“Our fate is connected with the animals”


Our Stolen Future is one of those potentially pivotal books. Like Rachel Carson’s Silent Spring, from which the above quote comes, this book presents an evocative call to the public—this time to force a change in how the chemical industry and governments have dealt with several persistent pass-a-long poisons in the environment that are potentially causing subtle, yet sometimes catastrophic reproductive and developmental effects in wildlife. Using wildlife as “sentinel species” for humans, just as miners used the canary as a living sentinel for deadly gases in mines, the authors assert that the effects of persistent pesticides and industrial chemicals on wildlife may have significant implications for us and our children.

Due to some prerelease publicity, an evocative foreword by Vice President Al Gore, and a great deal of interest by the chemical industry, this book was already controversial before its publication. Before its release, the book was mentioned in U.S. News and World Report, Time, and Newsweek; it was also excerpted in the March 1996 Natural History.

An umbrella organization for the chemical industry, the Chemical Manufacturers Association, set aside funds for responding to the book’s message, including preparing written instructions for chemical companies on how to deal with media inquiries. Scientific scholars selectively scheduled a scientific workshop supported by the chemical industry in South Carolina on the “Principles and Processes for Evaluating Endocrine Disruption in Wildlife” to coincide with the book’s release. What in this book stimulates such strong responses?

Our Stolen Future, a readable and compelling account of the consequences of environmental contamination, is written for the general public. It relies extensively on Theo Colborns’ previous book (Colborn and Clements 1992) and other scientific publications (e.g., Colborn 1994). The book recounts the story of how Colborn, her coauthors, and several like-minded scientists came to believe that the substantial amounts of industrial and pesticidal chemicals that have been continuously entering the environment may carry a risk of reproductive and developmental effects in the offspring of exposed individuals.

Sometimes this book reads like a detective story, with the clues that Colborn (the lead detective) at first missed being slowly put together to reveal that looking under the (cancer) lamppost had caused Colborn and many others to overlook important events (Wapner 1995). Because of our attention to human cancer, we failed to understand these events—debilitations to wildlife—for decades. Perhaps this failure should make us curious about what else we are missing.

The book begins with the chapter “Omens,” which gives examples of how, since the 1950s, the reproduction and development of eagles, otters, mink, gulls, alligators, and dolphins has undergone disturbing changes of then-unknown cause. For example, in 1947 eagles in Florida
lost their drive to mate and nest; in the 1960s, ranch mink that were fed fish from Lake Michigan failed to reproduce; in 1977, female seagulls were nesting with each other in California; and due to a pesticide spill in the 1980s, alligators in a Florida lake have developed shrunk penises. These vignettes forge the first link in "the wildlife/human connection"—a central theme of this book—by also mentioning the purported 50% drop in human sperm counts reported in Denmark and elsewhere. However, for both humans and wildlife, although adult animals were being exposed to widely distributed persistent and bioaccumulative chemicals, the adults themselves often looked fine and appeared not to be directly affected.

It was not until recently that several scientists, including the authors, concluded that to understand the reproductive problems seen in wildlife they should analyze the reproductive (dys)functions of the adults and the structures and dysfunctions of the resultant offspring or the lack of offspring. They needed to focus on problems in the body structures of the young (e.g., deformities), wrong or intermixed sex organs, impaired reproductive capacity, and also in changes in the normal sexual behaviors expected in the adults as well as in their progeny.

The authors then make several additional important points:

- Many man-made hormone-mimicking chemicals, such as PCBs (which can mimic thyroid hormones), dioxins (which can mimic estrogen-like effects), DDTs, and nonylphenol (which can mimic estrogen) are found (sometimes unexpectedly) in food, water, plastics, and mothers' milk.
- Females accumulate chemical residues over their lifetime and transmit them to their eggs, fetuses, and nursing young.
- Tightly timed pulses of vanishingly small amounts of hormones are crucial to normal reproduction and development.
- The many examples given of detailed development were due to exposure of young, in utero, to man-made hormonal mimics.
- The timing of the exposure to these hormone mimics may often be more critical than the actual dose.
- The dose–response paradigm of classical toxicology may be almost irrelevant for such hormone-disruptive chemicals.
- Humans appear to share with other animals a potential for susceptibility to these chemicals.

This last point was made vividly by what became a major unintentional human experiment, the widespread prescription of a synthetic estrogen drug DES (diethylstilbestrol) to prevent miscarriages and for several other purposes. The children of women who took this drug showed several reproductive, developmental, and/or cancer effects. To tie these effects of DES to the wildlife examples, the authors discuss structural similarities between DES and another probable endocrine disrupter, DDT.

A possible decline in human sperm counts over the last 50 years is one important issue in this book. The book summarizes a report of a 45% decline in human sperm counts that comes from a recent review of 61 studies on almost 15,000 men from more than 20 countries around the world (Carslen et al. 1992). The claim of declining sperm counts is already the subject of considerable scientific debate. Three studies scheduled to appear in an issue of Fertility and Sterility are reported to show that US sperm counts have remained normal (Lemonick 1996). Two other well-respected researchers—Stephen Safe at Texas A&M University and John Giery at Michigan State University—think that the links made in this book between environmental estrogens and sexual reproductive ills are debatable and unproven (Bailey 1996). New research is likely to help define the accuracy of the issues this book raises.

If endocrine disruption is occurring in the environment, can we do anything to mitigate or prevent chemicals causing developmental or reproductive dysfunctions? Certainly we can act to minimize the current exposures to such chemicals in our water and food and to prevent future exposures to endocrine disruptors. But how are we to determine which of the thousands of new chemicals being submitted to regulatory agencies by industry for entry into commerce each year may pose risks to human and animal health? What baselines should we use to measure positive changes? Increases of what percent in human sperm counts? Should we encourage wildlife to emigrate from relatively uncontaminated areas to highly polluted areas where the death of wildlife or the lack of reproduction are obvious? Is that not what we are now in fact doing when we restock some of the Great Lakes each year with cultured lake trout or salmon?

The authors discuss ways to minimize current exposure of humans to toxic chemicals in the chapter "Defending Ourselves." Also discussed are some potential new legal and regulatory ways to help stop the release of problem chemicals and to prevent the release of such chemicals in the future. For example, we need to shift the burden of proof of safety of new chemicals to the chemical manufacturers, require them to monitor workplace and environmental exposures, start setting chemical safety standards for children (not just adults), require cumulative exposure assessments, and broaden the public disclosure laws reporting chemical releases, such as the Toxics Release Inventory (TRI). Almost all are good ideas, but they will be accomplished only with substantial political consensus. Past experience shows that only public pressure can help force the growth of such a consensus, especially given the current adversarial political climate on environmental issues.

This book is not without flaws. For example, the authors talk about the chemical legacy being given to our children and state boldly that "[children have a right to be born chemical-free]" (p. 212). Certainly, the scientific authors must see this as factual nonsense, even if it is a good slogan. Also, some of the pronouncements seem overly certain. For example, some respected researchers in this field (Leatherland 1994) are not convinced that, as the authors assert, "all evidence indicates that these thyroid problems found in Great Lakes salmon and herring gulls stem from contamination" (p. 158).

However, for those who would maintain that this book is overly...
alarmist, consider the following facts: Our Stolen Future states that hundreds of billions of pounds of industrial chemicals (such as plastics, detergents, adhesives, and solvents) are made in the United States every year. This estimate is off by at least an order of magnitude—too low! The estimated US manufacture and import of industrial chemicals only (not including pesticides, pharmaceuticals, and human and animal food additives) for 1989 only was approximately 5.9 trillion pounds (INFORM 1995).

Even that mind-boggling amount is surely an underestimate. Several industrial chemicals are not included, because they were manufactured or imported by US firms in quantities below the reporting threshold of 10,000 pounds per site per year. Also consider the upward trend of production of most major chemicals in the United States since 1989. For example, in the seven years from 1989 through 1993, production of the top 50 organic and inorganic chemicals in the United States increased by 33% and 15%, respectively.

Carson had breast cancer while writing and defending Silent Spring. Her influential book helped the US public focus on both pesticides and cancer. These issues eventually became a seminal stimulus for the legislation that created the US Environmental Protection Agency and some of its programs and in providing significant direction for the programs of the National Cancer Institute.

If Our Stolen Future encourages the public, industry, and the government to reconsider the overemphasis we have placed on cancer as the major focus of chemical testing, that would be all for the good. However, if reproductive effects simply become the new “carcinogen,” effectively replacing all other concerns, one of the most important messages of this book (and also of Silent Spring) would again be missed.

This crucial message is that we need to care more about, and pay much more attention to, what the wildlife sentinel species are telling us about the long megachemical experiments that humans have accidentally been running in the environment for decades. With adequate toxicity testing we certainly would have been better able to anticipate the developmental and reproductive events that occurred, especially if we had simply conducted routine tests of surrogate wildlife species. For example, the authors describe research published in 1950 in which young roosters given doses of DDT over a two- to three-month period did not develop into normal males (Burlington and Lindeman 1950). The authors of this publication even suggested that DDT was acting as a hormone.

Thus far, the limited, and predominantly short-term (e.g., two to four days) laboratory testing currently required for industrial and pesticidal chemicals on fish, invertebrates, and plants is scarcely adequate to determine only the most obvious impacts, such as death. The development of laboratory surrogates as wildlife screens for the activity of new chemicals might not only protect humans, but might also provide reproductive toxicity data that would help prevent the now all too familiar litany of the significant adverse ecological impacts of chemicals released into the environment.

How else will we be able to get relatively accurate indications of harm to us and to the environment? Must we, once again, wait decades to see the effects in our wildlife sentinels? To judge from the recent past, this tragedy could well happen again, because of the apparent general lack of interest and political will to examine and monitor the field results of the enormous chemical experiments currently going on all over our planet. Remember that with our past huge chemical experiments, it often took decades for us to be able to “see” the first results important enough for humans to start paying any attention to. That neglect has left us with these large and intractable chemical messes to deal with. For example, how simple will it be for us to minimize the impacts of the PCBs in the Great Lakes environment? What about the persistent organic pollutants that are widespread in the Arctic?

Where the past is our example, when sufficiently pressed, we will once again spend an overwhelming proportion of our money, scientific interest, and political will on our concern for humans. What a missed opportunity to do better. Just as the cancers that are seen in fish and oysters in the laboratory and in the field could have more quickly told us meaningful things about what chemicals to allow or not to allow into commerce, adequate testing for these “new” toxicity concerns in our laboratory surrogates of our wildlife sentinels could provide invaluable chemical screening, perhaps even faster and for less money than the current (or soon to be revised) mammalian testing schemes.

By all means, read this intriguing book. It is well written and wide ranging, and it contains many important lessons. However, be aware that, just as cancer testing did not provide the ultimate answer to chemical toxicity, neither will reproductive and developmental effects testing become the panacea that answers everything. Ecotoxicology and comparative toxicology have taught us that there can be large differences in sensitivity between some species, and that no one species, or one toxicity endpoint, will always be the most sensitive. We must keep a broad spectrum of test species and test endpoints as arrows in our quiver, ready to be used as selectively as the need arises. Let us not, once again, put all of our eggs in just one basket.

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WHAT'S NEW IN ARTHROPOD WATER BALANCE


In 1977, Eric Edney's classic volume Water Balance in Land Arthropods appeared. The book brought together a wealth of physiological and anatomical information on insects, arachnids, terrestrial crustaceans, and myriapods within a context of their adaptations to the terrestrial environment. Given my own interest in the area, I was taken with the book, particularly by the excellent theoretical discussions of water relationships, the presentation of data, and the thoughtful and consistent summary of what it all means. Neil F. Hadley's book, Water Relations of Terrestrial Arthropods, is a worthy successor to Edney's original, containing many of the same areas of discussion, greatly amplifying information on technical methods used in arthropod research, and shedding some new light on many questions that were far from being answered at the time the previous text was written. In addition, and true to its predecessor, it is a most enjoyable book to read, one that can be appreciated by readers ranging from advanced students to researchers in the field.

The book begins with discussions of the terrestrial environment and special features of arthropods, then goes into an overview of body water and its management. An interesting addition is a consideration of anhydrobiosis, which is cryptobiosis (a reversible state of dormancy) induced by dehydration. This phenomenon has been well studied in plant seeds and fungal spores, as well as in nematodes and tardigrades. A few insect larvae and adults can withstand dehydration to less than 10% of normal body water content, and the biochemical mechanisms, such as increased synthesis of polyols, that allow for stabilization of membranes and enzymes under these harsh conditions may also be important in promoting survival under other difficult environmental situations. The book's discussion of osmoregulation of hemolymph offers new information on selective water loss among various body compartments and the importance of these options for retaining vital functions.

The major physiological problem for terrestrial animals is loss of water through transpiration, either over the body surface (cuticular) or as an accompaniment to respiration. These phenomena are treated in two chapters, which consider both macroscopic and microscopic anatomy. Terrestrial arthropods are known to have an epicuticular lipid layer that is thought to provide much of the barrier to water loss. Much more is now known about the chemical composition of cuticular lipids than was available to Edney, but it is still not clear how these lipids are distributed within the layered structure of the epicuticle or how they function. Some of the possible functions of the wax bloom common on desert beetles are shown in striking photographs.

Hadley carefully describes several of the methods used for estimating cuticular transpiration, including gravimetric, electronic, and isotopic methods, all of which can be applied in vivo or to isolated sections of cuticle in vitro. Although much data have been collected on cuticular transpiration, it is often difficult to compare the results of various studies because of the differences in methods used. One of the best-studied yet least-understood factors influencing cuticular water loss is temperature. Many early studies, which were well summarized in Edney's book, indicated not only that the transpiration rate increases with temperature but also that there exists a "transition temperature" at which there is a rapid and dramatic increase in rate of transpiration. For many years, evidence pointed to changes in orientation of a lipid monolayer on the surface of the cuticle as the responsible factor for the transition temperature, but recent work indicates that there is no consistent preferred orientation of these lipids, nor is there a correlation between changes in lipid mobility and the temperature at which water loss increases greatly. Thus, as Hadley states, "there is no satisfactory explanation to account for the marked increase in cuticular permeability that occurs at the so-called 'transition temperature'" (p. 93). The possibility still exists that other layers of the cuticle play a role in regulating permeability, although several recent studies (e.g., Machin et al. 1985) call into question earlier findings of a role for the epicuticle and endocuticle. Hadley offers a working model of the arthropod integument showing known and hypothesized barriers to water loss and provides many questions still to be asked and answered before we can understand this process.

The relative contributions of respiratory and cuticular water loss to the total water balance have been estimated in several experiments, but general statements are difficult to make. However, in arthropods at rest, cuticular water loss usually predominates. At high temperatures or during activity, when the metabolic rate increases, respiratory water loss is also likely to increase. Hadley points out the importance of new techniques, such as monitoring moisture in an airstream and combining these measurements with concurrent measurements of oxygen and carbon dioxide, in partitioning the components of water loss.

The third major avenue of water loss for terrestrial arthropods is through the excretory system. As Hadley notes, the hindgut of many insects is so well modified to retain water and ions that losses are minimal; however, major problems ensue when fluid feeders ingest a large meal and need to rid themselves quickly of excess water. The chapter on excretion and osmoregulation provides an excellent summary of structure, ultrastructure, and physiology of arthropod excretory systems, as well as both old and newer methods for study.

The other half of the water balance equation is, of course, uptake of water. Feeding and drinking are considered in the context of available fluids in the environment, and