#### • REPELLENT FACTSHEET

# **DEET**

DEET is a repellent used by almost one-third of the U.S. population every year. It is one of the few pesticides applied directly to skin and clothing.

Symptoms of DEET poisoning in exposed people include vomiting, rashes, drowsiness, headache, and seizures. Children appear to be particularly susceptible, and some pediatricians recommend that DEET not be used on children.

In both laboratory animals and human cells, DEET has damaged DNA, the genetic material in living cells.

**DEET** can cross the placenta and move from a mother to her unborn child. When pregnant laboratory animals are exposed to **DEET**, the exposure has caused fetal loss and abnormal skeletons in the offspring.

Male laboratory animals exposed to DEET produced abnormal sperm.

Exposure to DEET in amounts equivalent to what people typically apply to their skin has affected the behavior and nervous system of laboratory animals. Effects include reduced sensory and motor skills, a reduction in the ability of the blood-brain barrier to pass molecules through to the brain, changes in the activity of an enzyme that helps transmit nerve impulses, and death of nerve cells in the brain.

DEET has synergistic interactions with common insecticides, including permethrin and malathion. The combination of DEET and fenvalerate is synergistically toxic to pets.

**DEET** frequently contaminates streams.

Exposure of developing chicks to DEET caused birth defects.

## By CAROLINE COX

DEET (see Figure 1) is an insect and mite repellent. It was developed for use as a repellent by the U.S. Army during World War II and has been registered in the U.S. for use as a pesticide since 1957.

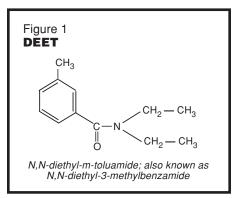
Over a hundred DEET products are currently available from over 30 different manufacturers.<sup>2</sup>

#### Use

DEET is used to repel a variety of animals: mosquitoes, ticks, flies, no-see-ums, chiggers, fleas, gnats, and midges. It is unusual "in that it is one of the few residential-use pesticides applied directly to skin and clothing." <sup>1</sup>

The U.S. Environmental Protection

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Agency (EPA) estimated in 1990 that about 30 percent of Americans use DEET every year. Estimated use in 2000 was between 5 and 7 million pounds. 3

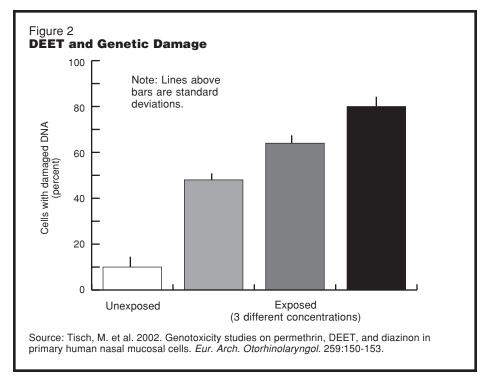
# How Does DEET Repel Insects?

According to the National Pesticide Information Center, "scientists are not completely sure how DEET repels biting insects." However, DEET probably affects the insect's ability to locate people and other animals. DEET prevents special receptors in the insects' antennae from functioning normally. The insect uses these receptors to sense chemicals produced by animals.<sup>4</sup>

## **Inert Ingredients**

Most commercial DEET repellents contain ingredients other than DEET. According to U.S. pesticide law, many of these ingredients are called "inert."<sup>5</sup>

There is not much public information about the identity of these ingredients. However, one common solvent used in DEET products is ethanol (ethyl alcohol). Ethanol increases the amount of DEET that is absorbed through the skin; researchers at the Medical University of South Carolina showed that 30 and 45 percent solutions of ethanol doubled the amount of DEET absorbed through skin. 6



DEET caused damage to DNA in human cells.

Most studies conducted to satisfy registration requirements at EPA use DEET alone.<sup>7</sup> Some of the research about DEET summarized in this article has been conducted with DEET mixed with ethanol.

## **Absorption of DEET**

Although DEET is typically applied only to skin, it is absorbed through the skin and moves to other parts of the body. Similarly, it is also absorbed by the intestines.

According to the World Health Organization, up to 77 percent of applied DEET is absorbed through skin.<sup>8</sup>

This article includes research based on exposure to DEET through the skin, as well as research based on ingestion of DEET.

# **Symptoms of DEET Poisoning**

Over 20,000 people called poison control centers because of incidents involving DEET repellents between 1993 and 1997, the most recent years for which this information has been summarized. Symptoms reported in these calls included eye irritation or pain, skin irritation or pain, irritation of the mouth, tears, vomiting, nausea,

rashes, dizziness, headache, drowsiness, slurred speech, and coughing. Seizures, tremors, and changes in heart rate are serious symptoms that are occasionally reported.<sup>9</sup>

## **DEET Poisoning in Children**

Hazards of DEET to children have been a controversial issue because of reports of seizures in children who used DEET repellents. EPA believes that these reports are inconclusive and in 1998 stated that "the available data do not support a direct link between exposure to DEET and reported seizure incidences."

However, some pediatricians have a different perspective. In 2001, physicians from the Aghia Sophia Children's Hospital (Greece) treated a child poisoned by DEET and then reviewed all available published reports of children who had developed brain-related problems following DEET exposure. Symptoms reported in these cases were seizures, coma, and behavior changes. Seizures were the most common symptom following skin exposure, and occurred when low concentration (less than 20 percent) DEET products were used. The pediatricians

warn that "repellents containing DEET are not safe when applied to children's skin and should be avoided in children."<sup>11</sup>

The link between DEET and seizures in children is strengthened by research from the University of Mississippi Medical Center. Scientists there showed that injection of DEET in laboratory animals caused seizures.<sup>12</sup>

Based on tests of laboratory animals, girls are more susceptible to DEET poisoning than boys.<sup>13</sup>

# **DEET Poisoning in Pets**

Symptoms of DEET poisoning in cats and dogs are not unlike those in people. They include vomiting, tremors, excitation, incoordination, and seizures.<sup>14</sup>

# Ability to Cause Genetic Damage (Mutagenicity)

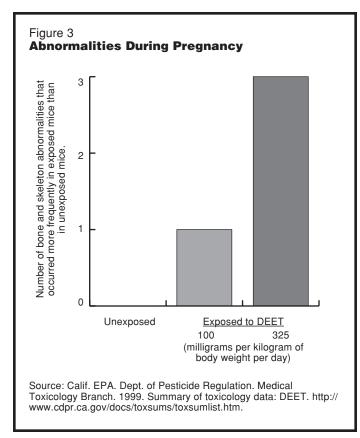
The National Institute for Occupational Safety and Health labels DEET as a mutagen.<sup>15</sup> EPA, on the other hand, summarized tests sponsored by DEET manufacturers and concluded that "the results are all negative [no genetic damage]."<sup>16</sup>

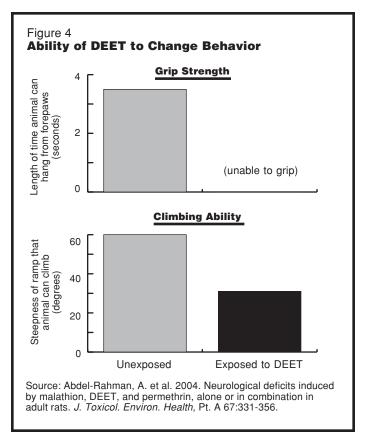
Mutagenicity concerns about DEET are supported by a 2000 study from the Duke University Medical Center. This study showed that damage to DNA, the genetic material in living organisms, occurred following application of DEET and ethanol to the skin of laboratory animals.<sup>17</sup>

The most recent study of DEET and genetic damage NCAP has located also supports concerns about its mutagenicity. A team of researchers affiliated with the German armed forces showed that DEET caused damage to DNA, the genetic material in living organisms. This experiment used cells taken from surgery patients. DNA damage occurred at all dose levels tested in this experiment. <sup>18</sup> (See Figure 2.)

# **Oxidative Stress**

Oxidative stress is a term used to describe an increase in the amount of reactive oxygen-containing molecules in a cell. Exposure to a variety of chemicals results in oxidative stress. It is also linked with Alzheimer's disease and rheumatoid arthritis. In 2001,





In laboratory animals, DEET exposure increased bone and skeleton abnormalities and reduced sensory and motor skills.

research from the Duke University Medical Center showed that DEET mixed with ethanol and applied to the skin of laboratory animals causes oxidative stress.<sup>19</sup>

## **Effects on Pregnancy**

DEET exposure during pregnancy can impact pregnancy success in a variety of ways.

The World Health Organization (WHO) reports that pregnant laboratory animals exposed to DEET (applied to their skin) had a greater incidence of fetal loss than did unexposed animals. The increased loss occurred at both dose levels tested in this experiment.<sup>8</sup>

In a study sponsored by DEET manufacturers, the offspring of rabbits exposed to DEET during pregnancy developed a variety of bone and skeleton abnormalities. (See Figure 3.) These effects occurred at all but the lowest dose level tested in this experiment.<sup>20</sup>

In addition, a study of women who

applied DEET repellents regularly during pregnancy showed that DEET crossed the placenta and moved into fetal blood.<sup>21</sup>

## **Effects on Sperm**

DEET also has a variety of effects on sperm.

According to EPA, laboratory studies sponsored by DEET manufacturers showed that DEET affects the testes of hamsters. DEET reduced the size of the testes in addition to causing degeneration. These effects occurred at the two highest dose levels tested in this study.<sup>22</sup>

Following inhalation of DEET, according to WHO, male laboratory animals produced abnormal sperm and sperm with a reduced ability to move. Females mated with the males exposed to DEET became pregnant less often than did females mated with unexposed males.<sup>8</sup>

## **Effects on Behavior**

Research at Duke University Medical

Center showed that DEET has effects on behavior. In these experiments DEET was applied daily to the skin of laboratory animals. After 30 and 45 days of exposure, the animals performed a variety of behavioral tests designed to measure sensory and motor skills. The researchers found that typical application rates of DEET mixed with ethanol, as well as amounts equivalent to 1/10 of the typical application rate, decreased sensory and motor skills. (See Figure 4.)<sup>23-25</sup>

### **Effects on the Brain**

Some of DEET's most sobering effects occur when the chemical disrupts normal functions of the brain. New research shows that DEET, at exposure levels that do not cause typical symptoms of neurotoxicity in laboratory animals, causes several types of damage to brain activities. These include effects on the blood-brain barrier, effects on nervous system enzymes, and damage to brain cells.

• Blood-brain barrier: The blood-

brain barrier regulates the entry of molecules into the central nervous system. The Duke University Medical School researchers mentioned above showed that DEET mixed with ethanol reduced by about 25 percent the permeability of parts of the blood-brain barrier. Permeability is the scientific term used to describe the rate at which molecules pass from the blood into the brain and other parts of the central nervous system. The reduced permeability means that the brain may not be able to acquire the molecules that are necessary for it to function normally. These effects on the bloodbrain barrier were measured in laboratory animals after 60 daily applications of DEET to their skin at typical rates.<sup>23</sup>

• **Enzymes:** Acetylcholinesterase is an important enzyme in the nervous system. In the brain it carries nerve impulses between certain nerve cells.<sup>26</sup> In tests with laboratory ani-

mals, the same Duke University Medical Center researchers showed that exposure to DEET mixed with ethanol (at typical application rates) increased the activity of this enzyme in various parts of the brain. The researchers believe that this may be caused when the brain repairs damage to nerves caused by DEET.<sup>24,25</sup>

• Damage to brain cells: The Duke University researchers also demonstrated that DEET mixed with ethanol actually kills brain cells. Following application to the skin of laboratory animals at typical application rates, the number of dying nerve cells was greater, and the number of living cells less, than in unexposed animals. (See Figure 5.)<sup>27</sup>

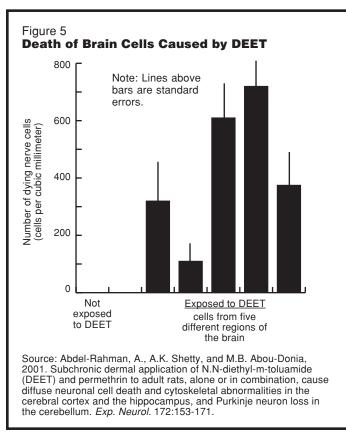
# **Synergism**

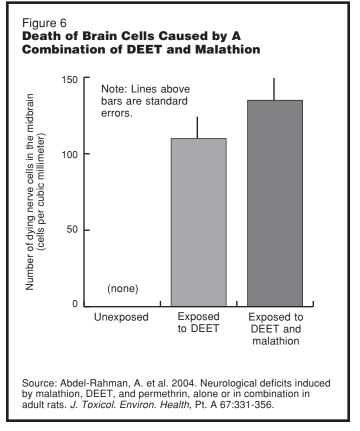
Synergism is the interaction of two chemicals "such that the total effect is greater than the sum of the individual effects." <sup>28</sup> This kind of interaction has been documented between DEET and

commonly used insecticides.

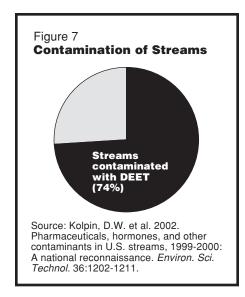
Permethrin is a common household insecticide also used to control mosquitoes. An array of synergistic effects have been documented between DEET and permethrin by researchers from Duke University. The combination decreased activity of the nervous system enzyme acetylcholinesterase, decreased the permeability of the blood-testes barrier, caused behavioral changes, caused more damage to DNA than was caused by either chemical alone, and reduced the ability of the liver to break down either chemical. (Both chemicals were applied to the skin, in ethanol).29

DEET also has synergistic interactions with malathion, another commonly used insecticide. (See Figure 6.) The Duke University research team showed that a combination of DEET and malathion increased the number of dying nerve cells in the midbrain, and that this increase was larger than with exposure to DEET alone.<sup>25</sup>





Exposure to DEET, either alone or in combination with exposure to the common insecticide malathion, causes death of brain cells in laboratory tests.



Chlorpyrifos is one of the most commonly used agricultural insecticides. 30 Like permethrin and malathion it has synergistic interactions with DEET. In a study led by researchers from North Carolina State University, DEET increased the transformation of chlorpyrifos to chlorpyrifos-oxon. (Chlorpyrifos-oxon is a potent nerve poison.) Chlorpyrifos also completely inhibited the breakdown of DEET by certain enzymes. 31

Finally, the synthetic pyrethroid insecticide fenvalerate and DEET are synergistically toxic to pets. The two pesticides were used together in a flea and tick product called Hartz Blockade in the 1980s. In the year that the product was introduced, hundreds of cat owners called a national pet poison control center to report poisoning symptoms following use of this product. Symptoms included tremors, incoordination, vomiting, depression, and seizures.<sup>32</sup>

## **Water Contamination**

DEET is a common water contaminant. When the U.S. Geological Survey (USGS) conducted what the agency calls a national reconnaissance study of DEET in streams, the agency found DEET in over 70 percent of the samples analyzed. (See Figure 7.) This study sampled 139 streams across the country. USGS noted that the results imply that compounds such as DEET "survive wastewater treatment and

biodegradation."<sup>33</sup> DEET has even been found in the ocean, where it has been transported by streams and rivers.<sup>34</sup>

#### **Effects on Birds**

According to the World Health Organization, DEET has caused birth defects in birds.<sup>8</sup>

In a study in which DEET was applied to the membrane under the shell of chicken eggs, about one third of the surviving chicks developed what WHO calls "gross malformations." These included defects of the circulatory system, muscles and skeleton, and the central nervous system.<sup>8</sup>

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