's causing the harm we see?

*Lou Guillette*

just as only a subset of recipes in a cookbook are used to prepare breakfast. A genetic mutation is an error in the recipe for making a protein. When genes are mutated, the proteins they make are faulty and these faulty proteins prevent cells, tissues and organs from functioning normally. In contrast, when gene expression is altered, the collection of genes that is turned on or off in a cell is inappropriate for the kind of cell it is, much like it would be inappropriate to prepare soup, coleslaw and a hamburger for breakfast. Altered gene expression can also cause genes to respond abnormally to hormonal signals, leading to the production of either too much or too little of a protein. Altered gene expression may mean that a gene that normally produces a lot of a protein that kills tumors barely produces any, or that the collection of genes that are programmed to be active in cervical cells make these cells behave more like uterine cells. Altered gene expression can be as harmful to health as genetic mutations.

If we are all exposed to chemicals that can harm our fertility and reproductive health, why is it that we are still able to reproduce? The adult, fully developed human body is resilient and has mechanisms for adapting to and repairing damage from chemical exposure. Much like a thermostat that turns on the heat or the air conditioning when it gets too cold or too hot, our biological systems maintain a steady level of performance by adapting to times of surplus and times of shortage. For example, if we are exposed to a chemical that blocks the thyroid's ability to produce a hormone that is crucial for fertility and fetal development, our brain will produce a second hormone that signals the thyroid to intensify hormone production. Through feedback mechanisms that monitor and adjust our biological functions, our bodies are able to compensate for challenges from chemical exposures, but only as long as the challenges are minor. Other aspects of our environment (such as nutrition, exercise, stress, health status) as well as our age and genetic background determine how resilient our bodies are to the threats posed by chemical exposures.

There are times when the body cannot adapt. During certain periods of development — in the womb, during infancy,

It may come as no surprise that you can wreak havoc if you disturb the intricate and rapidly changing patterns of gene expression that occur during development.

*Cheryl Walker*

early childhood and puberty — we do not have all of the systems in place to compensate for and repair damage from chemical challenges. Furthermore, these periods of development are times when cells are dividing, growing and being programmed to specialize into tissues and organs. It is during these times that communication systems between organs are established and the thermostats that control adaptive responses are being set. And it's a rather inflexible process. Developmental events must occur in a specific hormonal milieu and within a narrow time frame. Interrupting any of these processes, which chemical exposures can do, can produce severe and permanent defects in our reproductive systems. Furthermore, these defects can be passed on to subsequent generations without any additional exposure.

Females and males initially develop the same reproductive system tissues. In about the fifth week of pregnancy, the genetic sex of the embryo determines whether or not certain cells develop and produce the hormone testosterone, and this determines whether the fetus will develop into a male (testosterone produced) or a female (testosterone not produced). From there, the process of development continues to be determined by how much of which hormones the fetus produces. Three male hormones — testosterone, dihydrotestosterone and Müllerian inhibiting hormone — shape the development of the male reproductive system. Though less well understood, it is thought that the hormones estrogen, inhibin and follicle stimulating hormone have roles in shaping the development of the female reproductive system. Hormones also play a key role in setting up brain functions involved in reproduction. This process starts just before birth and continues through the first years of life. If the correct amounts or types of hormones are not produced by the fetus, if hormone signaling does not occur or if the developing tissues and organs are exposed to the wrong types of hormones, the reproductive system doesn't develop correctly. This can lead to the need for surgery, and to infertility, cancers and other diseases of the reproductive organs.



It's a tremendous irony that we believe that the womb is safe, and that something that is supposed to be so sacred — where life begins — is where the problem begins.

*Mary Lou Ballweg*

## Hormones Important to Fertility, Reproduction and Fetal Development

**Dihydrotestosterone** A potent form of testosterone that is essential to the development of the male reproductive system during fetal life — specifically, the prostate gland, the penis, the urethra and the scrotum — and the male brain. During puberty, dihydrotestosterone stimulates the maturation of the male reproductive system, including facial and body hair growth, the deepening of the voice and prostate function. In adult males, dihydrotestosterone stimulates sperm development and maturation and plays an important role in sex drive. Dihydrotestosterone is produced in the prostate gland, testes, hair follicles and adrenal glands by special proteins that convert testosterone into this hormone.

**Estrogens** A group of hormones that are most known for their role in directing the development and function of the female reproductive system, but also are essential to fertility and reproduction in men. During fetal development, estrogens guide the development of the female reproductive system, including the ovaries, uterus, vagina and external genitals. In early infancy, estrogens shape the development of the brain, including the endocrine glands in the brain that will regulate reproduction later in life. In adolescence, estrogens direct the development of breasts, the growth of body hair and the distribution of fat in girls.

Estrogens are essential to fertility and reproduction in both women and men. For example, in women, estrogens signal cells lining the uterus to grow and thicken in order to support a fertilized egg, and, in the event of pregnancy, these hormones guide and maintain pregnancy and prepare the breasts for milk production. In men, estrogens influence the function of the prostate, the testes (testicles) and other sex organs and tissues, and have an important role in sperm production.

In females, estrogens are produced primarily by cells in the ovaries. In males, estrogens are produced by cells in the testes. Small amounts of estrogens are also produced in both sexes by cells in the adrenal glands, brain, liver and fat tissue.

**Follicle Stimulating Hormone** (also called FSH) One of the endocrine hormones produced by the pituitary gland in the brain. In females, FSH stimulates ovarian follicles to mature in preparation for ovulation and fertilization. In males, FSH prompts the development and production of sperm.

**Lutenizing Hormone** (also called LH) One of the endocrine hormones produced by the pituitary gland in the brain. In females, LH triggers ovulation. In males LH stimulates cells in the testes to produce testosterone.

**Progesterone** A hormone that is most known for its role in female fertility and pregnancy, but is also important for male fertility and reproductive health. In females, progesterone signals the lining of the uterus to prepare to receive and nourish a fertilized egg. In the event of pregnancy, progesterone, in combination with estrogens, maintains and directs pregnancy and signals the growth of milk-producing glands in the breast. Progesterone also controls breast growth in girls during puberty. In males, progesterone is essential for the maturation and production of sperm. Progesterone is produced mainly by cells in the ovary (in females) and in the testes (in males) and is also a building block for producing testosterone and estrogens.

**Testosterone** A hormone that is most known for its role in male reproductive health and fertility, but is also important to female health. During male fetal development, testosterone (produced primarily by cells in the testes) directs the growth and development of the reproductive system, including the testes and the duct system through which sperm travel, and signals the testes to descend into the scrotum during the last two months of fetal life. In early infancy, testosterone is converted into estrogen in the brain; this estrogen masculinizes and programs the brain to direct reproduction later in life. Testosterone triggers puberty in boys, directs the maturation of the male reproductive system during adolescence, and is essential to sperm production in adulthood. In females, testosterone is produced in lesser amounts by the ovaries and the adrenal gland, and is important for maintaining muscle mass and sex drive.

**Thyroid Hormones** Produced by the thyroid gland in both males and females. Thyroid hormones are essential to nearly all body functions, including the production of other types of hormones, the normal function of the ovaries and the menstrual cycle in women, the production and quality of sperm in men, and thus to fertility. Thyroid hormones are also essential to brain, nervous system, bone and muscle development during fetal development, childhood and adolescence. Thyroid hormones are unique in that they are made, in part, out of iodide — an element that the body does not produce itself, and therefore must be obtained through our diets. (This is why foods, particularly salt, are supplemented with iodine.)

## Chemical Exposures and Female Reproductive Health

Exposure to chemicals can damage female reproductive function and health in a variety of ways. Some exposures cause structural malformations and disease; others more subtly damage tissues or cells of reproductive organs. Still others interfere with the endocrine system. Exposure to chemicals has been linked to impaired fertility and reproductive function as well as to a higher risk of cancers, diseases and disorders of the **female reproductive tract** and ovaries.

### *Fibroids*

Fibroids are noncancerous tumors that grow in the middle muscle layer of the uterus. They are the leading cause of **hysterectomy** in the United States, can be extremely painful, and are also a risk factor for infertility, miscarriage, abnormal position of the fetus in the womb, premature labor, and complications with the placenta. Estimates are that between one half and three quarters of all women of reproductive age have fibroids (only some of these women are diagnosed because their tumors grow large enough to cause recognizable symptoms). Despite the common occurrence of fibroids, little is known about what causes them. We do know that fibroids are partly genetic (hereditary) and that the hormones estrogen and progesterone, which are produced by the ovaries and can also be given as medication, cause existing fibroid tumors to grow.

Exposure to estrogenic chemicals in our environment may have a role in causing fibroids. Women exposed to DES in the womb are two-and-a-half times more likely to develop fibroids. Rodents exposed to DES and other estrogenic chemicals also have an increased risk of fibroids. Recently, researchers have looked at how exposure to estrogenic

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**Female reproductive tract** A term used to refer to the fallopian tubes, uterus, cervix and vagina.

**Hysterectomy** An operation to remove a woman's uterus, and in some cases, her ovaries and fallopian tubes as well. It is used to treat a variety of diseases or conditions, including fibroids, endometriosis and cancer of the uterus, cervix or ovaries. Hysterectomy is the second most common surgery among US women, with over 600,000 performed each year. One out of every three women in the United States has a hysterectomy by the age of 60.

chemicals in our environment might cause fibroids by studying the effects of chemical exposure on rodents. They have focused on exposure during the time that the uterus is developing, specifically, when muscle cells in the uterus are being genetically programmed for how and when they will respond to estrogen during the menstrual cycle, later in life. The researchers found that exposure to estrogenic chemicals during this period of development makes genes in the muscle cells permanently hypersensitive to estrogen. And, because estrogen triggers fibroids to grow, this hypersensitivity causes existing fibroids to grow faster and larger than they normally would in these animals. These experiments also showed that cells that will become fibroid tumors later in life may be created, in part, by exposure to chemicals in the womb.

So far, only a few chemicals have been screened for these effects in animals, including DES, genistein (a natural hormonal chemical found in soy food products) and bisphenol A (a chemical commonly used in clear, shatter-proof plastic water and baby bottles and in the material that lines the inside of canned foods and beverages). But it is likely that a host of other estrogenic chemicals may have similar effects on the development of the uterus and the risk of fibroids. It is also worrisome that these effects are not the result of unusually high exposures: In fact, exposure to the same level of bisphenol A that is currently found in our bodies causes these harmful effects in animals and in laboratory studies of cells.

### *Endometriosis*

Endometriosis is a disease that causes the tissue lining the inside of the uterus (called the endometrium) to grow outside of the uterus and in other parts of the body, for example, the ovaries, abdomen and pelvis. Estimates are that about 10 percent to 20 percent of women of reproductive age in the United States suffer from endometriosis. Younger women are more frequently diagnosed with endometriosis now than in the past, and specialists believe that the disease has become more common since World War II. Endometriosis, like fibroids, can be extremely painful and is a leading cause of infertility and hysterectomy. Risk factors for this complex disease are largely unknown.



However, we do know that the immune system is involved, that the hormone estrogen causes endometriosis tissue to grow and that endometriosis tissue does not respond normally to the hormone progesterone.

The possibility that chemical exposures might be one of the factors that cause endometriosis was first recognized in 1993, when rhesus monkeys that had eaten food contaminated with dioxins (chemicals that are formed when items that contain chlorine are burned) developed endometriosis 10 years later. Researchers looked further at this possible link by using surgery to implant endometrial tissue outside the uterus of monkeys and rodents. Animals that were exposed to dioxins and certain dioxin-like polychlorinated biphenols (also called PCBs) developed endometriosis as a result. And, the more these animals were exposed, the more severe the disease became. Exposure to dioxins and dioxin-like PCBs also altered the way immune cells in the endometrium functioned and the way endometrial cells responded to the hormone progesterone. These effects in animals are very similar to what we see in the endometrial tissue of women with endometriosis.

Of particular concern is that humans are exposed to levels of dioxins that are two to twenty times higher than the levels that cause monkeys to develop endometriosis. And the question of whether exposure to other chemicals that affect the immune and endocrine systems also contributes to the development of endometriosis remains unanswered. Increased rates of endometriosis among DES daughters and higher levels of phthalates (an endocrine disrupting chemical used in fragrances and in soft plastics) in women with endometriosis suggest that the answer may be yes.

### ***Reproductive Tract Development and Disease***

Exposure to estrogenic chemicals during fetal development can also harm the development of organs in the female reproductive tract. Many women exposed to DES in the womb have a uterus that is abnormal in size and is shaped like a T instead of a triangle. These deformities make it harder to get pregnant and cause higher risks of miscarriage and premature labor and birth. Exposure to

DES during fetal development also increases the risk of a rare form of cancer that can affect the cervix and the vagina. Recent inquiry has focused on how DES causes this harm. Researchers have found that exposure to DES causes permanent changes in the expression of a group of genes called Hox genes that are essential to the development of the reproductive tract and, later in life, to fertility. These permanent errors in how Hox genes function cause abnormalities in the tissues of reproductive tract organs (the fallopian tubes, uterus, cervix and vagina). As a result, the tissue in the uterus looks and behaves like tissue that is normally found in the fallopian tubes; the tissue in the cervix is more like uterine tissue; and tissues in the vagina look and act more like tissues normally found in the uterus and cervix. These errors in tissue development are believed to contribute to the increased risk of cervical and vaginal cancer and the high rates of infertility in women exposed to DES in the womb.

Researchers are beginning to look at whether the estrogenic chemicals we are commonly exposed to also alter Hox gene expression in reproductive tract tissues the way DES does. To date, they have found that exposure to bisphenol A and the pesticide methoxychlor during fetal development also modifies the programming of Hox gene expression in mice. As a result, fertilized eggs are less likely to implant in the uterus, offspring have abnormally developed bones and the uterus of female offspring appears to also have structural defects.

### *Effects on Ovarian Follicles*

Healthy ovaries and **ovarian follicles** are essential to both a woman's fertility and her overall health. A woman's entire, lifelong supply of ovarian follicles is created during fetal development by about the 20th week of gestation. No new ovarian follicles are produced after this time. We know little about the conditions that support the growth of an ample and healthy supply of ovarian follicles prior to birth. However, there is growing evidence that exposure to

Reproductive health problems, including cancer, can be determined by chemical exposures that occur early in life, possibly decades before the disease becomes apparent.

*Cheryl Walker*

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**Ovarian follicles** A single egg, surrounded by layers of two types of cells which produce the hormones estrogen and progesterone and which nurture the egg as it matures during the menstrual cycle.

Granddaughters' eggs are scrambled by environmentally relevant exposure to bisphenol A in the womb.

*Pete Myers*

estrogenic chemicals during development can affect both the quality and the quantity of ovarian follicles.

Alligators living in Lake Apopka, Florida, are exposed to pollution from nearby industry and agriculture and consequently suffer from reduced fertility and increased fetal death. Problems with ovarian development, caused by exposure to estrogenic chemicals in the water, contribute to this reduced survival. The female alligators have more ovarian follicles with two or more egg cells, instead of one. These deformed follicles, called multioocyte follicles, have lower rates of fertilization and embryo survival.

Laboratory mice and rats exposed to estrogenic chemicals, such as DES, bisphenol A, genistein or ethinyl estradiol (the synthetic estrogen in birth control pills), when their ovaries are forming also develop multioocyte follicles. Some women develop multioocyte follicles, but their association with exposure to estrogenic chemicals has not been explored. However, wildlife and animal data indicate that such research is needed.

Exposure to estrogenic chemicals during fetal development can also damage the genetic quality of ovarian follicles. For example, a recent study reports that when developing mice are exposed to levels of bisphenol A commonly measured in humans, nearly half of the eggs they ovulate later in life have **chromosomal abnormalities**. Embryos that develop from these eggs also have this genetic defect. Chromosomal abnormalities are the leading cause of miscarriage, birth defects and mental retardation in humans.

These findings are new and it is unknown whether these effects are also occurring in humans. However, an association between exposure to bisphenol A and recurrent miscarriages in humans has been reported. Whether other

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**Chromosomal abnormalities** A term used to describe problems with the number or the structure of chromosomes (the structures that contain genetic information) in a cell. These problems are inherited or can occur spontaneously in an individual. Chromosomal abnormalities produce problems with the genetic information in a cell: Genes can be missing or duplicated, or located in the wrong place or order. These problems prevent cells from functioning normally and can have a range of consequences on health.

similarly-acting chemicals that interfere with estrogen signaling can damage the genetic quality of ovarian follicles is a question that science has not yet answered, but the pattern and clues suggest the answer is likely yes.

### ***Early or Delayed Puberty***

Puberty begins a set of orchestrated biological events and hormonal changes that result in the ability to reproduce. A girl's age at puberty is a risk factor for diseases that are influenced by hormones that are produced in higher amounts after sexual maturity. For example, the duration of exposure to estrogen is a risk factor for breast cancer: The earlier puberty (and the production of estrogen) begins, the longer a woman is exposed to estrogen, and the higher is her risk of developing breast cancer. Accumulating evidence suggests that girls in the United States are reaching puberty at younger and younger ages, prompting attention to their exposure to chemicals that may adversely alter the timing of sexual development. Laboratory and wildlife studies point to numerous chemicals that can hasten puberty in animals, including the pesticides DDT, atrazine, vinclozolin and chlordecone; PCBs; dioxins; polybrominated biphenyls (a type of flame retardant); bisphenol A; alkylphenols (cleaning agents used in detergents and other consumer products); and DES. Recent studies in girls have found associations between younger age at puberty and exposure to many of these chemicals, including PCBs, polybrominated biphenyls, dioxins, phthalates and phytoestrogens (estrogenic chemicals found in plant foods such as beans, seeds and grains). We also know that exposure to lead delays puberty in girls. However, this harmful effect has been reduced by the removal of lead from gasoline and consumer products. It is likely that more connections between chemicals and altered timing of puberty in humans will be drawn as nascent research on this topic continues.

### ***Menstrual Cycle Irregularities***

Menstrual cycle irregularities (such as altered cycle length, abnormal bleeding, lack of ovulation, absence of menstruation and disrupted hormonal control of the menstrual cycle) can cause subfertility or infertility and can also be

a sign of other underlying problems with reproductive health. Exposure to numerous chemicals has been linked to menstrual cycle irregularities in adult women. For example, women exposed to lead at work as well as those who drink water contaminated with chlorodibromomethane (a chemical that can be produced when water is disinfected using chlorine) have shorter menstrual cycles and, in the case of lead, more frequent, intense and prolonged bleeding. Women exposed to dioxins, endocrine disrupting pesticides, PCBs or chemicals used in the semiconductor industry have longer cycles and a higher chance of missed periods. Women exposed to a variety of endocrine disrupting chemicals have lower levels of hormones that regulate the menstrual cycle, including follicle stimulating hormone, progesterone and estrogen. No studies have examined the effect that exposure to endocrine disrupting chemicals during fetal development may have on menstrual cycle irregularities later in life.

### *Premature Menopause*

Menopause begins to occur when the ovaries are no longer able to transform ovarian follicles into mature eggs that are ready for ovulation and fertilization. Normally, menopause occurs between the ages of 45 and 55. Premature menopause is when a woman experiences menopause before the age of 40. Premature menopause signals a problem with the supply of ovarian follicles or with the ovaries' ability to support the process of developing an ovarian follicle into a mature egg.

We have only begun to understand the role that chemical exposures play in altering the timing of menopause. We know that medical chemotherapy treatments can trigger menopause temporarily or permanently, and that women exposed to dioxins, DDT, DDE or other pesticides as well as women who smoke experience menopause at younger ages. The chemical benzopyrene, which is found in cigarette smoke, has been shown to destroy ovarian follicles in studies of both humans and animals. Animal studies provide hints about the ways that chemicals may cause premature menopause in humans. For example, exposing female mice to lead prevents their ovarian follicles from developing into mature eggs. And, exposing rodents and

rabbits to a wide array of chemicals destroys ovarian follicles before they begin to mature into eggs. These chemicals include mancozeb (a pesticide), dibromoacetic acid (a chemical that can be produced when water is disinfected using chlorine), polycyclic aromatic hydrocarbons (a group of chemicals that are formed from the incomplete burning of coal, oil and gas, garbage, cigarettes or charbroiled meat), cyclophosphamide (a chemotherapy drug) and 4-vinylcyclohexene diepoxide (an industrial chemical). Whether these chemicals deplete the lifelong supply of ovarian follicles or interfere with the process of follicle maturation in women is an area of research that needs exploration.

### **Chemical Exposures and Male Reproductive Health**

The development of the male reproductive system depends on sufficient production, by the male fetus, of androgen (male) hormones such as testosterone, dihydrotestosterone, Müllerian inhibiting hormone and insulin-like 3. Müllerian inhibiting hormone prevents the development of tissues that would otherwise transform into a female reproductive system. The other hormones cause the remaining tissues to develop into the male system. Testosterone is essential for the development of the duct system through which sperm travel. It is also the raw material for making the hormone dihydrotestosterone, which is essential for the development of the penis, the scrotum, the prostate and, along with the hormone insulin-like 3, the descent of the testes (testicles) into the scrotum.

The male fetus must produce quite large amounts of androgen hormones to support the development of the male reproductive system. For example, the levels of testosterone during fetal life can reach about two-thirds the levels in adult life. Anything that interferes with the production of androgen hormones can disrupt the development of the male reproductive system. In adult life, androgen and other endocrine hormones are needed to support the production of sperm.

Exposure to chemicals can produce a variety of effects on male reproductive health by interfering with hormone production or signaling, by altering the normal programming of gene expression or by damaging or destroying vital cells, to



name but a few ways. These effects range from subtle problems with sperm production to obvious deformities or diseases in male reproductive organs.

### *Testicular Dysgenesis Syndrome*

Research over the past ten years has drawn a connection between various malformations and diseases of the male reproductive system. These include a birth defect of the penis (**hypospadias**), a birth defect of the testes (**undescended testes**), low sperm counts and testicular cancer. These malformations and diseases tend to cluster in men (in other words, men with one condition are more likely to also have the other conditions). These four conditions are currently considered to be symptoms of an overarching **testicular dysgenesis syndrome** because they are thought to have a common cause: During the early stages of fetal development, something goes awry with the development and organization of two types of very important cells in the testes. One result of this problem is that the fetus does not produce enough hormones to support

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**Hypospadias** A defect in the development of the urethra in the penis (the urethra is the tube through which urine and semen travel). The urethra normally runs the full length of the penis, with the opening at the tip of the penis. In hypospadias, the opening instead forms on the underside of the penis or below the penis. Hypospadias is the second most common birth defect in the United States and national studies report that the rate of hypospadias has more than doubled since the 1970s.

**Undescended testes** A birth defect in which one or both testes fail to move from near the kidneys into the scrotum during fetal development. This process of migration occurs in two stages and each stage is thought to be controlled by different hormones. The hormone called insulin-like 3 is thought to direct the first stage (when the testes move from near the kidneys to the pelvic area), which occurs between the 8th and 15th weeks of gestation. Testosterone controls the second stage (when the testes move from the pelvic area into the scrotum), which occurs in most cases by the 7th month of gestation. Undescended testes is a risk factor for testicular cancer and, if not corrected surgically, a risk factor for low sperm production later in life.

**Testicular dysgenesis syndrome** A collection of disorders and diseases of the male reproductive system that may be related to one another and have a common cause: abnormal development of the testes during fetal development. These include: hypospadias, undescended testes, low sperm counts, and testicular cancer.

the normal development of the penis, which can lead to hypospadias, or to trigger the testes to migrate through the body to the scrotum, which leads to undescended testes. A second result is that the cells that support and nourish the development of sperm do not multiply enough, which limits the capacity for sperm production later in life. Sperm counts are also lowered because the cells in the testes are not organized properly, and this disarray destroys sperm cells throughout life. Although it is not known what causes testicular cancer, men with this disease have the same problems with the development and organization of cells in their testes. Also, men with hypospadias, undescended testes or low sperm counts have a higher risk of developing testicular cancer.

Some of the risk factors for testicular dysgenesis syndrome are known, including premature birth, **intrauterine growth restriction**, maternal stress during pregnancy and some rare genetic disorders. However, these conditions cause only a small percentage of testicular dysgenesis syndrome cases.

It is also known that interfering with the production of testosterone or its ability to trigger responses in cells that are necessary for development will cause testicular dysgenesis conditions. Therefore, increasing attention is being paid to the role of endocrine disrupting chemicals, which have been proven to disrupt the production or function of hormones, and to impair development of the testes and the male reproductive system in laboratory animals and wildlife populations. For example, rodents exposed to DDE, DDT, vinclozolin, PCBs, bisphenol A, phthalates, DES, flutamide (an anti-androgenic drug used to treat prostate cancer) or ethinyl estradiol during fetal development develop

We still don't know what causes 95% of the cases of hypospadias. And that's where I think the environment may really be the clue to what causes it.

*Larry Baskin*

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**Intrauterine growth restriction** Also called IUGR. A condition in which the fetus does not grow at a normal rate and consequently is smaller than expected for its gestational age (the number of weeks of pregnancy). Babies who experience intrauterine growth restriction tend to be very light weight, and their tissues and organs may also be underdeveloped. These infants also have a higher risk of death shortly after birth, of problems with neurological and reproductive development and growth, and of cardiovascular disease later in life.

hypospadias, undescended testes, low sperm counts, testicular tumors and **hermaphroditism**. Alligators in the polluted Lake Apopka have abnormally small penises, and the high rate of undescended testes in the Florida panther is possibly due to exposure to DDE that has accumulated in the bodies of prey. Recently, the damage that phthalates cause in rodents has also been observed in exposed non-human primates. There is also evidence that, for at least one of these chemicals, the harm is passed on to subsequent generations of males.

Emerging studies are examining the relationship between endocrine disrupting chemicals and testicular dysgenesis syndrome in humans. Infant boys whose mothers have higher levels of phthalates in their urine during pregnancy were more likely to have a shorter **ano-genital distance** — a physiological measurement that indicates low testosterone production or function and a higher risk of testicular dysgenesis syndrome conditions. Boys in this study who had shorter ano-genital distances were also more likely to have undescended testes and a smaller penis volume. Also, a parent's exposure to pesticides at work or from living near agricultural fields has been associated with higher rates of undescended testes, and mothers of adult sons with testicular cancer have been found to have higher levels of PCBs.

### *Semen Quality*

In 1977, an abnormal number of male workers at a dibromochloropropane (also called DBCP) pesticide plant in

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**Hermaphroditism** A condition in which either an animal's genetic sex is not consistent with the sex organs that develop, or the sex organs that develop are not entirely male or female. For example, a genetically female animal may develop testes, a male reproductive tract or male external genitalia. Or, both sperm cells and egg cells may develop in the testes of a genetically male animal.

**Ano-genital distance** A measurement of the length of the perineum (the area of the body between the anus and the genitals). During male development, the hormone testosterone triggers the perineum to lengthen as part of the normal development of male sex organs, such that the ano-genital distance of male humans and rodents is twice as long as that of females. Researchers study ano-genital distance because it is a sensitive measure of whether a chemical has interfered with testosterone production or action during fetal development.

California were found to be sub- or infertile. They were producing either very little or no sperm, and the sperm they did produce had genetic defects. Wives of exposed workers had higher rates of pregnancy loss, and couples tended to have more female infants than normal. The discovery that DBCP was highly toxic to sperm raised awareness that chemicals could harm human reproduction.

Since then, a wide range of agricultural and industrial chemicals has been shown to negatively affect male reproduction in humans and animals. For example, exposure to the metals cadmium and lead has been linked to poor sperm quality. Men exposed to PCBs have reduced sperm counts and poor sperm quality and these effects appear to be passed on to male offspring when exposure levels are high. Men with higher levels of the pesticides atrazine, alachlor or diazinon in their urine have low sperm counts and poor semen quality. We know that exposure to the pesticide atrazine increases the conversion of testosterone into estrogen and decreases testosterone levels. Male amphibians and rodents exposed to levels of atrazine commonly found in our environment are both demasculinized (due to decreased testosterone) and feminized (due to increased estrogen) as a result. Effects range from low sperm counts, to the growth of eggs instead of sperm in testes, to overt hermaphroditism. Reduced semen quality, reduced fertility and fetal loss in animals and humans have been associated with bisphenol A, phthalates, ethylene oxide, glycol ethers, **solvents**, tobacco smoke, pesticides (DDT, vinclozolin), PCBs and dioxin exposure. Damage from some exposures, like lead and vinclozolin, can be passed on to subsequent generations.

### *Prostate Cancer*

Recent research on the link between chemical exposures and prostate cancer provides another example of how exposures during fetal development can permanently alter

All the available data suggest that sperm counts have declined about 1% per year over the past 50 years and new data show that testosterone hormone levels are declining at a similar rate.

*Shanna Swan*

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**Solvents** Liquids that cause other liquids, solids or gases to dissolve. Solvents are most often used to clean things. For example, they are used in dry cleaning, spot removers, detergents, paint thinners, nail polish remover and perfume. They are commonly used in numerous industries to remove oil and grease from metals and electronics.

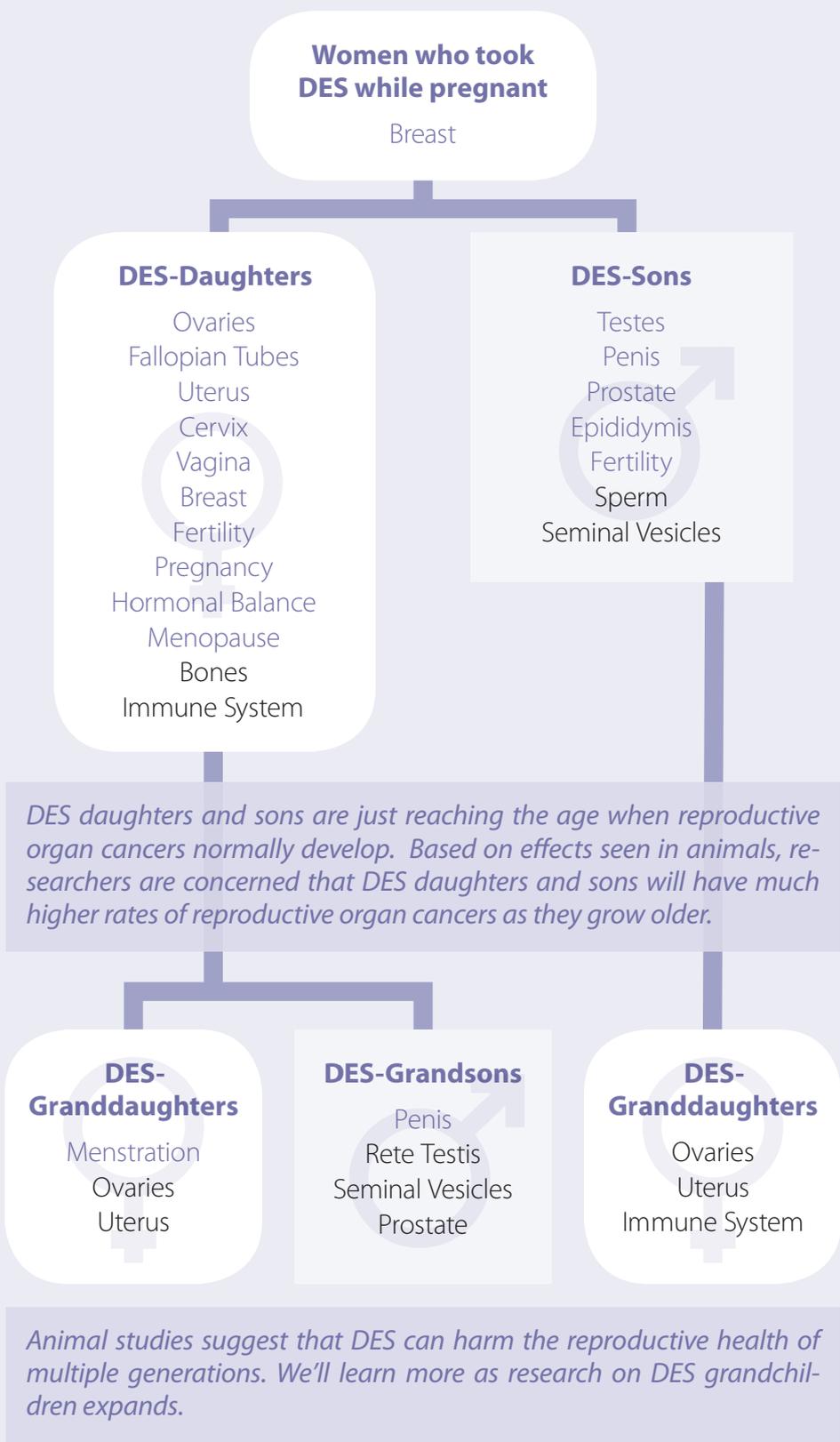
## **DES: Harming Multiple Generations in Multiple Ways**

DES (diethylstilbestrol) is a synthetic chemical that was first created in 1938. Although DES was known to be highly estrogenic and to cause cancer when it was first manufactured, DES was marketed as both a pharmaceutical drug and a growth stimulant for livestock.

Between the 1940s and the early 1970s, DES was prescribed to as many as 3 million pregnant women in the United States to prevent miscarriage and stillbirth. (Subsequent studies showed that DES is ineffective at preventing pregnancy loss.) In the early 1970s, some of the grown daughters of these women, who were teenagers or in their early 20s, developed clear-cell adenocarcinoma of the cervix and the vagina — a type of cancer that was previously unheard of in young women. After the link to DES was made, the Food and Drug Administration banned doctors from prescribing DES to pregnant women. However, by then, 5–10 million people in the United States had been exposed to DES, either as adults or in the womb.

Since then, the health effects caused by DES have been studied extensively in both humans and animals. This chemical has become an example of how exposure to an endocrine disrupting chemical can harm multiple generations in multiple ways.

**Reproductive Organs and Functions Harmed by Taking DES During Pregnancy**



Purple = effects seen in humans.

Black = effects seen in animals and therefore possible in humans.

New studies are showing air pollution to be associated with higher rates of spontaneous abortions, low birth weight and other poor reproductive outcomes.

*Linda Birnbaum*

gene expression and thereby increase susceptibility to disease. The developing prostate is extremely sensitive to estrogen. We know that exposing animals to high doses of estrogenic chemicals perturbs prostate development and increases the risk, later in life, of developing precancerous tumors that form and grow in response to estrogen. (Males produce more estrogen later in life as a natural part of aging.) Recent investigations have examined whether the levels of exposure to estrogenic chemicals that humans typically experience can also harm prostate development and increase the risk of precancerous tumors. The answer is yes. Exposing developing animals to levels of bisphenol A found in human bodies produces the same effects as exposure to high levels of this chemical in animal studies: permanent alterations in the way prostate cell genes respond to estrogen, leading the animals toward greater susceptibility to precancerous tumors later in life. Rates of prostate cancer in men have increased 76 percent in the past 30 years. The possible contribution of exposure to estrogenic chemicals during fetal development to the increasing occurrence of this disease has not been explored.

### **Chemical Exposures, Fertility and Pregnancy**

Human studies of chemical exposures and human fertility and pregnancy have often focused on broad measures of health, such as infertility (inability to conceive or carry a pregnancy), reduced fertility (difficulty conceiving), miscarriage, preterm birth and intrauterine growth restriction, rather than specific effects, such as failure of the embryo to implant in the uterus. These studies tell us an important bottom line — whether or not exposure to a chemical makes it harder for us to conceive and harder for the embryo and fetus to survive and flourish — even if they cannot pinpoint the specific biological processes that are affected by chemical exposure.

Fertility is most often studied using information on how long it takes couples to conceive. Longer periods of time are considered to be a sign of reduced fertility and have been associated with smoking and exposure to second-hand tobacco smoke; working with or applying pesticides; exposure to metals such as lead and cadmium; working where organic

solvents (industrial chemicals used to dissolve other compounds) or formaldehyde (a chemical used to make paper products, plywood and resins) are used; working in the semiconductor industry; and exposure to air pollution. Reduced fertility also appears to be associated with exposure to endocrine disrupting chemicals such as PCBs, DDT and DDE, but this connection needs to be confirmed.

Our understanding of chemical and other risk factors for miscarriage is limited by our inability to identify and therefore study an estimated 30 percent of all pregnancy losses, particularly those that occur during the first two weeks after conception. Nevertheless, many of the same exposures associated with reduced fertility have also been linked to miscarriage, including lead, pesticides, DDE and formaldehyde. Miscarriage has also been associated with exposure to chlorinated hydrocarbons, a large group of chemicals that contaminate our environment and include industrial chemicals such as PCBs, and pesticides such as DDT. Recent animal studies suggest that exposure to certain chemicals, such as bisphenol A, may also cause chromosomal abnormalities (major genetic defects) in the embryo. Chromosomal abnormalities are the primary known cause of miscarriage and are thought to explain at least 50 percent of first trimester miscarriages, and an estimated 15 percent of second trimester and 5 percent of third trimester fetal losses. Thus, chemical exposures may play a role in both genetic and nongenetic causes of miscarriage.

Preterm birth (birth before the 37th week of gestation) is the leading cause of death in the first month of life, as well as a leading cause of health problems later in life. Similarly, babies with intrauterine growth restriction have higher rates of diabetes, obesity and heart disease when they grow up. They also are more likely to have problems with the development of their reproductive systems. For example, girls who experience intrauterine growth restriction are more likely to have smaller and poorly developed ovaries, which, later in life, do not respond well to the hormonal signals that direct ovulation. As a result, these women have a higher frequency of menstrual cycles in which they do not ovulate. Boys who experience intrauterine growth restriction are more likely to be born with undescended testes or hypospadias. Later in

In our clinic, we find that women who are exposed to second hand smoke are as compromised in their fertility as women who smoke.

*Warren Foster*

life, they are more likely to have reduced sperm counts and a higher risk of testicular cancer.

Smoking, exposure to second-hand tobacco smoke and alcohol consumption are known to cause premature birth, intrauterine growth restriction and low birthweight. Premature birth has also been associated with exposure to lead, air pollution, benzene, ethylene oxide, DDT and DDE, organophosphate pesticides and DES. Chemical exposures that have been associated with intrauterine growth restriction or low birthweight include air pollution, metals (arsenic, lead, mercury), pesticides (atrazine, chlorpyrifos, diazinon, DDT, DDE, lindane, metolachlor, pentachlorophenol), chemicals that are formed when chlorine is used to disinfect water supplies, PCBs and industrial chemicals (toluene, dichloroethane and other solvents).

# What We Can Do

**The *Summit on Environmental Challenges to Reproductive Health and Fertility* brought together people from a wide range of disciplines** that have a role in improving environmental reproductive health. Basic science, animal, human and clinical researchers conduct, analyze and communicate the science. Health care professionals are respected messengers who treat those potentially impacted. The media informs the public. Community groups bear witness to the chemical exposures we experience and offer expertise in fighting chemical pollution and exposure. They also offer data and partnerships to researchers. Advocacy groups connect with affected constituencies, policymakers and scientists to promote improvements in laws and policies. Legislators and policymakers create and revise laws and regulations to protect our health based on the work of scientists, public policy researchers and advocacy groups. Government agencies implement the laws and fund research to inform this process. Working together at the *Summit*, participants from these fields developed a series of recommendations for creating environments that are healthier for fertility and reproduction, specifically: how to expand our knowledge of the harm our exposure to chemicals causes; how to translate science into action to reduce exposures; and how to strengthen government protections.

## **Expand Knowledge**

We have learned a substantial amount about how chemical exposure can damage our fertility, reproduction and development. Yet we have many unanswered questions. Have we fully investigated whether chemicals affect development, including longterm consequences of exposure in the womb and early childhood? Do we know enough about the chemicals we have evaluated? What is the potential harm from



chemicals that have not been studied? These are but a few of the questions facing scientists. We need to expand what we know about the health impacts of chemicals so we can do a better job of preventing and treating chemical-linked diseases and disorders. In the meantime, the gaps in our knowledge should not keep us from supporting policy actions to prevent exposure, especially because the existing evidence is sufficient to justify such actions.

The following actions will advance environmental reproductive health research and knowledge:

**Continue to build our understanding of basic biology.**

Understanding the biology of reproduction and fetal development — the steps that must occur and the factors that guide these steps — improves our ability to identify the potential toxic effects caused by exposure to chemicals at various times in our development and life. This knowledge helps animal and human researchers to design their studies: It tells them which timings of exposure to consider, what types of effects to look for and when to look for them. There are several areas of inquiry that will be of most value to researchers at this time. Specifically, how do all of the biological systems involved in regulating pregnancy, development and reproduction interact and influence each other? What are all of the factors that control and guide male and female development? At what points in development are we most susceptible to harm by exposure to chemicals?

**Improve measurements of reproductive health and chemical exposures.**

We need better ways to identify and track reproductive and developmental health. For example, developing a way to measure the genetic quality of sperm and eggs or a way to detect pregnancy as soon as it occurs will enhance our ability to assess harm, particularly as it affects early pregnancy loss. There are some diseases, such as prostate cancer, that take decades to develop yet might be caused, in part, by chemical exposures that corrupt the programming of gene expression during fetal life or during other periods of development. Figuring out ways to measure whether gene expression has been corrupted by chemicals will make it much easier to understand the connection between exposures during early development and diseases

This is the plea for general biology: We have to identify and understand normal patterns before we can truly understand how the environment influences our own health.

*Lou Guillette*

that occur later in life. Developing an early detection screen for harmful chemical exposures will also alert us to potentially higher risks of disease later in life and the need for preventive screenings or treatments.

We also need more information about all aspects of chemical exposures. There are approximately 87,000 chemicals registered for use in commerce, yet we have developed techniques to measure just over 200 of these chemicals in the body. What chemicals are in our air, water, food and consumer products? How much gets into our bodies? What are the main sources of human exposure? Improvements in our ability to measure exposure to all the chemicals used in our surroundings will inform and strengthen our health investigations. This knowledge will also help to monitor whether chemical regulations are or are not effectively preventing human and environmental contamination.

**Consider timing of exposure and effect.** Chemical exposures at different stages of development or life can produce very different types or severity of effects. The same chemical can cause grave or mild effects depending on whether exposure occurs during a stage of development that is susceptible to harm. In addition, effects from exposure can manifest immediately or much later in life. Some exposures experienced by men or women won't harm them but will harm their children and their grandchildren.

In order to fully catalogue the toxicity of a chemical, it is necessary to consider an expansive timeframe in which exposure and effects occur. It is also necessary to consider the full array of systems that may be affected depending on when exposure occurs. Information on when to look and what to look for will greatly inform and strengthen human studies and, in so doing, will help to answer pressing questions about the impact of chemical exposures on our fertility and reproductive health.

**Improve methods to study chemical mixtures.** Humans are exposed to many chemicals at the same time, yet researchers have almost always studied the effect of exposure to only a single chemical. Chemicals can interact with one another to produce effects that are more or less harmful than what might be predicted based on studies of single chemi-

We must evaluate the effects of the complex chemical mixtures to which we are exposed every day.

*Pauline Mendola*



cal exposure. Therefore, to understand how our reproductive health is impacted by the exposures that we experience, we have to expand human and animal studies to focus on exposure to a mixture of chemicals. Statistical methods will need to be developed and expanded to support this new and much more complex area of research.

**Study all life stages.** We now know that exposures in the womb may not result in harm until much later in life — until we are teenagers, adults or elderly. Effects of exposure in the womb may also affect our children and our children's children. Therefore, we need to study animals, wildlife and humans long enough to follow them through all life stages and through several generations. These types of studies, called longitudinal studies, are time and resource intensive, but must be supported. Collaboration between researchers interested in studying different life stages will maximize learning.

**Identify early indicators of harm.** Too often, policies rely on finding severe health effects from chemical exposures before moving toward prevention. In some cases, human evidence is required in addition to animal studies, which only lengthens the time to action and increases potential suffering. We need a research program that identifies early indicators of harm in humans. This information can be used to develop policies that prevent problematic exposures before we experience consequences to human health.

**Investigate the ecological context of reproduction.** Fertility and reproductive success are determined by complex interactions of many personal and environmental factors. Genetics, age, infectious agents, nutritional status, fitness level, lifestyle behaviors, pharmaceutical use, social circumstances and stress all contribute, along with exposure to chemicals, to the success or failure of reproduction. Animals that we study do not differ in terms of these characteristics, so it is easier for experiments to provide an accurate evaluation of the harmful effects of chemicals. In comparison to laboratory animals, humans are genetically varied, have vastly different diets and exercise regimes, reproduce at different ages and are exposed to different levels of stress, social support and infectious agents. Human studies of the effects of chemical exposure on fertility and reproduction must account for these

We have failed at prevention if health care providers see patients harmed by chemical exposures in their clinics.

*Linda Birnbaum*

differences in order to identify important relationships and to produce the most accurate conclusions.

**Investigate racial disparities in reproductive health.** Researchers have identified important differences in reproductive health status among different racial and ethnic groups in the United States. For example, compared with other racial groups, African American women are more likely to have premature or low birthweight babies, African American men have higher rates of prostate cancer and African American girls go through puberty at even younger ages than other girls. There are also racial and ethnic differences in exposure to chemicals. Polluting industries are more often located in or near neighborhoods where minority groups live, work or go to school. Greater exposure to chemicals may also be caused by differences in the use of consumer and personal care products.

The causes of racial and ethnic inequities in reproductive health have not yet been identified, but could include differences in lifestyle, social circumstances or chemical exposure, a combination of these factors or something else entirely. Research on this topic is a valuable and promising investment. First, understanding the causes of health inequities is a prerequisite for efforts to correct them. Second, identifying what causes one group of people to be affected by disease or dysfunction when other groups are not is an important step in sorting out the risk factors for complex disease processes.

**Foster interdisciplinary collaboration and research.** Fertility and reproduction are complex processes that involve several systems in the body, and are influenced by many internal and external factors. The level of complexity is such that obtaining an understanding of the entire process requires input from numerous specialized fields of study. New interdisciplinary fields of study may be required to understand how the biological systems involved in fertility and reproduction interact and influence one another. Knowledge from basic science must be translated to animal studies, and findings from animal studies must be examined in humans. All of these steps require interdisciplinary collaboration between basic scientists, toxicologists, clinical researchers and epidemiologists with expertise in all aspects of reproductive health.

Genetics, exposure to chemicals, infectious agents, nutritional status and social circumstances collectively create a context in which reproduction succeeds or fails.

*Ted Schettler*

Funding agencies, research institutions and universities have a critical role to play in supporting collaborative research. These institutions can remove obstacles to collaboration by giving the same career recognition to the project leaders of center and program project grants as they do to principal investigators of individual research programs. Funding agencies can also promote collaboration by issuing grants for multidisciplinary research projects and by fostering ongoing communication and collaboration between researchers after research projects are complete. They also have a unique and broad view of research projects in potentially related fields, and can convene key players from these fields to explore and initiate new partnerships.

Communication tools can facilitate collaboration between researchers. Two specific tools were recommended at the *Summit* and have been established for the environmental reproductive health field. The first is a registry that connects researchers and health care providers with communities, patient groups and others who are in need of accurate and understandable information about environmental reproductive health science. The second is a venue for researchers to share tissue banks, study samples, data sets and other research tools used in human and animal studies. (More information on these tools can be found at [www.healthandenvironment.org/working\\_groups/fertility](http://www.healthandenvironment.org/working_groups/fertility))

### **Translate the Science**

Researchers have been sending the message that chemical exposures can harm human and animal reproduction for decades, but the message has only partially reached the public and policymakers. Those of us who have heard the message can try to avoid potentially harmful exposures in our own lives. We can identify the largest industrial polluters in our neighborhoods. We can read product labels. As workers, we can follow the guidance of material safety data sheets. But these practices offer inadequate protection because our environmental laws and regulations protect commerce in several ways that have negative implications for public protection and disclosure. Small polluters fly under the regulatory radar. Chemicals in consumer products that are considered “trade secrets” do not have to be included on product labels. Mate-

My research, no matter how good it is, isn't going to change industry's behavior; it isn't going to impact federal regulations. What is going to change that, is people. ...

rial safety data sheets publicize only a narrow slice of information on the toxicity of a given chemical. Furthermore, as individuals, we can't protect ourselves from the contamination of our air, our water and our food supply by industrial pollution.

Effective protection from chemical exposures cannot be accomplished solely on an individual level. This is a matter for social action. Key partners in this endeavor include researchers, health care professionals, community groups, advocacy and environmental organizations, and policymakers, who must all voice a consistent and cohesive message that is rooted in science.

To support the growth and success of the reproductive environmental health movement, we need to integrate the ample body of evidence that research has produced over the past 20 years into everyday life. We need to build on the experiences of environmental and health campaigns that have succeeded in fighting pollution, reducing exposure and improving public protection. We need to develop a coordinated strategy and create opportunities for collaboration among people and groups involved in related work. The following actions will help to broadcast scientific knowledge and to build effective campaigns to protect reproductive health:

**Increase the translation and dissemination of scientific findings to policy and stakeholder audiences.** Scientific information is of tremendous value to health care professionals, community groups and advocacy organizations. But, it has been immensely challenging for these groups to access this information. Researchers publish on narrow topics in highly specialized publications that are read primarily by other scientists and not by health care providers, policymakers or the general public. While some organizations have taken on the challenge of digesting and summarizing key research findings for the public (for example, *Our Stolen Future*, [www.ourstolenfuture.org](http://www.ourstolenfuture.org)), more independent institutional support for translation and communication is needed. Researchers can also contribute greatly to efforts to disseminate scientific findings by framing their work in a way that resonates with key audiences (policymakers, health care providers, and the general public) and by working with journalists to communicate complicated issues in a clear and scientifically-based

What this means is that scientists have to be very good at communicating with the public. And quite simply, we're not. We're good at talking to each other. We're not good at talking to the public.

*Pat Hunt*

## **In the Shadow of Chemical Valley**

*We thought it was normal.*

*We thought that seven miscarriages was normal.*

*We thought that the host of respiratory problems — 40 percent of our community requires a puffer to breathe — was normal.*

*We thought that sirens going off in the middle of the night was normal.*

*We thought that your shoes turning orange in the spring from the melting snow and the chemicals landing on the grass was normal.*

*It's not.*

— Ronald Plain, Aamjiwnaang First Nation

The 850-person Aamjiwnaang First Nation community lives in the shadow of what is called Chemical Valley in the Canadian town of Sarnia, Ontario (about one hour north of Detroit, Michigan). Each year, 52 Canadian and US industrial facilities that are located within 10 kilometers (6.2 miles) of their community pollute the air with more than 10 million kilograms (23 million pounds) of chemicals suspected to cause reproductive and developmental problems, as well as over 410,000 kilograms (900,000 pounds) of chemicals known or suspected to cause cancer or to disrupt the endocrine system. National Geographic has described Chemical Valley as the most polluted spot in North America.

In the summer of 2004, researchers reported a startling finding: For the past ten years, two girls were born for every boy in the Aamjiwnaang First Nation community. (In contrast, slightly more boys than girls are born in the entire Canadian population.) Subsequent studies revealed that this community also experiences elevated rates of miscarriage (39 percent compared to 25 percent in the general Canadian population), and severe learning or behavioral problems (27 percent compared to 4 percent in the general Canadian population).

This research raised international attention and has been a valuable asset to the community's effort to reduce industrial pollution. It has helped the Aamjiwnaang Environmental Committee to win every fight they've tackled from the day the committee formed. They have prevented Canada's largest ethanol plant from being located beside their community. They have stopped the expansion of each of the 52 nearby industrial plants. In the words of Ronald Plain, "all through hard work and the help of researchers."

way. Scientists will have the most impact if they articulate the implications of their research, explain how their findings fit into the larger context of fertility and disease, and describe how their research relates to past findings and other concurrent research on the topic.

Support for developing effective tools that translate scientific knowledge to wider audiences is essential, as these tools will help unlock the potential of science to catalyze policy, social and individual action.

**Provide a venue for environmental justice groups to share expertise and coordinate strategies.** Environmental justice and community groups have developed a valuable capacity for reducing or preventing industrial contamination in their communities. Examples include reducing or eliminating the use of chemicals, including pesticides, from school playgrounds and buildings (Pesticide Education Project, [www.pested.org](http://www.pested.org)); shutting down medical waste incinerators, which are a major known source of dioxin pollution (Asian Communities for Reproductive Justice, [www.reproductivejustice.org](http://www.reproductivejustice.org)); and convincing a “big box” retailer to post warnings about dangerous levels of mercury in fish carried by the store (Women’s Voices for the Earth, [www.womenandenvironment.org](http://www.womenandenvironment.org)). At the same time, advocacy organizations and reproductive health groups have developed nationwide contacts with the media and policymakers. They very effectively engage and mobilize networks of motivated audiences across the country. Providing an opportunity for these groups to share expertise and strategies, to identify needs and to network is an important step in developing a coordinated, national grassroots strategy for environmental reproductive health.

**Develop training for community-based research.** Collaborating with communities on research projects offers unique benefits that are valuable to scientific inquiry and to the translation of science into social change. It offers the opportunity to study real-life exposures in populations that are motivated to participate and assist in research efforts. It supports the improvement of environmental health by investigating questions that are relevant to local campaigns, and by providing a scientific basis to community action. Collaboration between researchers and community also offers unique challenges:

finding a common language, broadening goals to include the objectives of both groups, expanding definitions of expertise, to name a few. Training researchers and community groups how to navigate these challenges will support the initiation and success of more projects. Government support for these endeavors is also essential to their success and growth.

**Develop environmental reproductive health training and tools for health care professionals.** Health care providers are respected and therefore valuable health educators and patient advocates. Alert clinicians may notice unusual patterns of disease or disorders in their patient populations and can alert the larger medical and public health communities to signs of possible chemical harm. But health care providers are not trained in environmental health as part of their regular education. They are not fluent in toxicology or epidemiology, the primary fields of environmental reproductive health study. They often learn about effects of chemical exposure from the same sources their patients do: the news media and the internet. Therefore, they need training and support to begin dialogues with their patients about chemical exposures and health, to engage in the policy arena and to broaden their clinical skills.

To accomplish this, medical and nursing education must provide instruction on environmental reproductive health, and medical licensing exams must test this knowledge. Seminars must be provided at medical and nursing society meetings to educate current health care providers. Resources, such as provider toolkits, reference guides and patient brochures on the hazards of and ways to avoid chemical exposure, must be developed in order to support providers who want to enhance their care by incorporating environmental reproductive health into their practices. Much of environmental reproductive health science has to do with populations of people — for example, increases in rates of diseases or changes in the sex ratio (the number of boys born in a community compared with the number of girls) — rather than the individual experience. Bringing the science into the doctor's office and making environmental reproductive health a standard element of care is one way that individuals' lives can be improved.

## Strengthen Government Protections

Our current system of regulating chemicals is based on the assumption that chemicals are harmless until proven otherwise, and it places the burden of proof on the government. Labeling laws largely favor commerce over a user's right to know what ingredients are in the products they are purchasing or working with. Occupational exposure limits favor industry and do not protect workers' reproductive health or the health of their fetuses.

Evidence is accumulating that our regulatory system is failing to protect our bodies from exposure to chemicals and our fertility and reproductive health from harm. The increases in rates of chronic diseases such as testicular cancer, and declines in sperm quality show that we have reason to do better. Male reproductive development is being jeopardized by a mother's exposure to phthalates, while baby shampoos and lotions and soft plastic products continue to expose boys to phthalates after they are born. The average adult in the United States is exposed to as much as 20 times the level of dioxin that causes endometriosis in monkeys.

Furthermore, recent science teaches us that chemicals can scramble our hormonal messaging systems and permanently alter gene expression, that certain periods of development are particularly sensitive to chemical harm and that exposures in the womb can cause disease or disorders later in life. Yet the studies upon which our health standards are based do not adequately look for these effects.

The following recommendations will improve government protections of fertility and reproductive health:

**Implement a national, comprehensive chemical testing policy for both pre- and post-market chemicals.** Pharmaceutical drugs and new pesticides must undergo testing for health and safety before the government will register them for use. However, companies do not have to provide evidence that chemicals used in all other consumer and industrial products are safe before or after they are manufactured and sold. As a result, only a small percentage of the approximately 87,000 chemicals registered for use in this country has been evaluated for effects on health, and these studies only

People will come up to me and say, "You mean to tell me that products labeled 'baby products' are not specifically tested for safety for babies?"

*Mary Lou Ballweg*

crudely evaluate effects on reproductive health. For example, only 7 percent of the nearly 3,000 chemicals we produce or import the most (over 1 million pounds a year) have undergone basic health and environmental testing. We know very little about the toxicity of the products we use every day and the chemicals that contaminate our air, water, food and bodies. We also don't know exactly how chemicals are getting into our bodies, which makes it very difficult to take steps to eliminate exposure.

A national program to test all pre- and post-market chemicals will help to fill the void of information on the hazards of chemicals in our environment. This testing program should evaluate risks to the environment and wildlife as well as to human health. It should test for the effects of exposure during all stages of development and look for effects throughout the lifespan. It should test or otherwise account for our exposure to mixtures of chemicals, particularly chemicals that may cause similar damage. And it should identify the potential for chemicals to enter the human body. Knowledge gained from this testing program will support solid, scientifically based policymaking. It will enhance material safety data sheets (information materials that inform workers of chemical hazards) and consumer product labeling, and will allow for a more informed medical and public sector.

**Change the triggers of action used to make policy decisions about regulating potentially harmful chemicals.**

Current U.S. regulations permit use of most chemicals without evaluating their ability to produce harm. At the same time, they do not require companies to conduct any research that would produce evidence of harm for chemicals other than pesticides. Lack of research and lack of information translate into continued production and use. Even when government or independent researchers produce evidence, it takes years and major court battles to ban or restrict the use of chemicals.

A protective public health policy would turn our current paradigm on its head. It would take protective action when there is an indication of harm rather than waiting for absolute proof of harm. It would require information on the health effects of all chemicals used or registered for use. And, it would direct the most intensive action be taken on the most commonly used chemicals that we know the least about.

The discovery that particular reproductive effects are caused by environmental exposures rather than genetics is good news, because suddenly we have modifiable rather than unmodifiable risk factors. . . .

**Incorporate findings from environmental reproductive health research into hazard and risk assessment.**

Government agencies that conduct **hazard and risk assessment** have developed a collection of protocols and guidelines for evaluating information on a chemical's toxicity, assessing the extent of human exposure to the chemical and estimating the chemical's potential to harm the health of the public and the environment. In order to continually support the development of effective health standards, these hazard and risk assessment practices must evolve to stay current with scientific discoveries and knowledge. They must also adequately account for scientific uncertainties. Recent environmental reproductive health research has produced a new body of information and understanding that has yet to be incorporated into the risk assessment process. For example, even low doses of exposure can affect health or reproductive function; exposure to a mixture of chemicals can be more harmful than exposure to the same amount of a single chemical; exposure during a key point during development can have unique effects; and the harmful effects of chemical exposure may extend over multiple generations. Updating hazard and risk assessment protocols and guidelines to reflect these and other scientific discoveries will help to ground health standards in science and thereby maximize public health protections.

**Expand information on chemicals in products given to consumers and workers.**

Consumer product labeling and worker access to information on industrial chemicals are inadequate. This is largely due to laws protecting trade secrets and other aspects of manufacturing. As a result, consumers are not able to determine whether chemicals used in fragrances, such as phthalates, are in the products they are purchasing. They are unable to learn what chemicals the "other ingredients" on a label may include. Workers also cannot

We can't change our ancestors, but we can change our systems of agriculture. We can change our energy policies. We can change the ingredients in nail polish.

*Sandra Steingraber*

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**Hazard and risk assessment** Processes that federal and state governments use to support regulatory and policy actions regarding chemical production, use and pollution. The hazard assessment process identifies the harm that chemicals in our environment can cause to our health and the health of the environment, and the risk assessment process evaluates and estimates the likelihood that this harm will occur. Both processes collect and evaluate information on a chemical's toxicity, including what harm is caused and at what levels of exposure harm occurs, and on the levels of human exposure.

learn the full range of chemicals they are exposed to in their workplaces. Right-to-know laws should be improved so that consumers and workers can access information on all of the chemicals used in a product or in the workplace.

**Revise occupational health standards so that worker health is protected.** Occupational safety laws and regulations allow workers to be exposed to far higher levels of chemicals than the general public. For example, they can be exposed to about 330 times higher levels of arsenic and about 70 times higher levels of methanol. At least 100 chemicals used in commerce are known to harm reproduction. An additional 250 are suspected to do the same.

Several steps can be taken to improve worker protection from chemical exposure. One, reduce permissible occupational exposure levels to chemicals that harm reproduction and development so that they are more in line with environmental exposure limits. Two, change permissible exposure limits to reflect the toxicity of exposure to mixtures of chemicals used in the workplace, rather than exposure to individual chemicals. Three, expand exposure assessment and monitoring in occupational settings. Finally, expand occupational health researchers' access to workers, so that health consequences can be identified and corrected.

# Conclusion

Chemicals are integral to our society. We rely on them for every aspect of our daily lives to such a degree that it's difficult to imagine life without them. And yet, the evidence of harm that we are observing in animals and in our own species raises the question of whether life can continue with them.

The *Summit on Environmental Challenges to Reproductive Health and Fertility* assembled leading scientists, health care providers, community groups, journalists, policymakers and advocacy groups to begin to address this question. Participants advanced their understanding of the science of environmental reproductive health and laid out concrete recommendations for further progress in research, health care, policy, social action and occupational protection.

One point became increasingly clear during the *Summit*: Communication may be a bigger impediment to progress than our lack of knowledge. The array of stakeholders committed to understanding and improving environmental reproductive health includes fields that have traditionally been separated by institutional and cultural divides. Each of these fields speaks a different, highly specialized language and often communicates in a way that assumes their audience holds background expertise in the topic.

Overcoming the lack of common frameworks, language and expertise as well as cultural barriers will require substantial effort and commitment. Courage to step out of one's particular specialty area and interact with experts from different fields is mandatory. So too, is the ability to incorporate one's partners' goals, needs and directions. Simplifying technical information so that nonexperts can understand and participate in multidisciplinary collaborations requires time and effort, and therefore resources and patience.

Maybe communication is more of a barrier than the lack of proof.

*Richard Sharpe*

Language, courage, adaptability, resources and patience are formidable challenges. But, for the sake of our children, their children, and generations to come, failure to meet this challenge is not an option. It is our hope that the *Summit on Environmental Challenges to Reproductive Health and Fertility* will serve as the starting point for a new era of communication and that collaboration on behalf of environmental reproductive health will lead to an informed and adequately protective society in which future generations thrive.

# Resources

Please also refer to the “Learn More” section of the UCSF Program on Reproductive Health and the Environment’s web site: [www.prhe.ucsf.edu](http://www.prhe.ucsf.edu)

## Books

***Our Stolen Future: Are we threatening our fertility, intelligence, and survival? A scientific discovery story.*** Theo Colborn, Diane Dumanoski and John Peterson Myers. Plume Publishing, 1996.

A book about the health and environmental threats created by manmade endocrine disrupting chemicals.

***Generations at Risk: Reproductive Health and the Environment.*** Ted Schettler, Gina Solomon, Maria Valenti and Annette Huddle. MIT Press, 1999.

A book that reviews the linkages between four major classes of chemicals — solvents, pesticides, metals and endocrine disruptors — and reproductive health effects, including miscarriages, birth defects and fertility issues. It includes sections on exposure assessment, consumer and worker activism, regulation of hazardous chemicals and a primer for the clinician.

***Having Faith.*** Sandra Steingraber. Perseus Publishing, 2001.

A scientist’s personal encounter with the effects of chemical pollution on childbearing. This book presents a wide-ranging overview of new developments in genetics, embryology and infant development.

## Web sites geared towards the general public

**Collaborative on Health and the Environment (CHE)** ([www.healthandenvironment.org](http://www.healthandenvironment.org)). CHE’s web site includes:

- A searchable database that summarizes the links between chemical exposures and approximately 180 human diseases or conditions ([database.healthandenvironment.org](http://database.healthandenvironment.org))
- Scientist-reviewed papers on the links between chemical exposures and numerous reproductive health diseases and disorders ([www.healthandenvironment.org/science/papers](http://www.healthandenvironment.org/science/papers))

- Downloadable recordings of monthly CHE Partnership Calls on a variety of topics pertaining to chemical exposures and reproductive health ([www.healthandenvironment.org/news/calls](http://www.healthandenvironment.org/news/calls))

**Environmental Health News** ([www.environmentalhealthnews.org](http://www.environmentalhealthnews.org)) offers daily updates on the latest news, science and reports on the emerging scientific links between environmental exposures and human health. The site includes a flexible search engine ([www.environmentalhealthnews.org/archives.jsp](http://www.environmentalhealthnews.org/archives.jsp)) that allows you to locate articles most relevant to your topic of inquiry.

**Environmental Working Group** ([www.ewg.org](http://www.ewg.org)) publishes a variety of reports on human exposure to chemicals and on toxic effects of chemical exposures. Their web site also offer tools for identifying and reducing sources of exposure to chemicals. For example:

- **A Shopper's Guide to Pesticides in Produce** ([www.foodnews.org](http://www.foodnews.org))
- **10 Everyday Pollution Solutions** ([www.ewg.org/solutions](http://www.ewg.org/solutions))

**National Geographic Green Guide** ([www.thegreenguide.com](http://www.thegreenguide.com)) publishes a monthly magazine, weekly newsletter, product reports and reviews that focus on practical, everyday, environmentally responsible and health-minded product choices and actions. The Green Guide also offers **Smart Shopper's Cards** ([www.thegreenguide.com/issue.mhtml?i=SSG](http://www.thegreenguide.com/issue.mhtml?i=SSG)), which are printable, wallet-sized cards that list advice for selecting healthier foods and products. Topics include: cosmetics, personal care products and sunscreens; fish, meat, produce (fruits and vegetables) and eggs; plastic food and drink containers; food and product labels; non-toxic toys; cleaning products; and home renovation and furnishings.

**Natural Resources Defense Council** ([www.nrdc.org/health/](http://www.nrdc.org/health/)) publishes a variety of reports and policy papers on environmental health topics such as: children's health; health threats and effects; farming and pesticides; chemicals at home, school and work; and science and public policy. They also produce the **Simple Steps website** ([www.simplesteps.org](http://www.simplesteps.org)), which offers information to support healthy decisions for yourself, your home and the planet (for example, how to find a safe sunscreen or chose a fish low in mercury).

**Our Stolen Future Web Site** ([www.ourstolenfuture.org](http://www.ourstolenfuture.org)) provides regular updates about the latest science related to endocrine disruption. The site also posts information about ongoing policy debates, as well as new suggestions about what consumers and citizens can do to minimize risks related to hormone disrupting chemicals.

**Skin Deep** ([www.cosmeticsdatabase.com](http://www.cosmeticsdatabase.com)) is a safety guide to cosmetics and personal care products. This database pairs ingredients in nearly 25,000 products against 50 definitive toxicity and regulatory databases and provides safety ratings for nearly a quarter of all products on the market.

**Women's Health and the Environment** ([www.womenshealthandtheenvironment.org](http://www.womenshealthandtheenvironment.org)) offers the **Women's Health and the Environment toolkit**, which covers the science linking our health and the environment, everyday actions you can take around the home to reduce exposure to chemicals in our environment and resources to get involved in the larger movement to hold government and industry accountable for protecting us from chemical exposures.

### Patient Advocacy Organizations

**American Fertility Association** ([www.theafa.org](http://www.theafa.org))

**Endometriosis Association** ([www.endometriosisassn.org](http://www.endometriosisassn.org))

**InterNational Council on Infertility Information Dissemination**  
([www.inciid.org](http://www.inciid.org))

**Resolve: The National Infertility Association** ([www.resolve.org](http://www.resolve.org))

### Professional and Scientific Societies

**American Academy of Pediatrics** ([www.aap.org](http://www.aap.org))

**American College of Obstetricians and Gynecologists** ([www.acog.org](http://www.acog.org))

**American College of Preventive Medicine** ([www.acpm.org](http://www.acpm.org))

**American Society for Reproductive Medicine** ([www.asrm.org](http://www.asrm.org))

**American Society of Andrology** ([www.andrologysociety.com](http://www.andrologysociety.com))

**Canadian Fertility and Andrology Society** ([cfas.cfwebtools.com](http://cfas.cfwebtools.com))

**Endocrine Society** ([www.endo-society.org](http://www.endo-society.org))

**International Society for Environmental Epidemiology** ([www.iseepi.org](http://www.iseepi.org))

**Society for Male Reproduction and Urology** ([www.smru.org](http://www.smru.org))

**Society for Reproductive Endocrinology and Infertility** ([www.socrei.org](http://www.socrei.org))

**Society for the Study of Reproduction** ([www.ssr.org](http://www.ssr.org))

**Society of Toxicology** ([www.toxicology.org](http://www.toxicology.org))



# Glossary

**Ano-genital distance** A measurement of the length of the perineum (the area of the body between the anus and the genitals). During male development, the hormone testosterone triggers the perineum to lengthen as part of the normal development of male sex organs, such that the ano-genital distance of male humans and rodents is twice as long as that of females. Researchers study ano-genital distance because it is a sensitive measure of whether a chemical has interfered with testosterone production or action during fetal development.

**Biomonitoring** A kind of research that measures the types and amounts of chemicals in people's bodies. Biomonitoring studies collect samples of body fluids (such as blood, urine and breast milk) and measure the types and levels of chemicals or chemical breakdown products in these samples. This information gives us an understanding of human exposures to chemicals that complements measuring the levels of chemicals in our environment (air, water, soil, food, consumer products, etc.).

**Chromosomal abnormalities** A term used to describe problems with the number or the structure of chromosomes (the structures that contain genetic information) in a cell. These problems are inherited or can occur spontaneously in an individual. Chromosomal abnormalities produce problems with the genetic information in a cell: Genes can be missing or duplicated, or located in the wrong place or order. These problems prevent cells from functioning normally and can have a range of consequences on health.

**Endocrine disrupting chemicals** Chemicals that interfere with the function of the endocrine system (see endocrine system) in one or more ways. Once inside the body, endocrine disrupting chemicals can alter the amount of hormones that are produced or released into the bloodstream, or they can alter the supply of proteins that transport the hormones through the bloodstream. Endocrine disrupting chemicals can interfere with the ability of hormones to react with hormone receptors, thus blocking vital biological messages and responses. These chemicals can also send artificial messages and cause undesirable biological responses. Lastly, endocrine disrupting chemicals can alter the body's

supply of hormones by disrupting the process through which hormones are broken down and eliminated from the body.

**Endocrine system** An integrated system of hormone-producing glands that control body functions that happen slowly, such as reproduction, development, growth, mood, tissue function and metabolism. Endocrine glands include the pituitary, the thyroid, the thymus, the pancreas, the adrenals and the testes (in males) or the ovaries (in females). The endocrine system works in coordination with the nervous system and the immune system to regulate fertility and reproduction.

**Environmental reproductive health** A collaborative, interdisciplinary effort to understand and reduce the harm that chemical exposures cause to fertility, pregnancy, development, growth and health throughout life. This field includes the work of scientists, researchers, clinicians, policy-makers, community and advocacy groups, and the media.

**Female reproductive tract** A term used to refer to the fallopian tubes, uterus, cervix and vagina.

**Genes** Molecules that contain information and instructions for making proteins and other compounds that are necessary for a living organism to develop, grow and survive. Genes are passed down from parents to children, and are present in every cell in the body. Genes are organized in strands called DNA. DNA, in turn, is organized in structures called chromosomes.

**Gene expression** The process by which information stored in a gene is accessed and used to make (in most cases) a protein. Gene expression varies in response to changes in the internal (body) or external environment, so that different amounts and types of proteins are produced over time, depending on the body's needs. Hormones regulate how much and which genes are expressed in cells.

**Genetic mutation** A permanent change in the information contained in a gene. This change can cause problems with the proteins that the gene produces. For example, the protein may malfunction or may not be produced at all. The consequences of genetic mutation can range from slight to severe and life threatening. Genetic mutations can be inherited from a biological parent (called hereditary mutations) or they can occur during a person's lifetime (called acquired mutations). Acquired mutations are caused by environmental factors, such as radiation or chemical exposure. They can also occur when a cell divides.

**Hazard and risk assessment** Processes that federal and state governments use to support regulatory and policy actions regarding chemical production, use and pollution. The hazard assessment process identifies the harm that chemicals in our environment can cause to our health and the health of the environment, and the risk assessment process evaluates and estimates the likelihood that this harm will occur. Both processes collect and evaluate information on a chemical's toxicity, including what harm is caused and at what levels of exposure harm occurs, and on the levels of human exposure.

**Hermaphroditism** A condition in which either an animal's genetic sex is not consistent with the sex organs that develop, or the sex organs that develop are not entirely male or female. For example, a genetically female animal may develop testes, a male reproductive tract or male external genitalia. Or, both sperm cells and egg cells may develop in the testes of a genetically male animal.

**Hypospadias** A defect in the development of the urethra in the penis (the urethra is the tube through which urine and semen travel). The urethra normally runs the full length of the penis, with the opening at the tip of the penis. In hypospadias, the opening instead forms on the underside of the penis or below the penis. Hypospadias is the second most common birth defect in the United States and national studies report that the rate of hypospadias has more than doubled since the 1970s.

**Hysterectomy** An operation to remove a woman's uterus, and in some cases, her ovaries and fallopian tubes as well. It is used to treat a variety of diseases or conditions, including fibroids, endometriosis and cancer of the uterus, cervix or ovaries. Hysterectomy is the second most common surgery among US women, with over 600,000 performed each year. One out of every three women in the United States has a hysterectomy by age 60.

**Intrauterine growth restriction** Also called IUGR. A condition in which the fetus does not grow at a normal rate and consequently is smaller than expected for its gestational age (the number of weeks of pregnancy). Babies who experience intrauterine growth restriction tend to be very light weight, and their tissues and organs may also be underdeveloped. These infants also have a higher risk of death shortly after birth, of problems with neurological and reproductive development and growth, and of cardiovascular disease later in life.

**Ovarian follicles** A single egg, surrounded by layers of two types of cells which produce the hormones estrogen and progesterone and nurture the egg as it matures during the menstrual cycle.

**Proteins** Large, complex molecules that the body manufactures based on information stored in genes. (Different genes produce different proteins.) Each cell in the body contains thousands of different proteins and these proteins play many critical roles in the cell and in the body. For example, proteins perform most of the work performed by cells, and they give cells their shape and help them to move. Proteins make up the hormones that transmit signals throughout the body and the antibodies that recognize foreign substances in the body. Proteins also carry important molecules, such as oxygen and hormones, through the bloodstream.

**Reproductive health** The health and healthy functioning of the female and male reproductive systems during all stages of life. Reproductive health means that women and men are capable of conceiving, that a woman is able to maintain a pregnancy to full term and to breastfeed, and that the baby is born healthy and properly developed. Reproductive health also means that offspring will not develop diseases or disabilities later in life that are caused by exposures they experienced in the womb or during infancy, early childhood or adolescence, and that they will be able to conceive and bear healthy and properly developed children.

**Solvents** Liquids that cause other liquids, solids or gases to dissolve. Solvents are most often used to clean things. For example, they are used in dry cleaning, spot removers, detergents, paint thinners, nail polish remover and perfume. They are commonly used in numerous industries to remove oil and grease from metals and electronics.

**Testicular dysgenesis syndrome** A collection of disorders and diseases of the male reproductive system that may be related to one another and have a common cause: abnormal development of the testes during fetal development. These include: hypospadias, undescended testes, low sperm counts, and testicular cancer.

**Undescended testes** A birth defect in which one or both testes fail to move from near the kidneys into the scrotum during fetal development. This process of migration occurs in two stages and each stage is thought to be controlled by different hormones. The hormone called insulin-like 3 is thought to direct the first stage (when the testes move from near the kidneys to the pelvic area), which occurs between the 8th and 15th weeks of gestation. Testosterone controls the second stage (when the testes move from the pelvic area into the scrotum), which occurs in most cases by the 7th month of gestation. Undescended testes is a risk factor for testicular cancer and, if not corrected surgically, a risk factor for low sperm production later in life.

# Chemicals in our Environment and our Bodies

This chapter provides information on the uses and sources of exposure to the chemicals that were mentioned in this report. Also included, when applicable, is a list of page numbers where health effects are discussed.

**4-vinylcyclohexene diepoxide** A chemical byproduct of rubber, pesticides, flame retardants and plastics manufacturing. Human exposure to this chemical occurs primarily in occupational settings (pgs. 20–21).

**Air pollution** Outdoor air is most often polluted with carbon monoxide, lead, ozone, particulate matter, nitrogen dioxide, sulfur dioxide, benzene, butadiene and diesel engine exhaust. This pollution arises from a variety of sources, including motor vehicles, industrial production, coal-fired power plants, wood burning and small local sources such as dry cleaners. Indoor air can be polluted with the same pollution found in outdoor air. In addition, indoor air can be contaminated with environmental tobacco smoke and a wide array of chemicals used in consumer and household products (for example, furniture, carpets, cleaning products, glues and art supplies, air fresheners, perfumes, pesticides) (pgs. 28–29, 30).

**Alachlor** One of the most widely used herbicides in the United States. It is used to control grasses and weeds in corn, soybean and peanut fields. Most human exposure to Alachlor occurs from drinking or bathing with contaminated ground water (pg. 25).

**Alkylphenols** Surfactants (chemicals that “carry the dirt away”) that are common ingredients of industrial and commercial products, such as detergents, cleaning products, hair care products, cosmetics, spermicides, paints, paper, textiles, pesticides, plastics, rubber products, wood preservatives, coatings, lube oils, and fuels. Alkylphenols are present in treated wastewater and in sediment near wastewater treatment plants. Fish and seafood can be contaminated with alkylphenols. Some alkylphenols have also been detected in a wide range of foods and in air samples, especially in homes with PVC (polyvinyl chloride) floors or wall coverings (pg. 19).

**Arsenic** A naturally occurring metal that is used in pesticides, as a wood preservative and in various metal alloys. The primary ways we are exposed to arsenic are by drinking contaminated water, eating food grown in contaminated soil, or sanding or burning arsenic-treated wood. People can also be exposed to arsenic in workplaces that mine arsenic, process metals or burn fossil fuels (pg. 30).

**Atrazine** One of the most widely used weed killers in the United States and the most common pesticide contaminant of drinking water supplies. In the United States, approximately 1 million people a day are exposed to atrazine when they drink, bathe, cook or do laundry with contaminated water, or when they touch contaminated soil (pgs. 19, 25, 30).

**Benzene** One of the 20 most produced chemicals in the United States. Benzene is used to make plastics, resins, synthetic fibers (for example, nylon), rubber, dyes, detergents, lubricants, drugs and pesticides. Benzene is also part of crude oil, gasoline and tobacco smoke. Benzene evaporates easily into the air, so breathing contaminated air is the most common route of exposure. Outdoor air contains benzene from tobacco smoke, gas stations, car and truck exhaust, and industrial pollution. Benzene can also get into outdoor and indoor air when products that contain benzene are used, such as glues, paints, furniture wax and detergents (pg. 30).

**Bisphenol A** A chemical that is used in polycarbonate (clear and shatter-proof) plastic bottles, the lining of metal food and drink cans, pacifiers and baby toys, certain microwavable or reusable plastic food and drink containers, dental sealants, computers, cell phones, paints, adhesives, enamels, varnishes, and CDs and DVDs. Recent studies have shown that bisphenol A can leach out of many of these products, including metal cans and polycarbonate bottles, tableware, and dental fillings and sealants (pgs 15, 17, 18, 19, 23, 25, 28, 29).

**Cadmium** A naturally occurring metal that is used in many products, including batteries, pigments, metal coatings and plastics. Burning fossil fuels and municipal waste pollutes the air with cadmium. Breathing tobacco smoke is another source of exposure to cadmium. Cadmium contaminates some groundwater and builds up in food (fish, meat and plants). People who work where batteries, pigments, plastics and other synthetics are manufactured, or where metal is soldered or plated, can be exposed to high levels of cadmium in the air (pgs. 25, 28).

**Chlordecone** An insecticide used on tobacco, ornamental shrubs, bananas, and citrus trees, and in ant and roach traps until 1978 when it was banned. Chlordecone does not break down easily in the environment, and levels of chlordecone build up in the body and milk of ani-

mals and humans. Because of this persistence, chlordecone is still found in the environment, animals and humans today even though it has not been used for 30 years. Humans are exposed primarily by eating contaminated foods, drinking contaminated water, or touching contaminated soil (pg. 19).

**Chlorinated hydrocarbons** A group of chemicals that all contain chlorine, carbon and hydrogen. Chlorinated hydrocarbons include pesticides (DDT, lindane, pentachlorophenol), industrial chemicals such as PCBs, and chlorine waste products such as dioxins. Chlorinated hydrocarbons do not biodegrade easily and they concentrate, or build up, in the food chain because animals and fish are exposed to them faster than they can clear them from their bodies. The highest levels of chlorinated hydrocarbons are found in meat, fish, dairy, eggs and other fatty foods. The main source of exposure to chlorinated hydrocarbons in the United States is contaminated food (pg. 29).

**Chlorodibromomethane** A byproduct of chlorine-based water disinfection. Chlorodibromomethane forms when chlorine reacts with other naturally occurring substances in water, such as decomposing plant material. It is found mainly in chlorinated water that originally came from surface sources, such as rivers, lakes and reservoirs. Humans are exposed when they drink, cook and bathe or swim in such water. They can also breathe chlorodibromomethane vapors that enter the air when contaminated water is heated (for example, while cooking or in the shower) (pg. 20).

**Chlorpyrifos** A pesticide that was one of the most widely used home, garden and pet pesticides until 2001, when it was phased out of use for homes (the phase out process ended in 2005). Chlorpyrifos is still one of the most widely used agricultural pesticides. It is most commonly used on cotton, corn, almonds and fruit trees. Chlorpyrifos contaminates both outdoor and indoor air when it is used. It is also found in dust and on foods. Nearly everyone in the United States is exposed to chlorpyrifos either by eating contaminated food or breathing contaminated air or dust: A nationwide biomonitoring study reports that over 90 percent of the people tested had been exposed to chlorpyrifos (pg. 30).

**Cyclophosphamide** A chemotherapy drug that is used to treat cancer and autoimmune diseases (pgs. 20–21).

**DBCP** Also known as dibromochloropropane. A pesticide that was widely used on a variety of crops in the United States between 1955 and 1977. DBCP biodegrades slowly and has leached into groundwater supplies, contaminating the drinking water of at least 6 million people living in the United States (pgs. 24–25).

**DDE** Also known as dichlorodiphenyldichloroethylene. A breakdown product of the pesticide DDT (see DDT). DDE does not biodegrade easily and stays in the environment for years. DDE is found in soil and water where DDT was used. It also contaminates food. Because it accumulates in fat and stays in the body for years, DDE levels are highest in fat-rich foods such as meat, fish, dairy and eggs. For example, a US government study in 2005 found that 85 percent of milk samples were contaminated with DDE (pgs 20, 23-24, 29, 30).

**DDT** Also known as dichlorodiphenyltrichloroethane. A pesticide used widely to control insects on agricultural crops and insects that carry diseases like malaria and typhus, beginning in the 1940s. In the US, most uses of DDT were banned in 1972. DDT is still used in some countries for malaria control. DDT does not biodegrade easily and stays in the environment and in the body for years. DDT accumulates in fat tissue, so levels are highest in meat, dairy, fish and eggs. Most exposure in the United States occurs from eating contaminated food (pgs. 19, 20, 23–24, 25, 29, 30).

**DES** Also known as diethylstilbestrol. A synthetic chemical that was developed and marketed as a pharmaceutical drug and a growth stimulant for animal livestock. Between the 1940s and the early 1970s, DES was prescribed to as many as 3 million pregnant women to prevent miscarriage and stillbirth. (Subsequent studies showed that DES is ineffective at preventing pregnancy loss.) DES was also used to suppress lactation, to treat menopause, and as an emergency contraceptive. An estimated 10 million people in the United States were exposed to DES as a prescription medicine. It is also possible that people were exposed to DES when they ate livestock treated with DES (DES residues were found in poultry), but there are no estimates of the number of people who would have been exposed this way (pgs. 3, 9, 14, 15, 16–17, 18, 19, 23–24, 26–7, 30).

**Diazinon** A pesticide that was widely used in homes (against fleas, flies, cockroaches, ants) and gardens (on lawns, turf, shrubs) until it was banned for residential use at the end of 2004. Since 2004, diazinon can only be used by professional pesticide applicators and in agriculture. Exposure to diazinon can occur when this pesticide is applied. Residues of diazinon may also be present on or in foods and in contaminated drainage or ground water (pgs. 25, 30).

**Dibromoacetic acid** A chemical that is formed when water is disinfected using chlorine. Humans are exposed primarily from drinking water. Estimates are that the drinking water served to over 33 million people in the United States is contaminated with dibromoacetic acid (pgs. 20–21).

**Dibromochloropropane** See DBCP

**Dichloroethane** A chemical used to manufacture vinyl chloride, a leading ingredient in plastic and vinyl products such as PVC (polyvinyl chloride) pipes, furniture and automobile upholstery, wall coverings, housewares and automobile parts. Dichloroethane is also used as a solvent and to remove lead from leaded gasoline. Dichloroethane vapors enter the air when it is used, manufactured or disposed of. Some dichloroethane pollutes rivers and lakes. Humans are mostly exposed to dichloroethane by breathing it (pg. 30).

**Dioxins** A group of 219 highly toxic chemicals that have similar chemical structures and toxic effects. The group includes chlorinated dioxins, chlorinated furans and certain polychlorinated biphenyls (PCBs). Dioxins are formed when plastics and chemicals that contain chlorine are burned. The incineration of municipal and medical waste produces dioxins, as does the burning of coal and oil for fuel. Other sources of dioxins include metal smelting, diesel trucks, burning treated wood and household trash, forest fires, chlorine bleaching of pulp and paper, and certain chemical manufacturing and industrial processes. Tobacco smoke also contains small amounts of dioxins. Dioxins are virtually indestructible in the environment. Dioxins accumulate in fat and stay in the body for years. Most people in the United States are exposed to dioxins through the food they eat (primarily from meat, dairy, fish and eggs) (pgs. 16, 19, 20, 25).

**Ethinyl estradiol** The synthetic (manufactured) estrogen used in birth control pills (pgs. 18, 23–24, 28).

**Ethylene oxide** An industrial chemical that is used to produce ethylene glycol (antifreeze and deicing fluid). A very small portion is used to sterilize foods and medical supplies. Industries that manufacture or use ethylene oxide and automobile exhaust pollute the air with ethylene oxide. Smoking tobacco or breathing tobacco smoke is another source of exposure. Most human exposure to ethylene oxide happens when people work where it is manufactured or used (pgs. 25, 30).

**Flutamide** A pharmaceutical, anti-androgenic chemical that is used primarily to treat prostate cancer (pgs. 23–24).

**Formaldehyde** A chemical that is used to produce fertilizer, paper products, plywood, and urea-formaldehyde resins. It is also used as a preservative in some foods and in many products used around the house, such as antiseptics, medicines, and cosmetics. Automobile engines, power plants, manufacturing facilities, incinerators, cigarettes, gas cook-

ers, some household cleaners and open fireplaces release formaldehyde into outdoor and indoor air. The air is also contaminated when formaldehyde-containing carpets, permanent press fabrics and manufactured wood products off-gas (give off fumes). Most of our exposure to formaldehyde comes from breathing it, but we can also be exposed through skin contact with formaldehyde-containing products (pgs. 28–29).

**Genistein** An estrogenic compound naturally found in plants, specifically soybeans. We are exposed to genistein in the foods we eat, particularly soy milk, tofu and other products made out of soybeans. Small amounts of genistein are also found in chickpeas (pgs. 15, 18).

**Glycol Ethers** Chemicals that are widely used as ingredients in paints, varnishes, thinners, printing inks, electronics, semi-conductor industry chemicals and products, leather, photographic film, varnish, enamels, cosmetics, perfumes, brake fluids, and wood stains. People who work in these industries may be exposed to glycol ethers in their workplace. Exposure may also occur from the use of consumer products that contain glycol ethers, such as cleaning compounds, liquid soaps, and cosmetics (pg. 25).

**Lead** A naturally occurring metal that has been mined and used for thousands of years and, as a result, has spread throughout the environment. Lead is used in batteries, ammunition, building construction, certain ceramic glazes, pipes and is part of solder, pewter and certain metal alloys. Lead was used widely in paints until 1978 and was added to gasoline in the United States until 1996 (most lead was phased out of use by the mid-1980s). People are exposed to lead by drinking water that is contaminated either at the source or by lead-containing solder in pipes, by inhaling or ingesting lead-contaminated dust or soil, or by eating lead-contaminated food (pgs. 3, 19, 20, 25, 28–29, 30).

**Lindane** A pesticide that has been widely used in agriculture and to treat scabies and head lice for more than 60 years. Agricultural use is now restricted in the United States, but pharmaceutical use continues in all states except California. Lindane does not break down easily in the environment and has contaminated water and soil where it was applied. Lindane accumulates in foods, particularly fatty foods, and may also be found on or in produce grown in contaminated soil. Direct exposure to lindane also occurs when using pharmaceutical scabies or lice treatments (pg. 30).

**Mancozeb** A pesticide that has been used since the late 1960s on a variety of plants and agricultural crops to prevent or protect against damage from mold. The general population can be exposed to mancozeb if

they eat produce that is contaminated with residues of the pesticide, or if they use mancozeb in their gardens. People who apply mancozeb on the job can also be exposed (pgs. 20–21).

**Mercury** A naturally occurring metal that has been used in a large number of products, including auto parts, batteries, fluorescent bulbs, medical products, vaccinations, dental fillings, thermometers and thermostats. Many sources contaminate the environment, including coal-fired power plants (the largest source), industrial manufacturing, disposal (either incineration or landfill) of municipal waste and medical applications. Once in water and soil, mercury transforms into methyl mercury, which is also toxic to humans, animals and the environment. Mercury and methyl mercury do not biodegrade in the environment easily and they concentrate, or build up, in our food supply, particularly in large fish like tuna, swordfish, mackerel, marlin, orange roughy, shark, tilefish, sea bass, grouper and bluefish. (see [www.nrdc.org/health/effects/mercury/guide.asp](http://www.nrdc.org/health/effects/mercury/guide.asp) for more information). The most common way to be exposed to methyl mercury in the United States is by eating contaminated fish. Humans are also exposed to mercury and methyl mercury by breathing contaminated air and drinking contaminated water (pgs. 3, 30).

**Methoxychlor** A pesticide that is used in products for controlling insects in gardens or on pets. Methoxychlor is also used on agricultural crops (fruits, vegetables, alfalfa) and livestock, and in animal feed, barns, and grain storage bins. Methoxychlor has contaminated groundwater supplies and can remain on foods after application. People who work with or apply the pesticide can also be exposed (pg. 17).

**Metolachlor** A pesticide that has been widely used in agriculture (including corn, soybeans, peanuts, cotton and pod crops) since the mid-1970s. For at least several years, metolachlor was among the five most widely used pesticides. Drinking contaminated water is the most common way that people in the United States are exposed to metolachlor. It has contaminated the water supplies of over 6.5 million people (pg. 30).

**Organophosphate pesticides** A group of pesticides that are the most commonly used insecticide in the United States. They are used on fruits and vegetables, cotton, wheat, other field crops, and for termite and mosquito control. Certain pest control products for cats and dogs contain organophosphate pesticides. Exposure of the general population to these pesticides occurs primarily from ingestion of food products or from residential use. People who work with or apply these pesticides can be exposed to higher amounts of organophosphate pesticides in their workplace (pg. 30).

**PBBs** Also known as polybrominated biphenyls. A group of chemicals that were widely used as flame retardants in computer monitors, televisions, textiles and plastic foams. PBBs were produced and used in the United States until 1976. PBBs do not break down easily in the environment and they concentrate, or build up, in fatty foods, like meat, fish, dairy and eggs. PBBs were also accidentally mixed in with animal feed in Michigan in 1973, exposing the environment, animals and humans to this compound. Except for these areas in Michigan, exposure to PBBs at this point is negligible in the United States.

**PBDEs** Also known as polybrominated diphenyl ethers. A group of chemicals that have been widely used as flame retardants. They have been added to foam cushions in furniture, hard plastics in electronics and computers, upholstery fabrics, carpet pads and electric wire insulation. PBDEs have been measured in house dust and in food (particularly fatty foods). They contaminate water, treated wastewater and sewage sludge. PBDEs do not biodegrade easily in the environment and they concentrate, or build up, in fatty foods such as fish, dairy, meats and eggs. Humans are exposed to PBDEs when they eat contaminated food and breathe contaminated house dust and air. Whether there are other major sources of exposure to PBDEs is still being studied.

**PCBs** Also known as polychlorinated biphenyls. A group of 209 chemicals that were widely used as cooling and insulating fluids for electrical transformers and capacitors, and also in coatings of electrical components and wiring. The manufacture, use and disposal of PCBs and PCB-containing products have contaminated the environment globally. In the United States the use of PCBs was restricted starting in 1973 and the manufacturing of PCBs was banned in 1977, but old equipment that contains PCBs may still be in use today. PCBs do not biodegrade easily and remain in the environment and in the body for years. PCBs are stored in fatty tissues and concentrate, or build up, in the food chain and in our bodies because animals, fish and humans are exposed to them faster than they can clear them from their bodies. The general population is most frequently exposed to PCBs by eating contaminated fish, meat and dairy products. PCBs also contaminate the air and some ground water supplies (pgs. 16, 19, 23-24, 25, 29, 30).

**Pentachlorophenol** One of the most widely used pesticides prior to 1987, when its use was restricted to preserving wood. Pentachlorophenol is still used commercially on utility poles, fences, shingles, walkways, building components, piers, docks and porches, and flooring and laminated beams. In agriculture, it is used as to treat wood buildings and

products, and on fencerows and hedgerows. Pentachlorophenol contaminates our air, food, drinking water and soil and does not biodegrade quickly. The general population is exposed to pentachlorophenol by breathing contaminated air, drinking contaminated groundwater (pentachlorophenol contaminates the drinking water supplies of over 3 million people in 19 states), eating contaminated foods, and touching treated wood products and contaminated soils (pg. 30).

**Perchlorate** A chemical that is used in rocket fuels, road flares, automobile air bags and fireworks. Industries that manufacture or use perchlorate have polluted groundwater supplies in most US states as well as Lake Mead and the Colorado River, which supply drinking water to over 25 million people and irrigation water for agricultural fields in the southwest United States. Perchlorate has been found in produce grown with contaminated water and in dairy products. The general population is exposed to perchlorate by drinking contaminated water or eating contaminated foods.

**Perfluorinated Compounds** A family of chemicals that make materials resistant to oil, stains, heat and water. They are used in nonstick cookware, in stain-resistant fabrics, carpets and clothing, in grease-resistant food packaging and paper products (for example, microwave popcorn and french fry boxes), in some hair care and dental products, and water resistant clothing. Perfluorinated compounds have contaminated the environment worldwide. They are difficult to break down in the environment and remain in the body for years. Perfluorinated compounds are found in the bodies of nearly everyone in the world, but how we are being exposed is not yet fully understood. Consuming contaminated water or food or using commercial products that contain perfluorinated compounds is a leading theory.

**Phthalates** A family of chemicals that are used to soften plastics that are used in consumer products, flooring, wall coverings, food wrap and medical devices. They are also used in personal care products (perfumes, lotions, cosmetics, hair spray), lacquers, varnishes, wood finishes and coatings. Phthalates are absorbed through the skin. We inhale phthalate fumes and eat phthalate-contaminated food. Babies are exposed when they bite or suck on soft plastic toys that are made with phthalates (pgs. 16, 19, 23–24, 25).

**Polybrominated biphenyls** See PBBs

**Polybrominated diphenylethers** See PBDEs

**Polychlorinated biphenyls** See PCBs

**Polycyclic aromatic hydrocarbons** A group of chemicals that are formed from the incomplete burning of things that contain carbon, for example, coal, oil and gas, garbage, tobacco, wood, gasoline or meat. Polycyclic aromatic hydrocarbons concentrate in plants and animals. Exposure usually occurs by breathing contaminated air or by eating grilled or charred meats contaminated dairy products, or foods grown in contaminated soils (pgs. 20–21).

**Secondhand tobacco smoke** The smoke that nonsmokers are exposed to when other people smoke. Second-hand smoke is produced by lit cigarettes, pipes and cigars, and smokers when they exhale. A US national survey shows that about 43 percent of the nonsmokers are exposed to secondhand smoke.

**Thalidomide** A pharmaceutical drug that was widely prescribed to pregnant women in 46 countries throughout the world between the late 1950s and early 1960s to prevent morning sickness and to aid sleep. Thalidomide was not approved for use in the United States during this time, but “experimental” use of the drug was allowed and thalidomide was given to an estimated 20,000 people, including several hundred pregnant women. The toxic effects of thalidomide on the developing fetus were revealed shortly after it was first prescribed. Infants were born deaf, blind and with physical deformities such as a cleft palate (a birth defect of the mouth or lip), malformed internal organs and phocomelia (a condition in which when arms and legs are either extremely short or absent all together, with fingers and toes growing directly out of the torso). An estimated 40 percent of babies exposed to thalidomide in the womb died in their first year of life. Recent research suggests that the toxic effects can be passed on to the children of people exposed to thalidomide in the womb (pg. 3).

**Tobacco smoke** The smoke from cigarettes, cigars and pipes. Tobacco smoke contains over 4,800 chemicals. At least 250 of these chemicals are known to be toxic and 69 are known to cause cancer. Many of the chemicals in tobacco smoke are known to cause birth defects and reproductive problems. These chemicals include arsenic, cadmium, carbon monoxide, DDE, DDT, ethylene oxide, formaldehyde, lead, mercury, pesticides, polycyclic aromatic hydrocarbons and toluene. In the United States, about 26 percent of men and 21 percent of women of reproductive age (18 to 44), 10 percent of pregnant women, and 23 percent of high school students smoke. In addition, 43 percent of nonsmokers are exposed to secondhand tobacco smoke (pgs. 25, 28, 30).

**Toluene** A widely used industrial chemical used as a solvent (in paints, coatings, fragrances, adhesives, inks and cleaning agents), an octane-booster in gasoline, and an ingredient in benzene and other chemicals used to make nylon, plastic soda bottles, dyes, cosmetic nail products, pharmaceuticals and polyurethane foam. Toluene is also one of the thousands of chemicals in cigarette smoke. Toluene tends to vaporize, so most exposure to toluene in the United States occurs from breathing contaminated air. Outdoor air is contaminated most often by automobile emissions. Indoor air is contaminated when common household products (such as paints, paint thinners, glues and adhesives, synthetic fragrances and nail polish) are used or when cigarettes are lit or smoked. In addition, toluene contaminates the drinking water supply of over 31 million people in the United States; exposure occurs when this water is used for drinking, cooking or bathing (pg. 30).

**Vinclozolin** A pesticide applied to fruits and vegetables, vineyards, lawn turf and ornamental plants to kill fungus. Human exposure to vinclozolin occurs primarily from eating contaminated produce (pgs. 9, 19, 23–4, 25).







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